How mapping media may enable Knowledge Federation: *The Domain Map Prototype*

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Abstract

This thesis describes the design of a domain map prototype, which serves as a means of tackling wicked problems from the perspective of knowledge federation. This is to create a new way of problem-solving in a time of information glut. The domain map prototype is rooted in the vision of an open-hyperdocuments-system (OHS) by Douglas C. Engelbart, continuing his unfinished revolution by building on his prototype of a Dynamic Knowledge Repository (DKR). As part of the knowledge federation initiative, the prototype serves as a tool towards a paradigm shift within knowledge work. This means changing how information is presented and allow for new ways of interacting with knowledge work through models and graphical notations. This with the goal of solving wicked problems such as global warming and education systems.

The approach taken to design the domain map prototype was directly linked to the development of the knowledge federation website. Building the website was the first step towards launching knowledge federation, the second step is the design of the prototype. The information and structure form the website was used to inform the design of test models developed inside the debate graph application using the IBIS notation and other knowledge mapping techniques as a foundation. The test models which were made created the basis for developing the grammar and visual identity of the debate graph prototype and to identify necessary features.

The domain map prototype consists of three main elements as described in this thesis. Each element tackles an obstacle that comes with mapping complex issues. The first element is the structure of the map. The structure is focused on the use of tags as a means of organizing information. It does this by building on specifications of an OHS. The second part if the grammar which consists of the node objects which make up the domain map and the connections which contextualize the objects in relation to other data. The third element is the integration of the value matrix prototype as a means of establishing a rating system to better organize the information of the map. The value matrix is rooted in a QRI-model to derive the measure of a contribution.

The design of the domain map prototype results in creating a base language for an application to be built on, as well as highlighting new areas of study to continue the development of a domain map application. It serves to federate the need for a knowledge mapping tool and as an invitation to collaborate and create new knowledge work.

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Foreword

Information scarcity has plagued humanity for millennia, suddenly through the emergence of the information age, the tides have turned and now the world has changed from one of scarcity, to one of information abundance. This has led to information glut.

This thesis intends to design a domain mapping prototype as a tool for tackling complex problems. The goal is to explore the problems which arise in the age of information overload. Taking the lens of knowledge federation as a starting point. Through an exploration of the nature of complex problems, the aim is to generate an understanding of the nature of these problems. Furthermore looking into the previous works which inform the field of knowledge mapping and collective intelligence.

The design of the knowledge federation website aims to serve as a jumping off point to engage with complex issues and lead towards a paradigm shift in the knowledge field. Building on the development of the knowledge federation website and the debate graph application this thesis aims to design a prototype for a domain map. A modeling tool which enables the mapping of information in a manner which informs the approach to wicked problems and which allows for exploratory education.

The domain map prototype is the major contribution of this thesis. The elements which inform this contribution are the design and modeling of the knowledge federation website, the design of a domain map notation consisting of structure and visual elements of a map model, and the description of features which make up the design for a domain map prototype. The thesis also aims to generate new ideas that can be explored as a result of the design of the domain map prototype.

1 Introduction

This generation is faced with a problem that no generation before has had to face, access to too much information. Through the advent of globalization and the internet, access to knowledge is more readily available than ever before. More knowledge is being created than ever before in human history (Lyman & Varian, 2003). There is more information being created every minute than a human could consume in a lifetime (Marr, 2018). The abundance of information that is being generated and shared results in information glut. Information glut makes it difficult to find relevant information among the sheer volume of content that is being created (Wright, 2007).

The result of information glut is that knowledge is not being used effectively. The data that is being created is being gathered and stored. But as stated by Wright, it is not being used to its full effect. It can often take years for information to have its intended effect, simply because it is lost in the sea of information. There is an inherent need for a system by which information is organized, in a manner in which it can be applied effectively to make sense of complex problems (Weick, 1995). There is a need for a tool which allows for information to be applied more effectively.

Information glut may be a modern problem, but even in 1945, Vannevar Bush saw that information was not being used to its full potential for problem-solving (Bush, 1945). He would inspire Douglas C. Engelbart to dedicate his life to the pursuit of collective intelligence (The MIT/Brown Vannevar Bush Symposium, 2018). Engelbart envisioned a world in which information would be shared freely, and would directly be applied to the improvement of systems. Through the improvement of the improvement mechanism, the collective capability of humanity could increase drastically. A minuscule improvement in the Collective IQ could yield a vast increase in the global problem-solving capability. To this end Engelbart developed tools which he saw as necessary to fulfill his vision, becoming famous

for inventing the computer mouse, hypertext and more in the process of doing so. He died believing he had failed (Daul, 2013).

Knowledge Federation is an initiative which picks up Engelbart's vision where he left it off. Knowledge Federation aims to serve as a model in order to present a new way of approaching knowledge work, enabling a new paradigm (Karabeg, A paradigm, 2019). Through the institutions called transdisciplines, which exist outside of traditional domains, the aim is to transform knowledge creation and enable a paradigm shift. A domain is a specialized field or topic. Knowledge Federation is attempting to connect the dots of information into a larger picture capable of tackling the world's greatest wicked problems such as global warming, political strife and many more. In order to facilitate these changes, knowledge federation requires a tool which is capable of organizing knowledge in a manner which emphasizes connection and shows the big picture.

Realizing the aims of knowledge federation requires a tool with the means of organizing knowledge effectively. Knowledge mapping has been used as a way of visualizing complex information and to make it understandable more easily. Knowledge mapping tools have been developed in conjunction with mapping methodologies. Which can be separated into many different genres of knowledge mapping (Okada, Buckingham, & Sherborne, 2008). There is a need for a knowledge mapping tool which is designed to the specifications required by knowledge federation as a means of enabling a paradigm shift. A tool as such would require a visual language to be created to facilitate the federation of knowledge.

This thesis aims to design a prototype of a tool which fits the needs of knowledge federation. The design should include a visual language described as a grammar which is designed specifically for the federation of knowledge and which can be used across new transdisciples, spanning multiple domains. The problem statement of this thesis is defined as:

Design a mapping tool prototype with a grammar enabling knowledge federation across multiple domains.

1.1 Scope - Knowledge Federation

Designing a domain map can be approached from many different views and with many different aims. The domain map has the potential to have a major impact on many fields, as it may be applied to many different domains. When designing a prototype that is intended to fit every domain imaginable it is likely that it becomes too generic and not being robust enough to tackle complex problems.

This thesis is part of the knowledge federation initiative. Knowledge federation aims to achieve a complete paradigm shift by reinventing the way knowledge is interacted with. A natural approach for the design of the domain map is, therefore, information federation. The scope of knowledge federation that will be explored as part of the design is going to be focused on exploratory education. Through the use of a domain map allowing users to explore different domains as a learning experience. Through this approach, the user should gain an understanding of the bigger problems, which are the result of smaller information pieces and questions. The goal of using this scope is that by enabling education through a domain map the insight gained will generate new ideas and approaches for solving problems.

1.2 Personal Motivation

The choice of topic when approaching a master thesis can be a daunting task. Finding a project which resonates at a personal level as well as on an academic level can be a challenge. Knowledge federation was a natural fit. Fulfilling the three requirements that a project would need. First, the project falls in an area of personal interested, that being education. Second, the project allows for independent exploration and allows for the scope to be self-determined. Third and most importantly the projects has the potential to change the world for the better. The final point is what is crucial to making the work feel worthwhile. Knowing that even if the thesis is only a small pebble of a larger contribution. The end goal makes the contributions of every pebble leading to that goal worth it.

The domain map prototype has the potential to be a piece in a larger movement which leads to a global paradigm shift. Changing how knowledge is created, shared and applied to problems. By applying the information into the improvement of systems as part of development, a feedback loop can be created allowing for systems to improve themselves. Improving the underlying system which spans many different fields and disciplines could result in the effectiveness of those field's capabilities could be improved dramatically. Doing so could allow for the collective human capability to increase drastically solving many of the greatest problems facing the world today. Contributing a step towards that vision is the goal of this thesis.

The domain map prototype has the potential to be applied in many different fields such as politics, journalism, science and many more. This thesis approached the prototype from the scope of exploratory education and knowledge federation. The reason for this choice comes twofold. A personal interest in the field of education but also a belief that it is the approach which will be the most effective at achieving the end goal. Federating information and questions through the engagement people is how this thesis believes that the necessary insights to tackle major problems will be created.

The phrase; knowledge is power, has been used in a large number of situations and context. The meaning of power can be interpreted in many different ways. Power can be the ability to defeat one's military opponents, power might be the ability to make sure that major world problems are being addressed rather than minor political squabbles, power can also be the ability to feed ones family. If knowledge is power, then improving knowledge systems can increase the power to solve issues. It can be used to increase the problem-solving power of a society. And it falls in the hands of the academic community to make sure that the responsibility that comes with great power is used well, and effectively. It is the responsibility of this thesis to use the power of knowledge to make a better world.

1.3 Outline

This thesis is divided into five major parts. **Chapter 2** will introduce concepts and theory which the domain map is built on and which are crucial to understanding the domain map prototype. **Chapter 3** will highlight the approach that was taken to create the domain map prototype. **Chapter 4** builds on the approach and describes the domain map prototype in detail. Each aspect of the prototype is described. **Chapter 5** takes a critical look at the result of the prototype. Evaluating different approaches and seeing what worked well and what did not as part of the prototype. **Chapter 6** provides a conclusion to the thesis, as well as presenting future work that arises as a result of the thesis.

2 Background

The domain map prototype is part of the knowledge federation infinitive. The prototype is part of a larger field of knowledge work. The field consists of a large amount of contributions both small and big, all fitting together like puzzle pieces describing a bigger picture. This thesis aims to add a new piece to the puzzle. In order to determine where the piece fits in, one first needs an understanding of the neighboring pieces. This allows to sculpt a piece which fits in snuggly between the other pieces and which helps to enhance the big picture. Each section in this chapter describes a neighboring piece.

2.1 Information Glut

The problem that is facing this generation is a problem that no generation before has ever had to face, abundant access to knowledge and information. Through the advent of the internet and globalization, more information is readily available at a finger press than was previously stored in knowledge archives. More information is being created than ever before (Lyman & Varian, 2003), over the past years alone over 90 percent of all data in the world was generated (Marr, 2018). One might not think an overabundance of information a problem, traditionally lack of information has been the problem, however given the sheer volume of knowledge being created on a daily basis there is more information than any human could consume in many lifetimes. Given the volume of information and given that the information is scattered across many platforms a point has been reached of no longer being able to see the forest amongst the many trees. In order to leave the forest of knowledge behind and see what is relevant there is a need to find a vantage point from which one can not only start seeing the information needed but also to start using it in an effective way.

Information overload may be a more recent problem, but the information being created and stored rather than used to its full potential has much deeper roots. In

1945 American Scientist and inventor Vannevar Bush wrote: "Professionally our methods of transmitting and reviewing the results of research are generations old and by now are totally inadequate for their purpose" (Bush, 1945). He realized that information was not being used to its full potential for problem solving. Over seventy years later and still nothing has changed in the way that knowledge is shared and created. While the internet has enhanced the reach and speed at which information can be shared and created the underlying method has not. For all intent and purpose the knowledge field is still writing letter and publishing papers hoping that someone will read them.

The way knowledge media is being developed has not changed in centuries. Information is recorded as plain text sometimes accompanied by graphs and/or other visual aids. While a plain text environment is by no means a poor means of sharing information given that written language is very expressive and versatile it does however not make any particular relationships salient. Salience can be a very powerful tool to express concepts and ideas that are not well defined or that are being prototyped, as it can highlight information such as conceptual relationships. This can however come at the expense of other data (Larkin & Simon, 1987). Through the use of such methodology, one is more likely to move from a traditional plain text format to a more graphical notation which shows how information is connected to one another. This can be an advantage when dealing with complex issues on a problem-solving level.

2.2 Wicked Problems

Wicked problems are problems which are very difficult or even impossible to solve, they usually involve too many variables to be reasonably summed up, or are ever changing some wicked problems are incomplete. Understanding wicked problems is crucial to understand why the domain map prototype is necessary and to see how it fits in with existing approaches.

2.2.1 Characteristics

There are two notable ways to determine the common characteristics of wicked problems allowing them to be identified as suck. Rittel and Weber defined wicked problems by ten characteristics (Rittel & Weber, 1973), later Conklin devised his own shorter definition with six-point (Conklin J. , Dialogue Mapping: Building Shared Understanding of Wicked Problems, 2005).

Rittel and Weber, two professors from the university Berkley devised in 1973 what they saw as at least ten of the significant characteristics of wicked problems. They observed them from the perspective of exploring social policies. Wicked problems found in public policy issues such as tax rates, the development of school curriculum and the confrontation of crime rates stood in stark contrast to the more tame issues faced by engineers and scientists of the time. The term "wicked" was to signify the malignant nature of the problems as opposed to benign problems, though they made sure to clarify that it was not the intent that was malignant but rather to show the significance of overcoming these issues. The list of ten points is still one of the prime methods for determining the nature of a problem and its degree of "wickedness".

The ten characteristics found by Rittel and Weber are:

1) "*There is no definitive formulation of a wicked problem.*"
   The problem cannot be given as a simple well-defined statement that encompasses the scope of the problem. While an ordinary problem can be summarized in a statement, a wicked problem requires pre-existing knowledge of all possible solution to be understood.
2) "*Wicked problems have no stopping rule.*"
   Because there is no end in understanding a wicked problem there is also no way of determining when it has been solved. One could measure improvement, but never be certain to have solved the problem.
3) "*Solutions to wicked problems are not true-or-false, but better or worse.*"

There is no way to determine whether the solution to a wicked problem is correct or incorrect, it can only be evaluated is one solution is better or worse than another solution.

4) "*There is no immediate and no ultimate test of a solution to a wicked problem.*"

   The solution approaches to tame problems can be tested, this is not the case with wicked problems. When a solution has been implemented understanding the outcome can be a wicked problem in and of itself.

5) "*Every solution to a wicked problem is a "one-shot operation"; because there is no opportunity to learn by trial and error, every attempt counts significantly.*"

   When implementing a solution to a wicked problem it cannot be tested as the outcome will have significant consequence. Not being able to test a solution due to its complexity makes every approach to solving a wicked problem crucial in its understanding of the problem and cannot simply be done by trial and error.

6) "*Wicked problems do not have an enumerable (or an exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan."*

   How many solutions there might be to a wicked problem cannot be proven by any criteria. A problem might have no solutions and no measure can determine that this is the case for the given problem. It might also be the case the problem is dynamic and changing making it impossible to measure potential solutions as these solutions will dynamically have to the change with the problem.

7) "*Every wicked problem is essentially unique.*"

   Wicked problems are unique in that one cannot learn to solve a wicked problem the way one can be trained to solve a traditional problem. A danger when operating with wicked problems can be that one applies solutions which are practical for similar problems of lower complexity expecting

the same results which would result in unforeseen complications given the complex nature of the problem.

8) "*Every wicked problem can be considered to be a symptom of another problem."*

   Most problems are rather simple, having a root cause which created the problem, resolving the root cause should resolve the problem. Wicked problems are the result of one or more different problems which must be addressed. The danger is that by attempting to alter a lower level problem in order to solve the complex problem might result in unforeseen consequences within the higher level wicked problem.

9) "*The existence of a discrepancy representing a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's resolution."*

   When approaching wicked problems there are many actors and parties involved in trying to fix the problem and each will have a different approach to the matter depending on their world view and experience. This is the result of interpreting the problem through different lenses depending on the viewpoint one approaches. For example; a teacher might claim the lower test scored among students is the result of less funding to the school resulting in less time for the students to devote to a certain topic, whereas it could also be claimed that students owning smartphones in class might result in less attention being paid to the lesson and resulting in the low scores. Both viewpoints would go about changing the problem differently and might or might not improve the situation.

10) "*The social planner has no right to be wrong (i.e., planners are liable for the consequences of the actions they generate)."*

    Due to the high level of complexity and often interconnectivity involved in a wicked problem those who seek out to solve them will have a large impact on a large scale with grievous consequences. Therefore those who handle wicked problems cannot afford to be wrong in their approach.

In his 2005 book, Conklin reduces the number of characteristics which comprise wicked problems. His approach focuses less on planning and social policies but is rather a more generalized list of characteristics which define wicked problems. His list of six points shares similarities to those of Rittel and Weber, but is more broadly applicable.

1) "*The problem is not understood until after the formulation of a solution.*"
   Attempting to solve a wicked problem only results in new questions and problems. The problem also cannot be understood without the proper context to frame it. As there are many interpretations of the problem is not possible to formulate the problem in a matter which satisfies all parties. Where most problems require understanding of the problem first to attempt to find a solution, wicked problems require knowledge of the solutions in order to truly comprehend the problem.
2) "*Wicked problems have no stopping rule.*"
   A wicked problem does not resolve once it has been solved like mundane problems do, but rather ends once a party has exhausted all its resources invested into the problem or remains an ongoing improvement process. Solving a wicked problem is about ending with a satisfactory outcome, not a complete one.
3) "*Solutions to wicked problems are not right or wrong.*"
   As with Rittel and Weber's definition of the characteristic, wicked problems are quantified by better or worse solutions rather than by wrong or right.
4) "*Every wicked problem is essentially novel and unique*."
   Wicked problems may share many similarities but each is inherently unique. While wisdom can be taken from tackling a wicked problem and used to tackle a different wicked problem the complexity does not allow for direct application and the new problem must be understood and examined from the ground up.
5) "*Every solution to a wicked problem is a 'one shot operation*."'

One cannot solve wicked problems theoretically, a solution has to be tested by applying it to the situation. This is usually expensive and will generate a new set of outcomes which will result in new unforeseen wicked problems being generated.

6) "*Wicked problems have no given alternative solutions*."
   Wicked problems will have either no possible solutions or no solutions which are apparent. It is therefore a matter of creativity in approach which allows one to approach wicked problems with any manner of success.

The problem of information glut that has emerged is a wicked problem. Viewing it through the lenses of education makes this even more apparent (see example from 9) in Rittel and Weber list). Taking Cotlin's characteristics one can see that all six points are satisfied while looking at the information glut problem. 1) The problem of information overload is not always clearly visible from the outside, it would be easy to conclude that more material being published would result in more knowledge. Organizing and creating the knowledge is the problem which causes this and it becomes apparent how difficult a task it is to do so once one attempts to develop managing systems. Finding that a new way of creating knowledge is the wicked problem that is actually being discussed. 2) There will likely never be a perfect way of collecting all human knowledge and applying it effectively. There can be made many improvements, but there is no stopping point at which it is done. There will be the point that is good enough. 3) There is no one right way of solving the problem. The goal is to develop a new approach which is better than the one in use now. 4) While tools and applications that have been used to solve or at least improve similar problems such as the creation of hyperlinking (Implemented Hypermedia in the '60s, 2019) the problem is wholly unique. 5) Creating a new knowledge creation tool which becomes used (which it must be in order to be tested) runs the risk of compromising a large scale of knowledge creation and can generate new wicked problems such as for example the dichotomy between two entirely different approached to knowledge creation which split the talented researches in a way that could reduce the effectiveness of the research being made. It is therefore crucial that the solution presented be conscious of this

danger and be developed with that in mind. 6) It is not a matter of choosing which solution to use in order to solve the problem, but rather about developing a robust tool which can be customized for different applications (although the focusing on education and knowledge creation).

2.2.2 Tackling Wicked Problems

Tackling wicked problems is different from solving traditional problems which consequently means that traditional approaches to solving them also do not work. The traditional approach to solving a problem which is to first define the problem in its entirety, then analyze it before solving it step by step. Through the characteristics of wicked problems, it becomes apparent that this approach is not ideal and can even be detrimental to tackling wicked problems. Nancy Roberts presented three approaches to coping with wicked problems (Roberts, 2000).

Authoritative:

Authoritative strategies aim to tame a wicked problem by reducing the number of stockholders that are involved in solving the problem. While limiting the number of individuals involved in the decision making process limits the amount of knowledge and expertise that is being dedicated to the problem it does allow for a clear path to be taken. An example of an authoritarian strategy would be the U.S. Supreme Court giving a legal definition of a term in order to settle a locked Congress. This strategy is also very common in the business sector where CEOs have the power to make absolute decisions regarding the trajectory of the companies' direction (Camillus, 2008).

The advantages that come from authoritarian strategies are that by effectively electing a representative to make executive decision fewer people are directly involved allowing for faster and more concise decisions to be made. This also reduced the overall complexity of a problem by reducing the number of actors involved. Experts having to spend less time explaining the solutions to others is also a significant advantage, leaving them to focus on implementing the solutions and getting faster result.

There are disadvantages that come by using an authoritarian system. The reliance on few expert individuals rather than bringing in a wide pool of knowledge brings more danger with it. If the experts tackling the problem make mistakes these are less likely to be discovered and can have catastrophic consequences. A side effect of using such a system also can result in less learning opportunities due to the reliance on experts, creating a disconnect between the stakeholder that are connected to the wicked problem and the experts. It can also lead to tunnel vision as some important factors may not be considered by the expert panel. Rittel and Weber (Rittel & Weber, 1973) state that in the long run taming a wicked problem will only result in the problem to manifesting into a different wicked problem or even worse create a problem even worse than the original being tackled.

Competitive:

The competitive strategy aims to solve wicked problems why setting up opposing viewpoints against one another in order to encourage growth through competition. Pitting different ideas against one another in order to gain a stronger viewpoint of the opposing points of view and allowing for a greater understanding of the problem and needing to greatly examine solution against external criticism. The competitive strategy often creates a win-lose scenario in which on position will come out on top. Military warfare scenarios represents a zero-sum example of a competitive strategy. The two opposing viewpoints clash, violently, and the side that comes out on top has its solution implemented.

The advantage of a competitive strategy comes from the fact that the perceived stronger idea comes out on top. This is often represented by the idea of letting the market decide on an idea. If for example two operating system provides have different approached to solving problems that their end users are facing, rather than coming to a consensus on how the problem is to be solved, they will each implement their own solution and present them to the public letting it decide on the solution that is better.

Disadvantages to competitive systems come in many forms. Looking at the examples stated above, they can have rather drastic consequences creating even worse wicked problems, such as the resulting conflict of a military action which can lead to war and long lasting disputes taking years to resolve. Presenting two solutions to a wicked problem can also fragment the user base making tackling the problem in the future even more difficult as a problem might arise within one implementation and a different problem in the other. Now two different problems have been generated and both require resources to fix the issues separately.

Collaborative:

The collaborative strategy stands in direct opposition to the competitive strategy. Rather than pinning two ideas against one another edging out the other it is about taking the best of both ideas in a win-win scenario. These ideas are often discussed in meetings or through other means of facilitating dialog. Collaborative ventures allow for cooperation cross international boards and within different organizations.

The advantages of collaborative approaches to wicked problems come from joining of knowledge and resources to tackle the problem. Though cooperation is allows for resources to be shared across the solution allowing for more efficient solution, as well as relieving a single party of the financial burden. Redundancies are also eliminated when the resources are pooled into solving the task combined.

The disadvantages to collaborative strategies are largely logistical. Cooperation requires cross communication and incurs transition cost between the entities working together. The number of actors involved grow and with that the likelihood of reaching a consensus. Bringing in large numbers of stakeholders runs the risk of dialog turning into debate and requires this to be facilitated. This is a skill which must be learned and trained to result in effective cooperation. The outcome of cooperation may also result in many

compromised which satisfy none of the stakeholders and as such runs the risk of creating new problems down the line.

Each approach carries with is a number of advantages and disadvantages and depending on the scope of the wicked problem different approaches might yield better results. Evaluating which methodology to pursue when tackling wicked problem is however one of the important decisions that need to be taken before approaching such a problem.

Making the involved stakeholder part of developing the solution was suggested by Rittel (Rittel H. , 1972) as a means of maximizing the pool of knowledge available. This effort can prove time and resource consuming without a way of facilitating the process. Computer designed and implemented cross-stakeholder argumentation techniques can facilitate such an endeavor (Shum, 2003). New techniques and tools are being developed to facilitate such debate such as Dialog Mapping (Conklin J. , Dialog Mapping: Reflections on an Industrial Strength Case Study, 2003) which allows stakeholder to come to a consensus through facilitated dialog. Robert Knapp also emphasizes this move from simply needing solutions to problem to moving into inventions which are capable of tackling growing problems as an ongoing process (Knapp, 2008). Through the development of tools which facilitate dynamic problem-solving though multiple stakeholders dynamically.

2.3 Systemic Innovation

When tackling wicked problems the design methodology which is used to approach solving such issues can be equally important as the problem itself. The term systemic innovation has been used in a wide array of contexts and definitions and has grown more popular in recent years. The lack of a clear definition of the term does require clarification as to its use within the context given. Building off of the deemed most popular definition of the term (Takey & de Carvalho, 2016) as a type of innovation which must be accompanied by complimentary innovation,

Midgley and Lindhult sugegst that there are four different popular defintions of the term (Midgley & Lindhult, 2017).

The first definition as alluded to before is found as the result of innovation spanning across more than a single organization or company and requiring a multitude of innovations in order to be successful. The definition derives its name from the fact that an innovation of systems is giving rise to it.

The second definition of systemic innovation is most commonly used in regards to the regional or methodical framework policies often provided by governments as a way of intervening or supporting the industry. Innovation is pushed by an external agent onto existing systems which are already in place and mostly autonomous. This innovation can come as a meta-level approach to enabling innovation with the ultimate goal of strengthening local economies and/or increasing employment. It is systemic innovation in that it is a meta-systems supporting the growth and development innovation within private or third-party organizations or systems of organization by a regional government.

The third definition is a much more high-concept approach to viewing innovation than the two other definitions given before. It is mostly used when viewing a larger social impact which comes from innovation leading towards a larger social shift. It is often about changing how the game is being played rather than improving a strategy by which to play the game. It is often with the goal of transitioning into a more sustainable society often leading towards a tipping point such as a paradigm shift (Karabeg, Information design - a new paradigm in creation and use of information, 2003). This definition defines systemic innovation as innovation to the underlying systems in place as a means of changing the methodology bringing forth groundbreaking innovation as a result.

The fourth and final definition given by Midgley and Lindhult is concerned with approching the innovation process through which the parties involved learn to view their methodlogies and methods as systems. The goal being to chagne the way in which people are viewing their approuch methods as part of a larger system in order to see the bigger picture. Changing the view of a system into a single

artifact and approuching it as a means of making sense of a much larger situation or problemt which requires innovativ thinking becomes the appraoch. Engaiging situations by thinking in terms of systems as a means of leading to clear action and innovation within the bigger picture scheme.

Having explored the wide selection of scopes in which the term systemic innovation can be used in it becomes possible to narrow in on defining the term in a manner in which it becomes useful for the context of developing a Domain Map prototype within the scope of exploratory education and knowldege federation.

Systemic innovation is a means by which an actor engaging withing a piece of knowledge work can be connected to the bigger picture and see how a piece of knowledge work fits into the whole of the puzzle which comprises the entire system. Using the view of the system gathering meta-data which enables innovation to the underlying methodology of the development of knowledge and its application within the larger knoweldge system. Using the new innovations to tackle the bigger picture issues which are being mapped as part of the whole system. Though viewing the entire system, it also beceoms clear in what areas the system is lacking and need new pieces and innovation to be placed to complete the whole system.

Defining systemic innovation as the innovation of the underlying methodology of a system and improving the system as a means of tackeling larger wicked problems.

2.4 Collective Intelligence

Changing how information is being created and shared is the first step towards again harnessing the full potential of the knowledge pool that is available. What is arguably needed is a way of dynamically creating knowledge. A way of having

knowledge work build on the newest information and to be interconnected globally. Standing on the shoulders of giants as a means of seeing further.[1] In the field of informatics there are few giants that loom as large as Douglas Engelbart, it is his vision of a collective mind which guides the creation of the domain map prototype.

2.4.1 Doug Engelbart

Douglas C. Engelbart is one of the influential inventors and visionaries that have entered the field of computing. Today Engelbart is best remembered for being the inventor of the mouse. He is also the invertor of display editing, windows, hypertext, network computing and more. The inventions he would become most famous for were all presented during a live tech demo in 1968, later dubbed "the mother of all demos". The 90 minute presentation included a live video conferencing tool as well as what would lay the foundation for graphical user interfaces in the future. Though they were only around 13 years old at the time these inventions would later set the foundation for Steve Jobs and Bill Gates as they worked on developing Apple and Windows respectively. While these companies developed what would become modern computing and commercialized it in the 80s and 90s Engelbart seemed largely only to be remembered for inventing the mouse at the time. In 1998 he was honored at the University of Stanford during the 30th anniversary of the mother of all demos, where he was celebrated for his major contributions to modern computing and the influence on the World Wide Web (Celebrating the 30th anniversary of Doug's 1968 Demo, 2018). In the year 2000 he was awarded the highest honor within the National Medal of Technology by U.S President Clinton.

Alan Kay has been quoted in saying, "I don't know what Silicon Valley will do when it runs out of Doug's ideas." (Landau, How Douglas Engelbart Invented the

[1] "If I have seen further than others, it is by standing upon the shoulders of giants." - Isaac Newton

Future, 2018) While this is an exaggeration it highlights the deep impact that Engelbart's inventions and ideas had on the technological community as well as the world. Despite his many accolades and successes when he passed away on July 2, 2013 people close to him such as Bill Daul have noted that he did so feeling he had failed (Daul, 2013). The title of his 1998 symposium where he was being honored was "Engelbart's Unfinished Revolution" which even then implied that only a small part of Engelbart's vision had yet been realized. Engelbart viewed the tools he had created as just that tools, which were there to help achieve his greater vision. Daul also notes that Engelbart was well known for exclaiming to people "You just don't get it." He felt that he and his vision had been largely not understood. When asked how much what he had envisioned had been attained he said "About 2.8 percent." So the question arises, what happened to the remaining 97 percent of his vision? What was Doug Engelbart's Unfinished Revolution?

In order to understand Doug Engelbart's vision it is important to understand where his philosophy came from and how he approached problems. A key inspiration for Engelbart was a paper published by Vannevar Bush called "As We May Think" which Engelbart read while serving in the Navy as a radar technician (The MIT/Brown Vannevar Bush Symposium, 2018). The paper would inspire him to change his career trajectory towards the betterment of mankind (The unfinished revolution, 2000). He believed that this could be achieved by harnessing a collective human intelligence facilitated though technology to tackle the world's biggest problem. He coined the term collective IQ as a means of describing how people would collectively work on solving important problems. By achieving even a minimal increase in the worlds collective IQ it would allow for problems to be solved across a large spectrum of domains. As a means of achieving this goal Engelbart turned to digital technology (O'Brien, 1999).

Engelbart's inventions were the first step in implementing his larger vision of a collective IQ. The tools allowed for much faster communication, knowledge gathering and distribution as had been possible before. He also realized that it was

important that in order for a true collective intelligence to exist the way he envisioned it, the approach would have to change.

> "*Digital technology could help make this a better world. But we've also got to change our way of thinking.*" (Douglas, 1995)

It was the Human-system that Engelbart viewed as the difficult task to change (Doug's Strategic Vision - A Human Endeavor, 2018). As he proved by developing the tool-system necessary (started to prove) it was not where he though the major challenge of a collective intelligence was lying. It was the Human element that had to undergo a change.

> "*Many years ago, I dreamed that people were talking seriously about the potential of harnessing a technological and social nervous system to improve the IQ of our various organizations. What if, suddenly, in an evolutionary sense, we evolved a super new nervous system to upgrade our collective social organisms? Then I dreamed that we got strategic and began to form cooperative alliances of organizations, employing advanced networked computer tools and methods to develop and apply new collective knowledge."* (Landau, The Engelbart Hypothesis: dialogs with Douglas Engelbart, 2009)

A social nervous system is what Engelbart saw as the key to raising our collective IQ. The technological progress that has been made since Engelbart's time is staggering. The technological advances that limited him at the time are now fully realized. But as technologies grow more advanced the underlying methods have not evolved and scaled accordingly. The nervous system that is in place is not capable so sending the message from the brain to the rest of the organism. If one were to view information technology as a living creature that has grown to the size of a blockbuster movie sized monster, the monster is in danger of running over a cliff or even collapse under its own weight unless it learns to move its limbs using a nervous system that is well designed for its size and purpose. For a nervous system to be capable of working at the scale and speed that technology moves the process of improving it must match the pace of technological growth.

Bootstrapping is the word Engelbart coined in order to describe the tools and processes that are being developed to improve the rate at which the process itself would be improved. The ideas being that increasing the effectiveness of the process improvement would drastically change the overall effectiveness across the entire field of application. The way bootstrapping is intended, is to "use what they build to boost their own effectiveness" (About Bootstrapping, 2018). Any process that is about improving team collaboration, knowledge technologies and innovation disciplines are bootstrapping the collective nature by their definition.

The Bootstrapping strategy is about improving the improvement process as a means of collective intelligence. Bootstrapping generated a feedback loop with the customer, feeding the advancement of the collective IQ back into the improvement team. Using the bootstrapping strategy allows for both the general improvement of the collective IQ, but also allows the teams and businesses implementing it to gain an edge over the competition as contributors of leading edge improvement.

The Bootstrapping strategy also carries other benefits, such as faster and smart growth. As the developer becomes the customer by means of development as the improvement gained through the development will be directly applicable to the further development of the project and of future projects. The integration of improvement strategies also becomes streamlined and improved as part of the overall efforts as they are a direct part of the end product. By raising the collective IQ the provider will see stronger return of investment as the creation and deployment becomes faster and smarter. The direct involvement of the customer as a stakeholder would also increase the amount of investment and knowledge dedicated to the research and development process. As the primary users of the product that is being improved they have the strongest firsthand experience and expertise with the product and have the strongest grasp on how to improve the process to benefit the user (themselves). Another benefit is the exponential benefit which the user receives from the improvements. The improvement that the customer is experiencing though the process is passed on straight to the end user. As well as the end user having direct access to the working environment and to the development,

thereby they can take part directly in the innovation work which results in a product which is shaped specifically to the needs of the end user and refined by all the stakeholders.

In order to achieve the bootstrapping strategy the development of an improvement mechanism needs to be in place, developing an improvement tool would be a form of bootstrapping. Engelbart's vision of such a tool was in line with his inventions, an open hyperdocument system.

2.4.2 Open hyperdocument system (OHS)

A key tool in Doug Engelbart bootstrapping strategy was the development and implementation of an Open hyperdocument system (OHS) (About An Open Hyperdocument System (OHS), 2019). Such a system would need to be worldwide accessible and accessible on all platforms in order to be most effective. The system would span across a multitude of knowledge domains allowing for more direct linking and accessing of knowledge.

The requirement of an OHS is that it allows an individual accessing it to have access to specific knowledge pieces which can be accessed directly as well as allowing for the big picture to be seen. While the internet has been used in great effect with hyperlinking as a way off connecting information to one another it does not fully satisfy what Engelbart envisioned with his OHS. Commonly a hyperlink will send the user to a different document which must be skimmed in order to find the desired information. Tagging individual parts of a document and linking to it is possible but is widely underused and would require a shift in the way the knowledge is being created, straying away from the conventional format and embracing a more modern digital native approach of piecing information together. Moving away from standard pipeline approaches has been the philosophy of Silicon Valley over the recent decade moving towards more agile development methods (Stavru, 2014). The same approach must be applied in knowledge work in order to satisfy the vision that Doug Engelbart laid out.

Some key attributes of the OHS as highlighted by Engelbart himself are broken down into three major categories; internal attributes, key features and Further support (Lehtman, Engelbart, & Engelbart, 1998).

Internal attributes:

The key attributes that must be in place for an OHS system to function the way Engelbart envisioned it are reliant on developing the knowledge creation in a way that is tailored to the system. Each knowledge object, which can be anything from written text to a visual slide, an email or even voice and video recordings, must be tagged automatically and tagged by the author. Each object must also include timestamps and dates noting the creation and every modification of the object. The system should also encourage the user to structure the objects in a natural and logical manner.

Key Features:

The key features that would be enabled though the internal attributed and make and OHS possible are the core of the system. The ability to link and jump between each knowledge object freely and allowing for different views to be possible having both a top down birds eye view of the system and seeing the big picture as well as seeing the specific knowledge object self-contained as an individual piece. The view must be highly customizable allowing the user to only see the information that is required and desired, allowing for information such as dates and timestamps not to appear unless required. Directly integrated messaging system linked directly to emails allowing for direct integration and accessing of messages as part of knowledge objects. Control over the access control over the information objects.

Further support:

There are additional support items which would allow to round out the full OHS as a complete implementation of the vision. Merging the browsing and editing process, allowing to seamlessly switch between editing and creating knowledge and accessing and reading knowledge. Easy ways of tracking and collecting pieces

of knowledge into journals or libraries. The ability to subscribe and get notifications when certain knowledge objects or topics are being updated, connected or created. A key aspect would be the signature encryption for each knowledge piece allowing for clear identification. In addition to build in text and email support the system should also allow for video conferences to be held, both in a structured and moderated format as well as in a free format, being recorded and documented as a knowledge piece. A versatile UI-system which allows for point-and-click interactions as well as, direct commands, voice commands, macros and menus. The entire UI should be customizable to the individual user and to the individual domain that it is being applied to.

Some tools already exist which incorporate one or more of the desired features, traits and attributes, but no tool has combined all into a true OHS yet. For example an open source tool named hypothes.is (To enable a conversation over the world's knowledge., 2019) allows for individual parts of a text to be highlighted and then tagged as a piece of knowledge. The object can be commented on and discussed directly. There are also numerous other examples that have some or more of the features desired in an OHS, the Doug Engelbart Institute lists: Spreadsheets, Documents, Video, Wikipedia, Ubiquitous Linking and Annotation, Websites and finally specifically their own website (OHS-Like Tools, 2019). The feature that they highlight in their own website is the indexed number that accompanies every paragraph of text on the website allowing for sections to easily be found, tagged and linked to.

2.4.3 CoDIAK and Dynamic Knowledge Repository

Engelbart worked on defining and developing his own approach to OHS. As part of his the bootstrapping paradigm he saw two key aspects at the center of realizing this. The two prototypes he used to describe his ideas were the CoDIAK process and the Dynamic Knowledge Repository.

The CoDIAK process is describes what Engelbart saw as the methodology for his bootstrapping initiative. CoDIAK stands for: the concurrent development, integration and application of knowledge (Engelbart, 1992). It is the cornerstone for what Engelbart thought businesses at the time needed to do in order to increase their effectiveness and thereby their Collective IQ. Engelbart uses what he called the ABC model as a means of underlining the CoDIAK process and highlighting how the need for businesses to tackle improvement methods rather than simply applying improvements to the problems at hand.

The ABC model is a framework which outlines three basic activities (See Figure 1):

A Activity: Business as Usual:

The primary activity describes how the business or other entity in question is operating at a day to day basis. It is the baseline from which the improvements method can begin. It can involve many complex task or just one simple task as long as it the norm for the entity.

B Activity: Improving how we do that:

The base activity is set in A, the B activity is to look at how the A activity can be improved. This improvement can come in any form such as speed or productivity. Introducing new routines or changing existing ones are typical examples of a B Activity.

C Activity: Improving how we improve:

Finally the step that is what makes the ABC model stand out from other improvement strategies. Rather than focusing directly on improving Activity A the model focuses on improving Activity B as part of Activity C. This means improving the improvement method that is being used in activity B. If Activity B was about developing new routines for activity A then activity C would look at improving the development of routines. Improving how routines will be developed in the

future. The long term effect and broad scale improvement that can occur across multiple domains is what characterized the CoDIAK process.

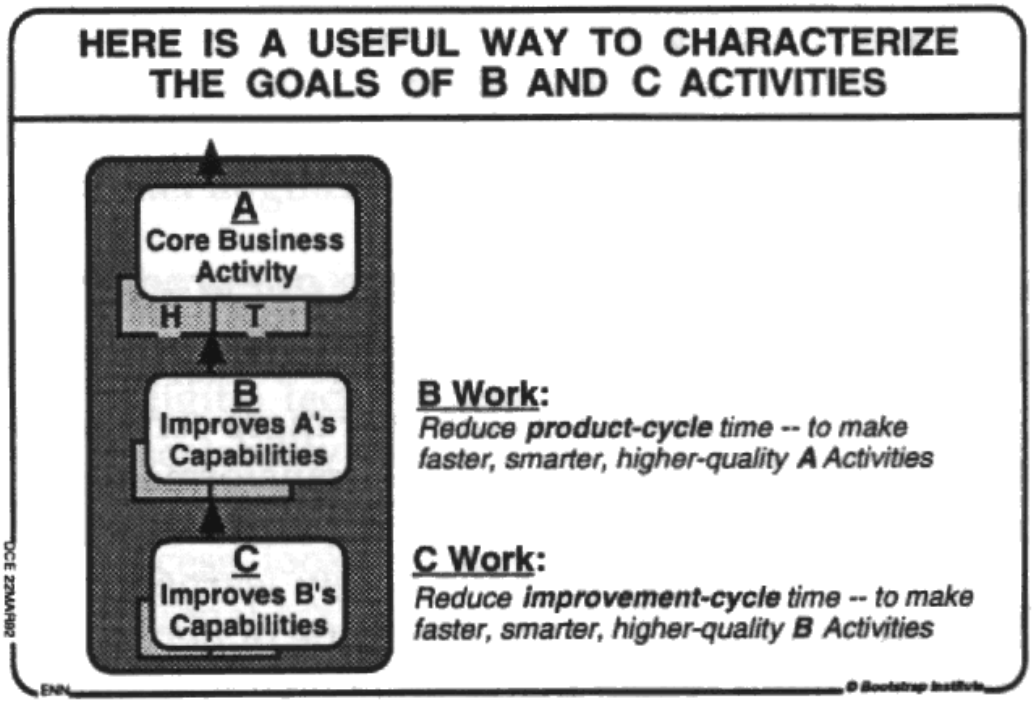


Figure 1- Chart characterizing the B and C steps of the ABC-method. From Douglas C. Engelbart 'Toward High-Performance Organizations' 1992

A repository is usually considered a static archive of published documents and files. The Dynamic Knowledge Repository (DKR) does as the name implies work towards making a knowledge repository that is actively and dynamically growing and changing. The DKR is how Engelbart envisioned the activities of the CoDIAK process would be recorded and achieved (About Dynamic Knowledge Repositories, 2019). He envisioned it as a brain of interconnected documents and snippets representing memories linked together in the collective intelligence. A DKR would span multiple domains and should be the tool in place in order to facilitate collaboration, discussion and innovation within an organization as well as across multiple organizations. The way it would connect people would allow them to easily search and access memories which were useful to the task that was

being tackled. Engelbart thought that the quality of DKR that was available to the organizations would be the key contributor to the increasing or lowering of its Collective IQ. In a way everything that Engelbart was envisioning was simply laying out the groundwork for the direction that he hoped humanity was moving towards, allowing for the solving of the world's greatest and most complex wicked problems. He was laying out at path that future generation one day could follow. He was drawing a map.

2.5 Knowledge Mapping

Maps are one of the oldest forms of visual representations of concepts by humans predating the written word and numerals systems. Maps allow for an abstract and symbolic representation of a concept to be visualized and for connections between objects and/or themes to be made. Maps allow for the complexities of grand landscapes to be condensed into the most important information elements, it simplifies the information without losing the big picture of the entire landscape. Wicked problems are complex and interwoven, they typically involve a large degreed of complex actors and issues. Simplifying the issue through the use of maps without losing the overview of the big picture and the connection between the points of interest seems a good approach to tackling wicked problems. Or allowing for allowing for a better understanding of wicked problems. In the time of information overload how to interact with the complex problems becomes increasingly crucial to the success of tackling big problems and complex issues. Mapping allows for the abstract to be communicated visually. For the first time in human history a generation is growing up that has never know the absence of connected information networks. Connecting information through linking and as nodes is a natural way for this generation to communicate and interact with knowledge media. Creating the strongest models that allow this to be enables is therefore significant in building up knowledge work moving forward.

Representing knowledge as an interconnected map in virtual space it how Knowledge Mapping can bridge the gap between knowledge work and interactive

problems solving engagement. Knowledge Mapping or Knowledge Cartography is a large field with many approaches and definitions. In the book literally titled Knowledge Cartography (Okada, Buckingham, & Sherborne, 2008) it is defined as:

- "*the art, craft, science, design and engineering of different genres of map to describe intellectual landscapes – answering the question how can we create knowledge maps?*
- *and the study of cartographic practices in both beginners and experts as they make and use such maps – answering the question how effective are knowledge maps for different kinds of users?"*

In short Knowledge Cartography is about making sense of the world and gaining new understandings through the process of doing so. It allows for sense to be gained in a manner which the written word struggles to do, the way humans can communicate sense through body language, subtle speech patterns, tone, film, and other forms of communication of ideas. In the book Knowledge Cartography emphasis is placed on three key concept which are central to the digital design of connected ideas.

I. "*Clarify the intellectual moves and commitments at different levels. (e.g. Which concepts are seen as more abstract? What relationships are legitimate? What are the key issues? What evidence is being appealed to?)*

II. *Incorporate further contributions from others, whether in agreement or not. The map is not closed, but rather has affordances designed to make it easy for others to extend and restructure it.*

III. *Provoke, mediate, capture and improve constructive discourse. This is central to sensemaking in unfamiliar or contested domains, in which the primary challenge is to construct plausible narratives about how the world was, is, or might be, often in the absence of complete, unambiguous data*."

I. is centered on establishing the major aspects that need to be developed as part of the model. It highlights what is existing and what areas are to be explored. It established the boundary objects which can then be interacted with. This is where

meta-connections and trans-disciplines can be established where they are lacking and appropriate. It is in part building the structure of the knowledge domain.

II. Knowledge creation can yield strong results through cooperation. Knowledge mapping is therefor also enhanced though the collaborative process. As the strength of knowledge mapping is the sharing and communication of complex and often difficult to understand topics it becomes an ideal tool for sharing and collaborating on knowledge work. Incorporating the ability for multiple people to be involved on the development of knowledge through the map.

III. Gathering and resenting knowledge is important, but there value of mapping comes from the insights which can be gathered though the connections made by the map as part of the network of interconnected information. The purpose of a map is to navigate a landscape and to get to a desired destination, similarly Knowledge Cartography requires for the navigation of topics, opinions and actors as a means of reaching the concluding goal of solving a complex problem. The goal can be in the scope of learning and exploration as long as it allows the user to generate new insights as part of step I. and II.

Developing a DKR or similar knowledge system could benefit from being structured as a knowledge map, employing the methods of knowledge cartography as an underlying grammar for the development of knowledge work. It would allow for the creation of meta-connections and meta-domains which generate new field of research and development as new domains for knowledge creation. The flexibility of maps allows for scaling and adapting to complex growing problems, such as wicked problems.

Knowledge cartography is a wide field and has seen many techniques and models which are being used, all with different focuses which come with strength and weaknesses. There are a range of mapping techniques and support tools available, so many in fact that they can be split into genres (Okada, Buckingham, & Sherborne, 2008). The different genres of knowledge cartography are designed with a specific purpose in mind. Some are educational (Cañas & Novak , Concept Mapping Using CmapTools, 2008) (Hyerle, 2008), some are developed for debate

(Culmsee & Awati , 2008) (Groetker, 2008), and others are information linking tools (Zeiliger & Esnault , 2008).

For the foundation of a domain map and the tackling of wicked problems, two mapping techniques stand out, concept mapping and issue mapping.

2.5.1 Concept Mapping

Concept mapping was first developed in 1972 by Joseph D. Novak and his research team and was initially developed to measure the learning progress of children, but has since then been used as a tool for facilitate learning and as a teaching tool for students and educators alike. Concept mapping is a mapping technique which strived to combined images, words and ideas into a diagram map and highlight connections between them and how they stand in relation to other existing pieces of knowledge. It has been shown be an effective learning tool at many levels, ranging from elementary school to higher education and even at a corporate level (Novak & Gowin, Learning How to Learn, 1984). Concept mapping also has a highly collaborative application, and has been shown to be an effective tool to both build knowledge in collaboration with other (Novak, Learning, Creating, and Using Knowledge: Concept Maps(tm) As Facilitative Tools in Schools and Corporations, 1998), but also allows for the result to be achieved and accessed later. Concept maps are usually arranged in a hierarchical manner having the more general concepts at the top and becoming increasingly more specific towards the bottom. The concepts are generally defined as words which are connected through linking phrases to form sentences of meaning and linking ideas together. The linking phrases should be kept as short as possible to simply the model and highlight the concepts themselves which are being networked together.

The underlying theory behind concept mapping lies in David Ausubel's theory of cognitive learning which was first introduced in 1963 (Ausubel, 1963) and is the foundation for the development that Novak and his team used for concept mapping. The core principle is what Ausubel refers to as meaningful learning, which

is described in three ways. The first entails that the person that is learning must choose to relate new ideas and concepts into their existing body of knowledge and preexisting notions and concepts. The second is the person learning must possess the necessary concepts already to make connections to new ones. And third is that what is learned must be meaningful within the domain. Meaningful learning is presented as an alternative to what he calls rote learning. Rote learning is when one does not attempt to assimilate new knowledge into ones existing pool of knowledge, but rather memorizes it without integrating the new concepts into own knowledge, it is the opposite of meaningful learning which is also part of assimilation theory by Ausubel. Concept mapping is underlines by constructivist psychology and constructivist teaching (Cañas & Novak , Concept Mapping Using CmapTools, 2008) which as opposed to early twentieth century education thinking encourages knowledge to be engages with rather than simply consumed, it also recognized that knowledge work are growing and changing and that learning methods must adapt as well. Adapting to it through the use of tools such as concept mapping.

Creating a concept map begins with defining what the central concept is that is going to be mapped. This is the focal point of the map and located at the top as the most general concept. All other concept are going to be placed below it in a hierarchy based on their generality. In order to start the process one should generate a focus question which is tied to the main concept. It is there to serve as a guideline for what specific view within the concept that is taken, f. ex. If the topics is 'School' a focus question could be; what makes up a school? This limits the scope of the topics and allows for new concepts to be generated such as classrooms, teachers, students, etc. The focus question should be an open question to allow for exploration rather than a closed question. And questions that require that the subject concept be explained are ideal (Derbentseva , Safayeni, & Cañas, 2006). Once the focus question has been established, a brainstorming session should occur where all concept that are linked to the main concept through the focus question are listed in what is called the 'parking lot' and is simply a list located to the side of the map before being added. Once a large amount of concepts

have been gathered, typically ten to twenty, they are sorted by how general they are. Evaluating the order in which the concepts are presented and how they should be integrated into the map is what Bloom refers to as synthesis and evaluation (Bloom, 1956) which he deems the highest levels of cognitive thinking. Integrating and connecting the concepts into the map are also synthesis and evaluation activities and according to Bloom improve the cognitive learning of the topic. Connecting the concept from top to bottom is helpful, but in order to utilize the full strength of concept mapping, cross-linking concepts vertically allows for greater insights to be gained, as well as connecting concepts from across the map to generate new phrases between the concepts and thereby new relationships. A map will typically go through several iterations before being complete. For an example of a complete concept map over the concept of concept mapping see figure 2.

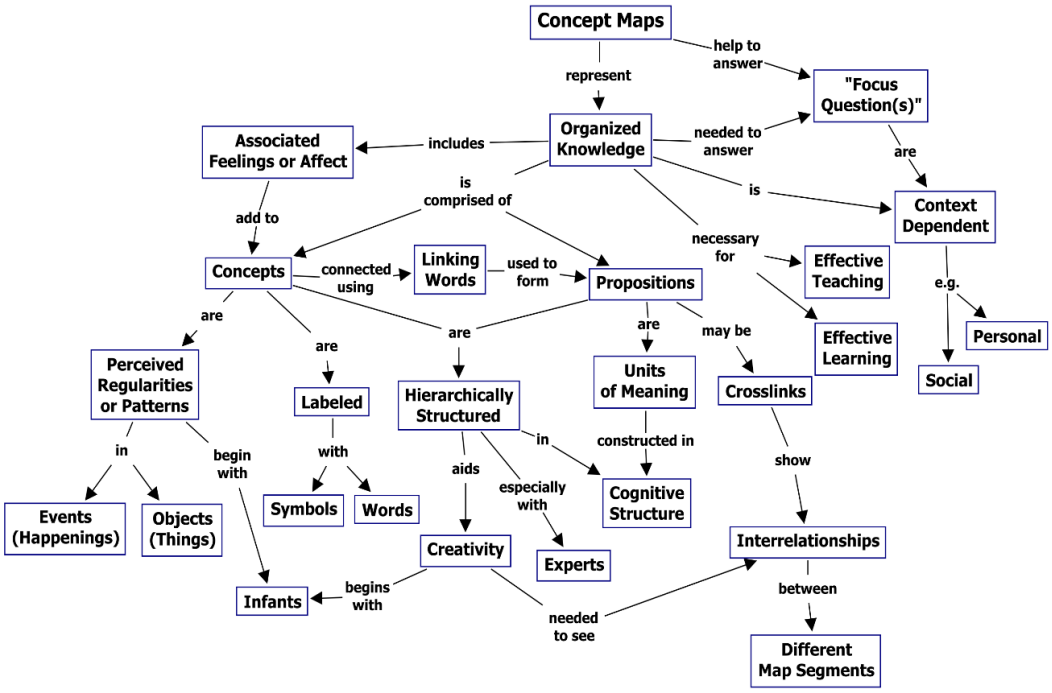


Figure 2- A concept map as shown in Knowledge Cartography

Traditionally concept maps were developed using analog methods such as pen and paper and post-it notes. This is still commonly practiced when developing concept maps such as in classrooms and in company meetings. The advent of digital technology has however introduced new tools which allow for some new advantages which were not resent in the traditional implementation. The digital solution to concept mapping is perhaps exemplified by CmapTools (Cañas, Hill, & et al., CmapTools: A Knowledge Modeling and Sharing Environment, 2004) which allows for the creation of concept nodes digitally. Some features which make the digital solution stand out are the storing capability, allowing for users to much more easily create their portfolio of maps and share those more easily. The collaborative element is also enhanced allowing for people to share and discuss maps globally through the internet. Revising the maps becomes simpler as the nodes only require to be moved and adjusted while the connections automatically update to reflect the adjustments. A digital solution also allows for different media to be implemented into the concept map such as making images more easily introduced, video and linking to external resources becomes much simpler.

The strength and weaknesses of concept mapping have been explored both inside and outside of the classroom (Chang, Sung, & Chen, 2001). Advantages are wide ranging, the wide application range allowing to be used in most learning environments, as well as well integrated learning which occurs during the modeling. Given that the connections between concepts are verbalized phrases which make up sentences it becomes clear to see connections between concepts and allows for cross connections to be made, which is often a challenge in rote learning. The information is condensed and easy to read and consume, making it also very simply to visualize and creates a clear visual image which can help with memorization. The collaborative nature of the concept map also makes it well suited for working in larger groups or even working on the same project from different location given a digital solution.

While concept mapping is well suited to its purpose and has shown strong results (Tarté , 2006) there are limitations and drawbacks which prevent its large scale

implementations. A disadvantage that comes from the use of concept maps comes in the form a double edged sword, while the simplicity in concept and phrasing allows for a clean and simple visual map which is easily read and remembered it does also limit the disruptiveness that is possible for the concepts and connections. Some concepts or connections might prove too difficult or complex to reduce to a single phrase connection or node. Another disadvantage can be that fact that it can be time consuming to create a complete map and then to revise to and incorporate all elements such as images and external resources. Mapping also generally comes with the downside of having a learning curve which can make it difficult for new users to adopt it over conventional methods of knowledge creation and learning. While concept mapping has a very simple notation it does still require to be learned and practiced, through revision, in order to achieve the best results.

2.5.2 Issue-based information system (IBIS)

Issue mapping derives its name from "Issue-Based Information System" (IBIS) and was originally developed by Horst Rittel and Werner Kunz in the late 1960s to early 70s (Rittel & Kunz, 1970), the IBIS principles and notations have also directly inspired conversation mapping or dialog mapping. IBIS was originally developed with the intent of supporting political planning and coordination process. It is intended to guide discussion and allow for issues to be settled through problem-solving groups. It does this through the examination of an issues taking in arguments from all sides involved.

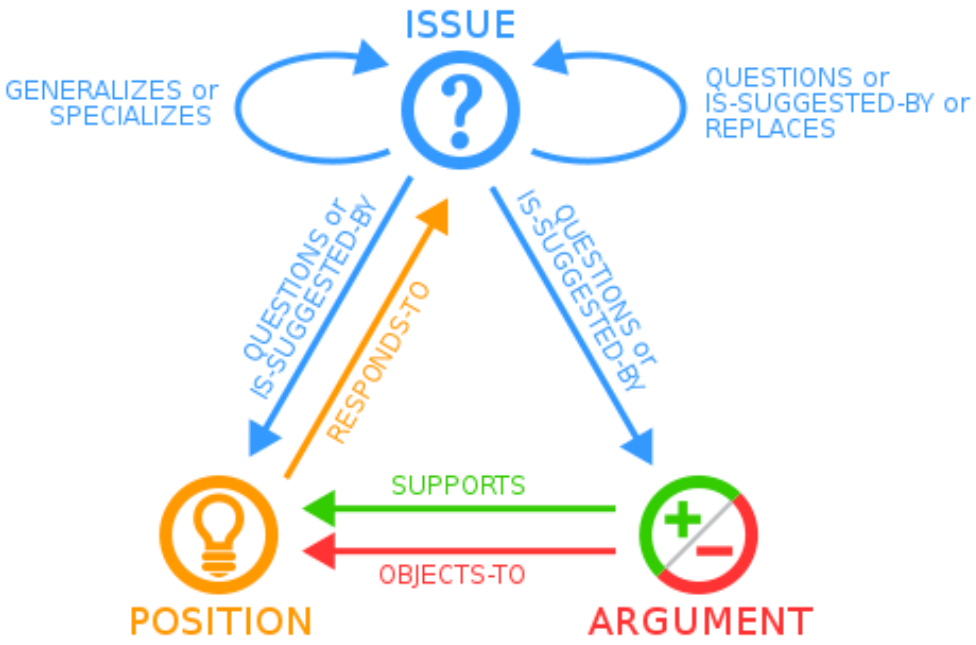


Figure 3- Shows the core elements of the IBIS notation and how they relate to one another.

Issue mapping takes the notation from IBIS and applies it to tackling great issues and to find solution through organized debate. The IBIS notation centered around questions which is represented as an issue which needs to be solved. The core issue is placed at the far left and can be pointed to by positions to the Issue. The positions are a response to the issue, and thereby is an attempt at answering the questions. A positions can be also be pointed to by another issue which may arise as a result of the positions. Arguments either in favor or against the position can also be raised and point towards the position. Arguments in turn can also be the subject of new issues that are raised as a result, opening the map for new positions and arguments. While an Issue map can keep on going, it is the responsibility of the actors and moderators to return the discussion to the core issue the discussion leads further from the core issue than is intended. Figure 3 shows the IBIS notation as it is used in Issue mapping, noting the three main elements of Issue, positions and arguments, and how they relate to one another within the map.

Dialog mapping is a method and notation for quickly and accurately recording a conversation or meeting in an efficient way. Dialogue Mapping was developed by Jeff Conklin (Conklin J. , 2005) as a means of utilizing IBIS as a way of mapping a conversation, but more importantly he saw it as a way of tackling wicked problems.

Dialog mapping aims to work towards solving wicked problems by creating models which are non-linear and try to reflect how humans really think and communicate. Instead of trying to create models based on the problem the approach is to start a dialog and discus the problem, by having a more organic conversation this can allow individual to think more freely and not the reliant on the formatting of a problem. A dialog can be mapped by a designated individual which does not partake in the discussion, or if everyone is versed in the grammar everyone can keep track of the conversation with their own map and use these to generate new ideas and topics in relation to solve a problem.

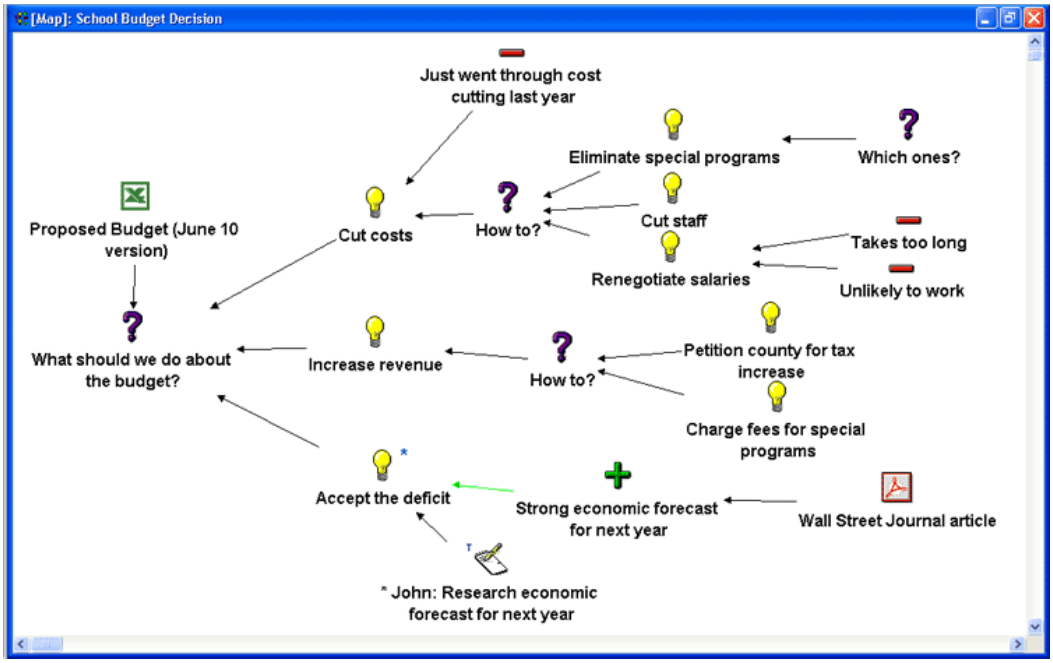


Figure 4 - Example of dialog map from Dialog Mapping by Jeffrey Conklin

Dialog mapping is conducted using a shared visual display which allows all actors involved to view the progress of the debate and the topics that have already been explored and argued. As the purpose of a dialog map is to suspend decisions and generate a clear understanding of all the viewpoints and arguments involved in an issue, before coming to a conclusion. Coming to a consensus is arguably easier when the information is clearly displayed with all accompanying arguments.

The notation of Dialog mapping is simple and deeply rooted in IBIS. The terminology used is slightly different and is accompanied with a visual language of symbols which make the overall readability simpler to view, which is important given the dynamic nature of the creation. The basis of the notation is centered on questions symbolized with question marks and correspond sing to issues in issue mapping. Positions are labeled as answers and are still supported by arguments which are represented using a green plus symbol or a red minus symbols respective to their supportive or opposing nature. Dialog mapping also introduces to additional symbols to the notation, namely the introduction of information elements, represented as documents and which can make up the basis for a question, an answer or arguments. In Figure 4 several different information elements have been introduced. These elements range from an excel document, a wall street journal article and a research forecast. Each element is shown supporting a different element. Important to note is that not too many such elements are to be introduces as to enhance readability and not clutter the map. The final symbol introduced to dialog mapping is a gavel which symbolized the conclusion of a topic and will highlight the conclusion or decision that has been reached within the issue. If no conclusion is reached the symbol will be absent. A map can be complete without having a conclusion, as it will still serve to give an insight into the debate and can be used historically as a recording of the session. Using a dialog map can also prevent debates from being repeated, as the facilitator can simply point to the element on the map and show that it has already been argued.

Making use of dialog mapping, as part of issue solving, brings with it several advantages that yield positive results in the solving of wicked problems. Conklin highlights some of the following in his book.

- Given the large number of potential contributors, the dialog map retains input from all involved and reflects this as part of its map. This gives all participants a voice that is incorporated into the map.
- The map allows for group thinking as a collaborative activity. The shared display of elements give a shared understanding and visual clarification if the questions and arguments that have been presented.
- Through the logical display of the topics the map focuses the group to discuss in a guided direction.
- The session is recorded as part of its process and can therefor easily be references and cited later.
- Actors that were not involved in the debate can get an understanding of the debate after the fact, as the topics discussed are clearly visible and noted.
- The rationale behind answers and arguments is made visually clear through the IBIS notations.
- The map encourages collaborative work as a means of gaining a large number of views and arguments and has a better chance of covering many actors and viewpoints to a problem. This makes it well suited to discussing wicked problems.

Some drawbacks to the use of dialog mapping are common with general drawbacks of mapping techniques. Other issues are more specific to dialog mapping itself.

- Given the broad number of actors involved a large number of solutions and answers might present itself to a questions and it might be difficult to choose a point of action if the arguments are evenly distributed.
- The IBIS notation is simple and easy to read, but it requires that someone actively create the map as it is being debated for it to be effective during

the debate. This can be resource effective as it requires a practiced mapper well versed in dialog mapping.

- Through the simple display elements there can be a lack of understanding from the actors if an element requires greater explanation to be fully grasped.

2.6 Debate graph

When looking for an implementation of DKR like knowledge systems the debate graph stands out as an implementation of many of the ideas discussed by Engelbart in his Vision. The debate graph is a web-based tool which allows for collaborative discussion of issues through visualized mapping of debate. The debate graph was created by former Australian Minister for Higher Education Peter Baldwin and David Price with the goal of developing public service discourse platform which would allow for global cooperation and debate from a clear and neutral scientific standpoint free from the distractions of repetitive clutter. Through the creation of communities and the development of graphical maps within the debate graph issues are under constant discourse and the map is to be revise throughout the development.

The debate graph has seen application at high levels of political discourse being used by the US Whitehouse (Noveck, 2009) and the UK Foreign and Commonwealth Office (Nuclear 2010: NPT Review , 2011) amongst many other mass media outlets and newspapers. The political application was highlighted the complexity of issues that can be approached though mapping tools such as this. Over the span of four week the development of a Gaza map took place in 2009 aiming to help reach an understanding the Middle East (Price, 2009).

The debate graph is a web based application where one interact directly with knowledge maps. The only requirement is to create a free account before being able to create and share maps. The maps can be used by individuals, small teams or even large corporations as a means of structuring debate and information. The interface is split into two main components; and inspector which contains long

form information such as text, video, citations, commends and history, and the navigation map, which shows how the pieces of information connect to one another and which create the bigger picture. The navigation is done through interacting with nodes which have connections going in and out depending on the relation. The view of the map can also be changed highlighting different features such as how much is to be shown and expanded. The navigation map takes its roots in the IBIS notation.

The notation of the debate graph which includes the nodes and connection between them will be referred to as the grammar of the debate graph. This is to indicate the connection between mapping and language. The debate graph has a large number of different ways for information to be stored and interacted with. The grammar is heavily based on the IBIS notation, following the structure of an Issue or a question being raised than then having positions be taken to the issues and supported by arguments. The debate graph also adds variants of as well as more specific elements to the notation. The different types of elements are highlighted in different colors with differently colored arrows allowing for quick and visual identification of the elements role at a glance.

A brief overview over the different elements with quick descriptions can be seen on figure 5 as taken from the debate graph website (debategraph, 2019).

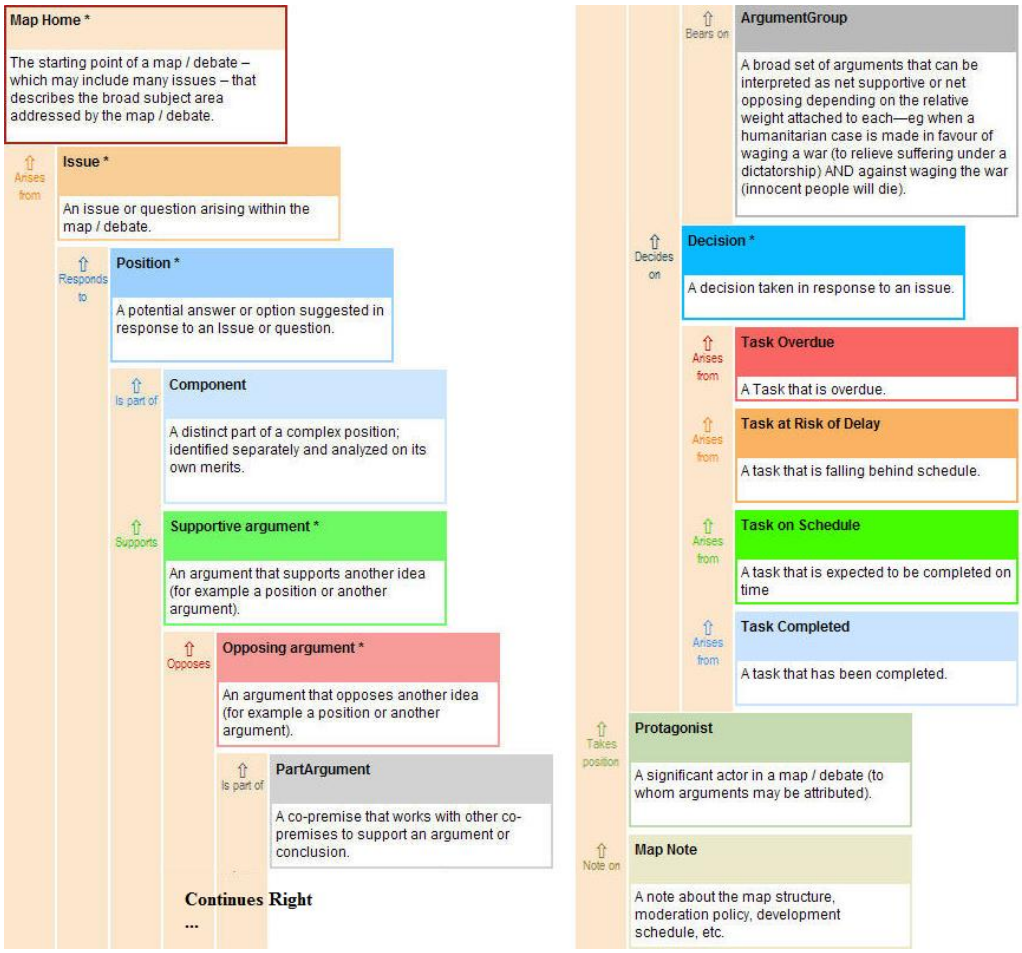


Figure 5 - Image from debate graph website highlighting the different types of nodes that can be created in the debate graph map and how they relate.

Visual elements are added to the map to allow for easier navigation. The node elements are centered on the current topic that is being viewed. Connecting elements are displayed as either being larger or smaller depending on how they stand in relation to the topic. Larger objects bring the user further up in the hierarchy and smaller go deeper. Symbols are sued to identify other properties that a node has; * indicated that the object has children (elements further down in the hierarchy) or that it is being linked to through an external cross-link, ° denotes that there is a detailed explanation to the element in form of either text and/or video. Cross-linking between objects and maps allows for information to be placed outside of the hierarchy and can create a connection between all types of elements.

The debate graph has its own notations for the different kind of cross-link references that can be made as well and is indicted by the ‘ symbol. (debategraph, 2019).

The information that is stored on the map can also be viewed in different modes. From variants of the initial setup to more traditional hierarchical views, for a visual reference on how such a view can look see figure 5 which displays the nodes in such a view.

A feature of the debate graph which allows it to ensure quality of the nodes and connection, as well as allow for interaction of many actors with the map. The rating system is simple to engage with, allowing for objects inside the nodes as well as relations to be rated on a scale from 1 to 9. The rating of an idea is represented in the thickness of the arrow, the higher the rating the thicker the arrow will be displayed to the rest of the community. Not yet rated items will by default appear as thin. The rating appears alongside any citations and comments which are made to the knowledge object. The rating allows for a visual representation of the strongest ideas and concepts to be highlighted and seen more easily.

2.7 Value Matrix

Assuring high quality of publishing is generated through the peer review system within academia. This is a tried and tested method which results in high quality publishing around the world. Internet resources are generally criticized for the lack of through evaluation of content. This creates an unappealing environed for academics to enter new forms of digital publishing and knowledge creation, leaving the alternative of digitalized versions of old school publishing. Creating a new academic ecology requires that the system keeps track and records contributions to knowledge work, giving a measurable impact that a contribution has to a knowledge work system, such as a domain map. The Value matrix object prototype is suggested to that end, being part of the knowledge federation applications (Karabeg, Federation through applicaiton, 2019).

The value matrix object prototype is an object which is attached to a contribution in a system and through a matrix estimates the value the contribution is providing to the system, as well as other value it adds as a knowledge object. The value matrix object can be attached to any knowledge object including documents as well as people and actors within a knowledge system. The overall relevance of a given knowledge object is determined by the overall value of that is provided by the matrix.

The value matrix is the result of the implementation of the QRI-model to a knowledge system. The QRI-model stands for Quality, Relevance and Importance, and is the basis of the matrix which makes up the value matrix object. The three are defined (Lachica, Karabeg, & Rudan, 2008) within the context of the value matrix as such:

> **"*Quality*** *reflects the intrinsic value of an information resource. Information that is unreliable or impossible to understand is valueless, even if it may otherwise be highly relevant or important.*
>
> ***Relevance*** *reflects the value of an information resource from the point of view of the user's needs as the user himself perceives them.*
>
> ***Importance*** *reflects the value of an information resource from the point of view of a larger context or as seen by people who may possess knowledge about what the user may need which the user himself may not possess."*

The factors are how knowledge pieces are to be captured and evaluated in order asses their value. In order to be implemented in a mapping system the question of how the value of an object is to be measure. A combination of two approached suggested by the prototype are manual and automatic.

The manual assigning of the QRI falls on the user of the system in order to demine the significance of the knowledge piece in respect to the system. The QRI-score is to be given on a scale between 0 and 10. Knowledge Objects with low scores are to no longer appear as part of the system to users (though will not be removed entirely). The ratings are to be given to each aspect of the QRI-model. The users

providing the ratings are weighted based on their ‘trustworthiness’ and contribution level which is to give an indication of their knowledge level. This measurement of contribution would be a reflection of their own value matrix as part of the system, creating a feedback loop between users and knowledge objects within the system. In the context or relevance its score is dependent on the location within the map. One knowledge object can have different relevance depending on is connection and context.

The automatic generation of QRI is to account for only a margin of the weight that is taken into the overall value score. It is to provide the guiding frame and smoothen the process resulting in a stronger result. It does this by recording the user’s activity and activities in relation to one another to determine the weight that is to be given every users input. By adding this automation the quality of the manual assignment is strengthened.

The role of the value matric within the context of a domain map is to record contributions to the map in terms of Quality, Relevance and importance. Creating a map where the valuable knowledge objects are more visible on the map and generating the most accurate map as a result. The prototype of the value matrix is designed to work together with other systems such as a domain map and is therefore ideal to be integrated as part of the domain map prototype.

3 Approach

The underlying foundation which allows for the domain map prototype to be designed has been set. It is a manner of deciding on an approach on how the model of the prototype is going to look. The approach strategy needs to be determined as a means of guiding which design methodology is used to approach wicked problems. This creates the guiding philosophy by which the modeling will be approached. Determining test models will be crucial to determine what features to include and what needs to be highlighted as part of a domain map prototype. Creating a general picture of that the prototype will look like well inform changes that need to be introduced.

3.1 What is the Prototype?

In order to get an understanding of how to approach the design of the prototype the general concepts need to be in place serving as a blue print to follow for the approach. These concepts have been introduced in the previous chapter. The blueprint is a how the domain map prototype is envisioned to work. Based on the problem statement there are several key aspects to incorporate.

Design a mapping tool prototype with a grammar enabling knowledge federation across multiple domains.

The model serves the primary goal of knowledge federation as part of the indicatives larger goal of a paradigm shift. The prototype is to work across multiple domains. A domain in this context can be a field, it can be a larger topic or it can even be a transdiscipline. Building on the principles of knowledge mapping the grammar is to be defined and well as the general use of the application (tool).

The intent for the domain map prototype is for it to be a web based application which enables users to interact with, create and share in domain maps. Maps are tied to specific domains but can intersect through the use of link connection which can span cross-domain. Through the creation of domain maps a web of maps is

crated which is the complete knowledge map. The map consist of nodes containing information as well as connection which connect the nodes, as well as providing some form of context. The map should be easy to navigate and interact with as well as be edited seamlessly as part of the exploration. Through navigating the map it serves as a learning tool and can allow for the education on specific topics while leaving room for new ideas and insights.

3.2 Mapping a Wicked Problem

The domain map prototype is being crated to address the complexity of modeling and understanding wicked problems. In order to tackle wicked problems getting a full view of the problem from as many different perspectives and with many ideas as possible allows for the problems to be managed more accurately. The creation of a tool which allows for wicked problems to be approached more easily can yield positive results across many fields. Some of the biggest problems facing the world a wicked problems. Creating a knowledge community organized though the domain map could allow for such problems to be attacked more strategically. In order to do so a strategy needs to be decided on.

When introducing wicked problems there where three strategies suggested as approached to wicked problems: Authoritarian, completive and cooperative (see 2.2.2).

Looking at the different strategies they all come with clear advantages and disadvantages. When tackling a wicked problem the strategy that is implemented is crucial to the success. In the scope of education a fully authoritarian strategy seems to go against the academic nature of knowledge development. Reducing the number of participants that partake in learning and development of knowledge is the opposite of the purpose of education. Competitive strategies can allow for debate to become a key aspect problem solving, it can however result in unideal solutions winning out. Cooperative strategies seem a natural fit in tackling information creation as if facilitated well it allows for all stakeholders to participate in the solution process as well as generating the most versatile solutions.

3.3 Knowledge Federation

In order to map a terrain on requires first understanding of the geography that one is attempting to map. The domain map prototype is only a small part in the knowledge federation prototype which is being spearheaded by Dino Karabeg as a means of finishing Doug Engelbart's unfinished revolution (Karabeg, Knowledge Federation Prototpye, 2019). Creating the prototype of the domain map requires something to map in order to assess what elements need to be in place to fully capture the complexity of a problem. As the domain map prototype falls under the domain of knowledge federation it seems an appropriate base line for modeling. By mapping knowledge federation is in fact modeling itself and is as such designing itself for its needs.

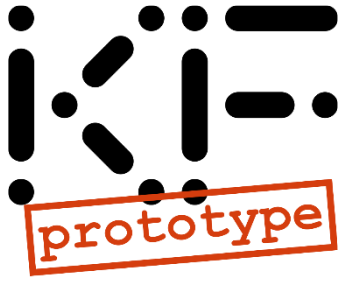


Figure 6- knowledge federation logo as seen on knowledge federation website

Knowledge federation is a prototype which aims to show how knowledge can be created and shared utilizing modern technology and methodologies. While the domain map prototype has the scope of exploratory education in this thesis, the knowledge federation aims to encompass many domains, such as politics, science, as well as education and others. The visual theme of knowledge federation and its motto are centered on connecting the dots. Visualized through the logo which are the letter K and F created through dots which are connected (See figure 6). The visual theme that resembles a map. The goal of the prototype is to change the way that knowledge is being approached, enabling a new goal oriented mindset, which seeks to improve our systems as a way of avoiding catastrophe. Steering towards a cultural revival on par with the resonance.

Why use knowledge federation as the basis of modeling for the domain map? The answer is twofold: First while knowledge federation encompasses many domains as a trans-discipline the core of what knowledge federation is about is enabling knowledge work. The domain map aims to enable the creation of

knowledge as well making the two well aligned. Second the complexity of knowledge federation and its connection to wicked problems makes it a strong test case for how robust the map will be at handling complex issues such as wicked problems. It acts as a sort of stress test for the domain map prototype.

The approach to map knowledge federation is going to steer the direction of the entire project and as such will give the basis for this thesis. The initial approach will be to take the knowledge federation prototype website as a starting point. Through the creation of the website the information becomes organized and can then be visualized more easily into a model. The website contains the major elements of what makes up knowledge federation and acts as an introduction to the topic. The Initial map will be designed using the debate graph application. Through the development of the map it should become clear in which areas it is not suited for the mapping of this nature. From there improvements and additional implementations will be viewed and designed. In order to get a better understanding of what needs to be mapped as part of the domain map prototype the first prototype towards that end will be the design of the knowledge federation website.

3.4 Knowledge Federation Website

The design of the knowledge federation website is the first step in a approaching the domain map prototype. Having been part of the design team which allowed for the website to launch at the start of 2019 allowed for a deep understanding of the information which makes up knowledge federation. The design of the domain map will be modeled in the website and is thereby an extensions of the project. The domain map prototype is a piece of the larger knowledge federation initiative. The website is therefore part of the domain map prototype as well (Karabeg, Knowledge Federation Protoype, 2019).

The knowledge federation website is designed as a jumping on point for people to understand what knowledge federation is about. It guides the reader through a series of discoveries and stories to help bridge the understanding of the ‘paradigm shift’, the Cultural Revolution that is the goal of the prototype. The website is

structured simple and straight forwards, containing five key parts. The first part is the main page which is the first point of contact for the reader. There are then four sections which each focus on brining understanding through a different lens or medium. The four section are called Federation through; images, stories, applications and conversations (Karabeg, Knowledge Federation Prototpye, 2019).

The homepage is designed in the same manner as the other pages, but the content tells the historical story of knowledge federation and its origin and inspirations of scientific 'giants'. The pages themselves are structures as small vignettes each with its own purpose and topic. Each vignette is then again split into several topics which are titled and can be accompanies by other media. Each vignette can lead or link to other pages and/or other media, but serves as a puzzle piece in the page as a whole striving to bring the reader out of the metaphorical forest and on top of the mountain from which they can see the whole big picture that knowledge federation is tackling.

Federation through images is the first of the pages the reader is directed to explore upon completing the front page. The page is as the name suggests centered on designed images which convey a concept or idea, building on the idea that images are worth more than a thousand words. In this case some images have the potential to be worth far more than a thousand words. The page is the first that the reader will begin to explore, and this is by intent. The images allow the reader to properly contextualize the information in a visually simple manner, and keeps the reader engaged. Each vignette in this section is centered on an image and is built around contextualizing and explaining it. This is an important detail to keep in mind in regards to mapping the website, keeping the image at the center of the element.

Federation through stories follows the most traditional format resembling a series of articles or journals. The vignettes in this section are telling historical tales which lead to a point of understanding or which informs a piece of knowledge or idea. The stories are usually centered on individuals whom embodies the knowledge federation spirit in some form or another such as Doug Engelbart, Erich Jantsch and Aurelio Peccei. The stories are the longest elements amongst the

pages and serves to give a more relatable context to the reader which might begin to feel somewhat overwhelmed by the amount of different information, ideas and concepts that the site has presented up until this point. The challenge in mapping this section will most likely derive from the long form structure which is somewhat different the digestible bites that the other vignettes have provided.

Federation through applications is the section which is most rooted in technology. The vignettes in this section are focused on presenting different application and prototypes which are being used and/or designed for the use by knowledge federation. The domain map prototype will find its home in this section once the prototype is completed. As an application which enables the visualization knowledge federation in an alternative medium to the website, there to accompany it. The section sends the reader to many different locations and sites as a result of fully exploring it, highlighting the advantages that direct linking within a map could provide. The challenge become incorporating the different applications and prototypes into the map in a map which is easy to explore and does the applications justice.

Federation through conversations is the section which stands to gain the most from a different medium as it is reliant on cooperation. The website follows the same structure of vignettes that is present in the previous sections, but hints at a more collaborative element. The creation process is being examined, letting the reader reflect and decide on how they can fit into the bigger picture. The section acts as a tail end to the website leading the reader off to explore. It does however hint at the collaborative nature that is desired. Creation through dialog. This section might include a more interactive part in the context of the map. Allowing for conversations to be recorded and engaged with as knowledge emblems of discovery.

Mapping the knowledge federation website can be approached in many different ways. This thesis will build on the debate graph as a discovery tool. Developing the map within the structure of the debate graph and highlighting what areas need improvement or change, as well as what features that might have to be added or implemented to fully take advantage of the visual medium more effectively.

The mapping must be able to incorporate all five sections of the website and should ideally also build on them making use of the mapping medium. The flow of the presentation should remain intact, allowing the reader to explore if desired, but also provide a road map which one can follow leading to the top of the mountain.

3.5 Debate Graph Model

The debate graph application was as the name implies designed for debate. The knowledge federation website was created as an ideas starter, as a way of introducing a very complex topic to readers and to invite them to join the knowledge federation. While the two are rooted in many of the same ideas and philosophies they inheritably to not overlap in practical use. The debate graph does however allow for many features and ideas which the website does not allow for, and would like to see implemented as stated in the applications section on the website. Such as the ability to directly comment on each individual piece and to start a dialog directly related to the topic in the element. The aim of modeling the website in the debate graph is to get a better understanding of the tools that need to be in place in order to achieve the desired domain map, and to see how they might be implemented. The domain map is intended to serve as a learning tool as well as a modeling tool, as such the development process will have its foundation in active learning (Wrenn & Wrenn , 2009).

One of the major challenges when attempting to translate the website from its static text based layout to a graphical model is on deciding how to divide the information that is on the website.

One approach would be to fully translate the content of the website into a different form so as to fit into the IBIS notation structure. Rephrasing and organizing the information into issues and questions and divide the supporting and opposing arguments that the website provides. This approach would result would likely work well in the creation process of the map, as it would be tailored to the grammar of the debate graph. It would however also require large amounts of restructuring of

knowledge as not all information on the website is structured to fit into the IBIS notation. Not only would that require terrible effort (something which isn't repeatable easily) but it also runs the risk of information being mistranslated or used incorrectly as many of the information elements are very multi-faceted. It would also eliminate the discovery of areas that might be lacking in the debate graph for a more education centered approach. Building on the outline by Conklin for this method (Conklin J. , Dialogue Mapping: Building Shared Understanding of Wicked Problems, 2005).

Alternatively approaching the mapping process with the intent to 'break' the map and see what does not work with this approach as a means of iteratively making improvements and seeing what needs to be implanted has the benefit of generating ideas more easily and to find problematic areas. A danger with this method is the potential disconnect between the notation that is in place on the debate graph and the general layout of the website. Testing both methods will give the best understanding, and generate a picture what to address in the domain map prototype.

Regardless of which approach is used there are a number of factors that will be taken into account when translating the website into the issue map. When presenting the information how to split it up becomes crucial. Each of the pages is intended as a whole, split into vignettes and split once more into titled paragraphs. This seems to give a natural way of splitting the information, but it does raise some questions. Should the vignettes be the smallest node element or should the paragraphs be nodes of their own? How should the information be connected? Should they be linked in order to maintain chronological order or be grouped by page and allow the reader to explore them in the order they see best? Fracturing the information too much could result in the reader losing sight of the connection, or read a piece which was intended with prior knowledge of a different element. Determining what elements might require their own nodes, or which could link to other nodes or even maps will also give insight into what grammar might be needed in the domain map. Should actors or individuals be mapped and linked? Creating a node for say Albert Einstein would allow for multiple maps to

connect to this element and view other works or references to the individual. Giving the individual a map of their own.

A factor to consider is what the intended view is for the information. The debate graph allows for a range of different presentations of the information which each have advantages and weakness in terms of presentation of information. The default view of the debate graph is the *explorer* view. In the explorer view the highlighted element is shown as a node with connection to all neighboring elements. The range of how many elements that are shown can be adjusted as well ranging from all, to only showing the highlighted item and its immediate neighbors. Figure 7 shows an example of how the default view looks like when all nodes are shows rather than being in focused mode which is the default edit mode.

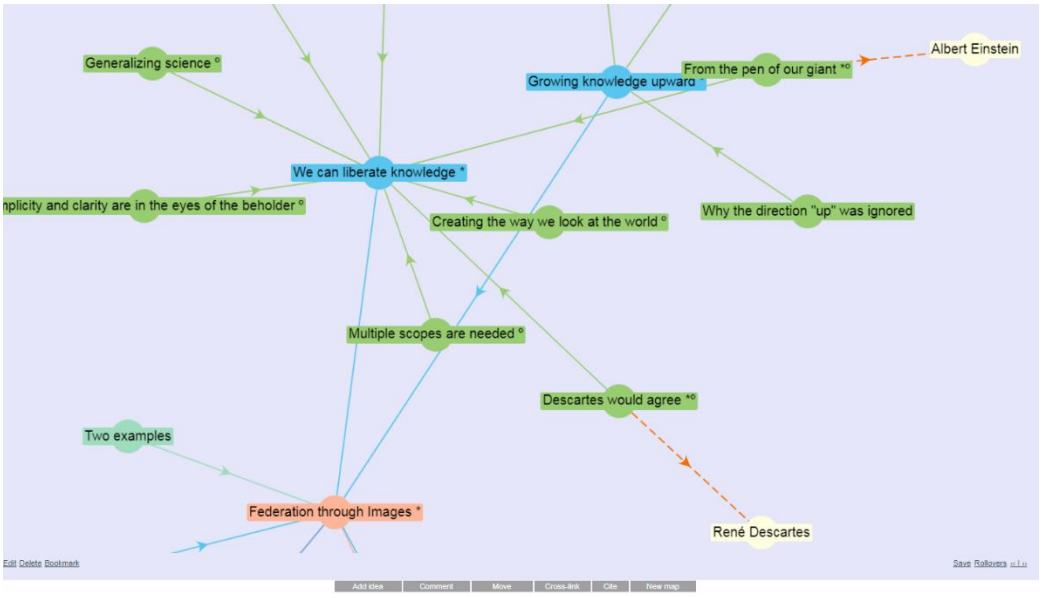


Figure 7- Model made in debate graph, showing a selected area of a map depicting the knowledge federation website.

The different displays allow for the reader to explore and create connections in different ways. Using different displays also gives perspective on what might be missing, or if information is getting clumped and/or too much is bound into one node and might need to be split up for ease of view.

A feature which will likely be particularly useful in translating the website into a map is the article function. The article view generates a plain text version of the map which aims to mirror a traditional article. The website follows the traditional structure of an article, meaning that if the article generated by the debate graph as a result of the map is the same as the website article, then it is clear that the information has been translated onto the map in its entirety. It does not however determine whether the presentation results in an equally good reading and learning experience.

Modeling the different parts of the website comes with different challenges as the different pages have different modeling needs. The views might also play differently for each of the different sections, benefitting one more than the other. The main page and introduction requires a certain sense of hierarchy. The information must be ordered correctly to allow the reader to result with the correct conclusion and understanding. This means that not splitting up the information becomes more valuable. Requiring the information to be in one place does however also reduce the precise links that can be made between ideas and concepts, especially cross-map. The image section of the website often builds on one image which takes center stage, it is therefore important that the image remain visible to the reader as it is being explained. The stories are the ones that benefit the most from being split up, connecting to a single argument or view point. Each story should stand on its own and only stand to inform the argument. Applications can prove challenging to the debate graph to the extent that much of the information is being linked externally, and not modelled inside the map itself. Attempting to model some of the prototypes however would provide some additional insight on what may need to be implemented in a domain map. For the conversations section of the page two factors stand out. The first being that multiple mediums need to be mapped which might not be supported, such as time coded video or conversation recordings. The second factor is conversation on the map. Discussing specific topics of the map and having the comments and discussion be a valuable tool that adds to the map rather than distract from it.

The approach to developing the domain map is going to be to create all the different models describes so far as a means of getting a better understanding. As the subject is complex by its nature and generating understanding of it is the main task of the map, using surveys or other methods of crowd sourcing the methods would likely not result in relevant insights outside of utility of the debate graph, which is not the primary goal. Once a solution for a domain map is completed, by its very nature the map will create a feedback loop which will allow for it to improve itself.

Each model that is created in the debate graph is testing a specific model or requirement for the modeling of a map. A list of the following factors which play into the models is what will generate the insight which will inform the creation of the domain map prototype:

- Information splitting models
    - Full page with linking to external sources
    - Vignette based splitting, keeping each vignette in place
    - Paragraph based splitting, each paragraph is a node in the graph
- Page models
    - Main page; a model which focuses on different implementations of the front mage
    - Image based; takes the image page and attempts to keep the image the center of focus. See figure 8.
    - Story based; focusing on longer stories, attempting to interconnecting them for insights
    - Application based; testing how external objects requiring more complex explanations are modeled.
    - Conversations based; allowing for different mediums to be implemented and for conversation to be tested as part of the model

Creating the models which are made from combining the task from the first list with a point from the second generates fifteen different domain maps. Each map

can give insight into different issues and suggest reasonable or unreasonable approaches.

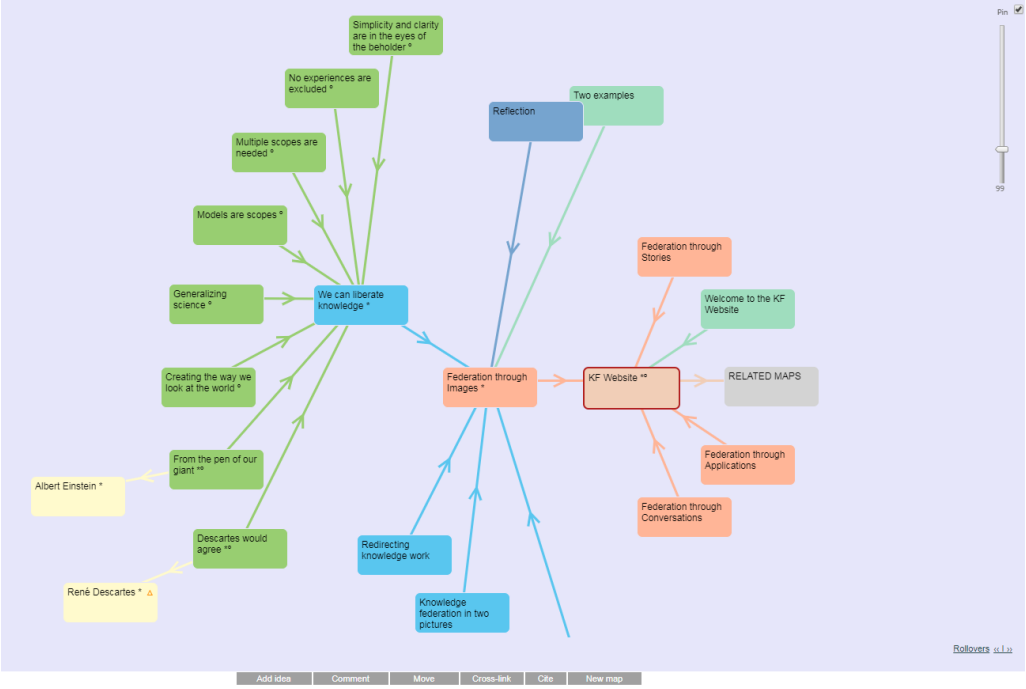


Figure 8 - Model of Images section from knowledge federation website, modeled in debate graph using a split at the paragraph level and linking to persons being quoted.

Different forms of linking will be tested in the maps as well. Testing direct linking of nodes, indirect linking through topics and linking to external sources. The different links that can be created through the debate graph notation are versatile and should allow for all connections needed in an IBIS based notation.

3.6 Evaluating approach

Building on the methods and concepts established in the background chapter the context and insights that can be gained will allow for the design of the domain map prototype. Having gained a thorough understanding of the problem through the literature as well as having established multiple approaches will allow for the

prototype to be rooted in existing knowledge, standing on the shoulder of giants. The vision that was laid out by Engelbart over half a century ago and which knowledge federation has picked up is creating the blueprint for how to approach the design of the prototype.

The models that are being established as part of the approach chapter will inform the design of the different elements what will encompass the domain map. Some models might result in many different issues that need to be addressed. The debate graph serves as a base model for the domain map, implementations of ideas that work well for the purposes of the domain map will be incorporated in the prototype.

The insights gained from the development of the models as part of implementing the knowledge federation website will dictate the features that will be highlighted in the grammar that will make up the domain map. The visual layout and interface as well as what view and visual layout the map is presented in will also be based on the results of the quasi-issue maps that are created. The different forms of linking and implementations of media are the most uncertain factors as they are more likely to be more different than the implementation of the debate graph. The domain map prototype will also attempt to intergrade a value matrix or value matrix like object which will approach rating and categorizing elements in a matter that makes the map more readable. As well as allowing for simple and effective citations and means of gaging the contributions of elements and actors.

The domain map prototype will attempt to be one more step towards finishing Doug Engelbart's unfinished revolution.

4 Domain Map Prototype

The domain map prototype is an attempt at developing a modeling language and tool which allows a reader to comprehend complex issues and topics which exist in the space between multiple domains. A traditional problem might exist within a classical field such as physics or journalism. In wicked problems such clear distinctions rarely exist. The issues span multiple actors in multiple different domains and requires a cross-domain approach. To facilitate such an approach there must be a shared language of the problem which enables the cooperation of multiple fields. The issue might also exist on a meta-level. Meaning that the issue is not domain specific at all, but rather exists within the routines and methods that are shared across multiple domains. Addressing the methods requires that they be tackled at a fundamental base level. The answers to a problem might already exist as a combination of best practice solutions and ideas which are present in one domain but not the other and vice versa. Through a domain map the diffrent domains can get a shared understanding and tackle the core issues within the new shared domain.

Achieving the domain map prototype requires several elements to be in place. Based on similar methodologies and technologies such as different knowledge mapping techniques (See 2.5) and the debate graph there is a need for an underlying grammar. The grammar will include definitions of the different elements and connections which make up the notations. The grammar will include and be supported by a visual representation which will be called the map. The map is what the user will experience when exploring a domain or issue. Ensuring quality and readability will require the integration of a rating and reviewing system to be in place to achieve an academic standard of quality and to measure the impact of contributions. The combination of all these elements is what makes up the domain map prototype.

The prototype is the result of implementing the insights gained from developing test models within the debate graph application and the theoretical knowledge gathered from examining existing methods and technologies. The modeling of the website into the debate graph, creating maps designed to test each side and feature of the website is what lead to the decisions on what missing and what would be included for a domain map.

4.1 Results from Test Models

The test models created in the debate graph application based on the knowledge federation website give the foundation of identifying what areas need to be addressed as part of the domain map prototype. The areas that the debate graph proves to not be suited for in the context of domain mapping, new solutions will be suggested and modeled as part of the prototype. The suggestions that are being made as part of the evaluation of the test models will be described in greater detail in the rest of this section. In areas where the debate graph is well suited in its features to create a model these features will be implemented and continued. Standing on what has come before, looking at it with a different lens to fit new issues.

The model structure of the debate graph is designed to address issues and to solve them directly whereas the domain map is focused on creating a view of the big picture in order to solve issues. The goals of the two models are mostly aligned, but the approach is different. The debate graph typically begins by positon a question which is then supported by positons and arguments. For the domain map, asking a question is central as well, but the positions should be more encompassing and are spanning multiple domains. The hierarchies for the position elements would therefor benefit from being more encompassing. Arguments can then exist on the high level the way the IBIS notation uses them, but also at a lower level to support or oppose base positions and information. The different levels of hierarchy also addresses the grammar needs to be different base on the conceptual level, as well as the view to reflect this. This insight is the result of attempting to model

the stories which were supporting an idea rather than a question. Understanding that a different structure would benefit such an approach.

The grammar defined as part of the IBIS notation and expanded upon as part of the debate graph does not addresses all facets of the domain map. When developing the test maps many of the different node types where not appropriate for the implementation of the webpage. The IBIS notation allows for the high concept map layer to remain mostly as it is implemented in the debate graph, with some slight changes to names and definitions to emphasis specifically what the purpose is in the context of the domain map. The lower level view which includes more informative and discovery based elements requires an approach which reflect its nature more accurately. The grammar requires new nodes to be introduces and existing ones to be modified. While relying on issue based mapping, but also introducing mapping more akin to concept mapping.

Changing the nodes which make up the language of the map will require for the connection to be changed adjusting. The connections are in essence no different from the nodes in that they can contain information but they serve a different purpose. The purpose of the connections is to link two ideas. The link can in some instances be as complex and contain as much information as the nodes themselves. The typing should therefor only be relative to the view the reader is currently exploring. A connection should have the ability to be a node in a different context and be used as such, by creating a new link which connects the link in one view to a node in a different view. This enforces the idea of hierarchies.

The different views are one of the most effective tools in creating understanding based on the models which were made in the debate graph. The views allow to see more information as it relates to one another and to get a better understanding. The Feature which proved to be effective in the evaluation of the models was the ability to adjust how many neighboring nodes should be made visible. In the case of the main page showing less seemed to encourage stronger buy-in and prevent overwhelming a reader. While in the case of the stories it was important to show what each story was informing. At times the inspector seemed to be given too

little focus in contrast to the map. The ability to switch between views from the inspector element would enable for a simple way of switching hierarchy and of gaining a perspective on the different context that the information object can be viewed in.

The debate graph allows for many different mediums to be place inside the node and connection objects, but the media is all used in the same manner. The focus on images and recordings of interview or meetings as part of knowledge federation and exploring new mediums of knowledge creation requires the domain map to support such exploration and implementation. The Doug Engelbart Institute (See 2.4.3) suggested a tagging system which each element has. This is true for video and audio as well. Through the creation of time stamp tags, a video file could be separated into different nodes based on the information that is being covered. Thereby a single video file as part of a high concept node can also be split into multiple information object and used and referenced as lower levels. This was particularly noticeable when exploring the ideas of a DKR as well as the conversations section on the knowledge federation website.

The collaborative focus of knowledge federation would suggest that the domain map require an emphasis on incorporating tools which encourage communication and collaboration. The comment feature in the debate graph does allow for dialog to happen and for it to be part of the model, but it is not fully incorporated into the map itself, it is part of the object inside the map. To enhance the connectivity of the dialog each comment is tagged in the same manner as every object in the map. Though this tag the element can then be connected to other elements in the map. A comment should always be clearly visible to be such however. Participants in the map (meaning the creator and/or experts) should be viewed as part of the map as well. This with the intent that they will be connected to their value matrix object as a means of measure credibility and contribution impact. In the same sense chat nodes will be weighted through the matrix.

The importance of citations are crucial to the credibility of any source and must be incorporated into a map. The citations should ideally be connected directly to

a tagged node which includes the source. The debate graph allows for citations to be connected to the object belongs to. It does not send the citation along to the next object. From the tests it would seem that a clearer indication of where a citation originates could be beneficial. The goal being to make the citation easier to track back and to view it. An object should ideally only occur once in a domain map and be pointed to from every other place.

The development of a map through the debate graph comes with a sometimes steep learning curve. The complexity of the application makes it at times difficult to use. The areas that are mostly impacted are the choosing of link type when cross-linking and the creation of long for connected information, such as in the stories section. The introduction of direct linking from a tag within the inspector would reduce some steps and me user friendly though drag and drop. Creating larger elements could also be done through the inspector allowing for the connection to be made as part of a structure. This makes the creation of new information more traditional while still implementing it into a map with full functionality.

4.2 Structure

In order approach the development of a mapping language the structure of how the map is built is what sets the foundation of everything else to be built on top off. The structure of a knowledge mapping language in this context is how the individual information pieces are fit together in order to create greater understanding. The domain map builds on the underlying idea of the IBIS notation that was also used in the debate graph. While Issue based notations are very good for addressing problems, it is not intended to convey large complex information to a reader. Concept maps are more commonly used in such a manner. In order to achieve high levels of problem-solving as well as be an effective teaching tool, in the sense of conveying information, a combination of the two methodologies will be the approach of the domain map. Following the IBIS notation on the high conceptual level, such as the creation and exploration of domains and meta-

information. For the low level of exploration of knowledge objects a different structure will be implemented which is being called a spider structure.

4.2.1 Spider Structure

The spider structure is what will enable the domain map to convey connected information in a manner where it retains its long for structure while still being interconnected and referenceable. The spider structure derives its name from the shape which resembles a web with a spider sitting at the center (See Figure 9). The spider structure is considered as one element for the high level application and connectivity. On the IBIS layer it can interact as a position or as an information piece. It could even serve as an argument if structured this way.

What makes the spider structure different from other nodes is that it is a node which is constructed of other nodes. The center ideas is what makes up the idea, it is treated as a regular node within the IBIS notation. The nodes that connect to it do so in the same manner as any other node. The spider node does however allow for the reader to zoom in, revealing the 'web' that surrounds the node. The web consists of several other nodes which each consists of a single information piece (a paragraph between 100-200 words typically, ideally no longer than 300 words). The information pieces are designed to act as standalone information nodes which can be connected to other maps and nodes. Each node is however part of a chain which makes up a larger piece. The same way a vignette in the knowledge website is built up of small information pieces. The Spider structure is built up of these nodes. They are ordered and have a previous and next node which is to be read next within the context of the structure. Should the node be linked to a different view the information will still be available, but only by changing view. A model of how a spider structure will look in the domain map can be seen in figure 9.

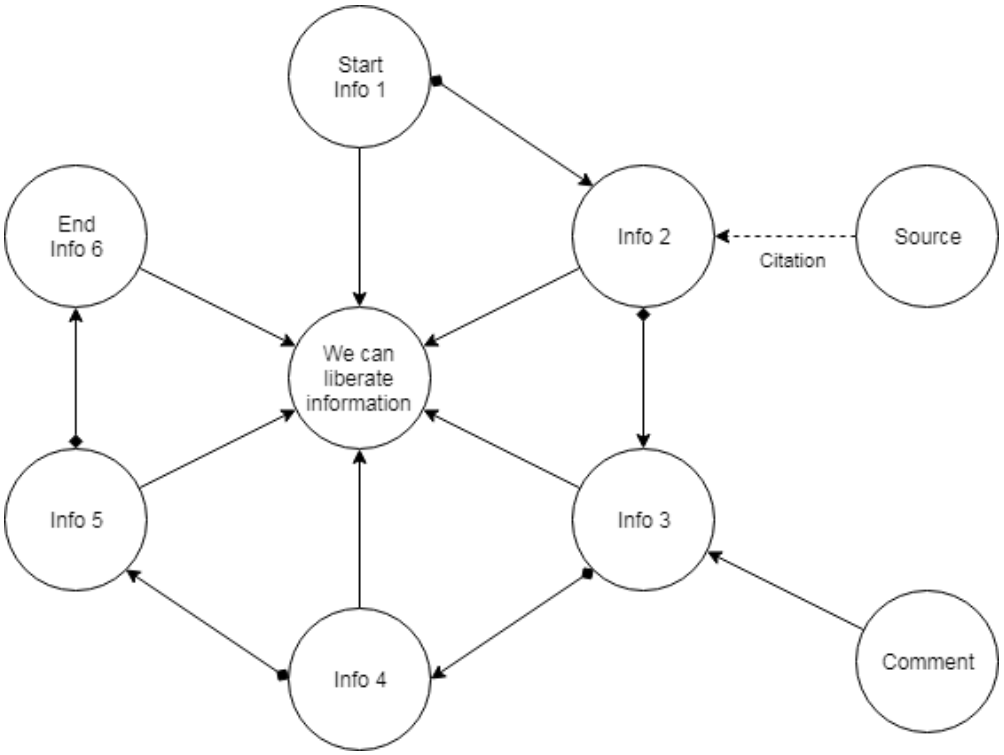


Figure 9- Visual representation of the spider structure element of the domain map

The series of nodes that make up the web are simply marked with simple number tags inside the larger spider object and read like an article. In the spider node the information is presented in order and is tagged. The spider node does not typically contain any information on its own, it only displays the information of all its child nodes.

4.2.2 Tagging

Central to the functionality of many features of the domain map is the idea of tagging information pieces. The concept of tagging was central to Doug Engelbart's vision of a DKR and it remains a central component of creating a highly interconnected domain map.

The reason tagging becomes so important is because of the large number of small individual information pieces that make up the map. In the analogy of the map tagging each element is the equivalent of naming each town on a map. It becomes

very difficult to orient oneself the further away one is from the main cities if the towns are not named and labeled on the map. By enabling tags it also encourages the writers within the domain map to consider information as individual pieces of a larger structure. A piece which does not stand well on its own might not be worth adding if it does not contribute to the overall. Some pieces however will always be needed to bridge information and this can come in the form of smaller connections. Such as the links between the web elements in the spider structure. These links contain no additional information other than to show the order in which the information is intended to be consumed by the author.

Tags are each unique parts of the domain map. A tag is an object more than it is a simple identification number. The tag is built up in a manner which indicates where it is located. Starting with a domain followed by a map, then identified by the object and any parent objects it may have. Finally it is numbered inside the node it is places in. A sample tag might look like this:

“Paradigm_Shift.Kowledge_Federation.Federation_through_Applicaitons.Domain_Map_Prototype.Result.Strucutre.Tagging.3”.

The tag is only displayed as a number within the node when the text is viewed (See figure 10). Upon inspecting the tag more information will be displayed. The information inside the tag can have multiple application, both front end as well as back end.

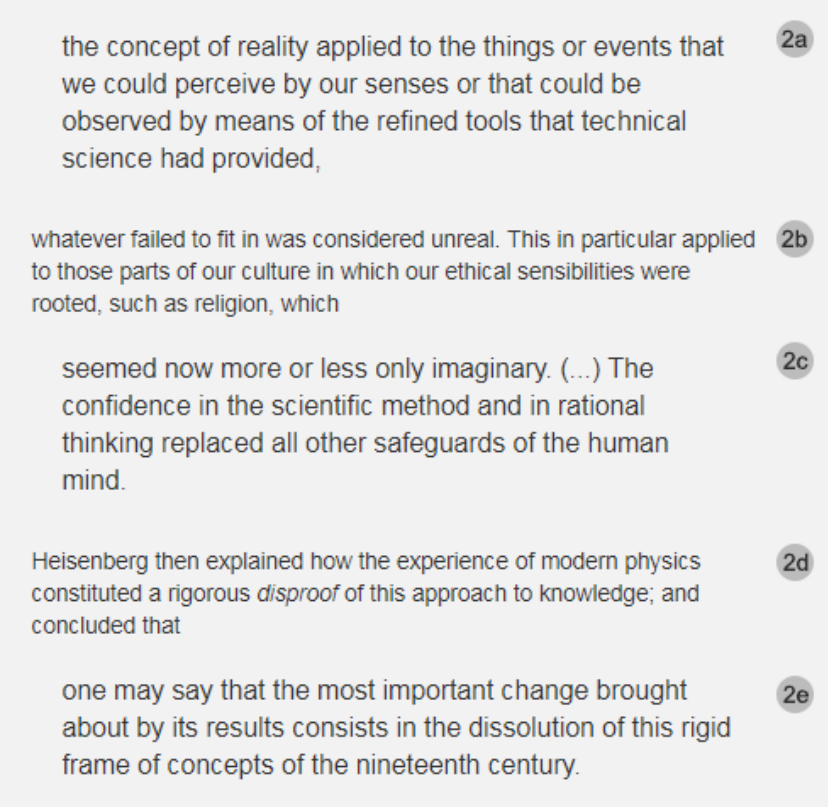


Figure 10 - Sample of content from knowledge federation website with appropriate tags for section.

The information inside the tag of an object can be used in several ways. The tag is an identifier for each object of the domain map across all different domains. It acts in a similar manner as a web address works inside a browser. Unlike a simple address it does also server to connect the object to its value matrix object which give the object its weight and tracks its impact. The Tag itself is as simple as it can be while containing the information which both the domain map require from it at a back end level as well as the value matrix requirement to create a value object connected to each knowledge object.

4.3 Grammar

The term grammar in the context of the domain map refers to the notations which makes up the elements of the model. The domain map elements are comprised out of Nodes which are the central viewing elements and are the landmarks and ideas

which make up the landscape. The connection between the nodes are the other side of the model. The connection are what binds the elements together and can be made either directly between elements or more indirectly as cross-linked ideas which can span across the maps and domains. The grammar is what enables a user to place at object in the correct locations. In terms of the map metaphor this means that a mountain is the result of earth plates colliding and as such can only be placed at such intersecting plates.

A Grammar is built with a primary goal in mind of what it is supposed to achieve. The focus of the domain map grammar is twofold. The First focus is on exploration and learning. The information and ideas are there to get an understanding of a topic or domain and allows for free exploration using the map to prevent getting lost. The second focus is much more aligned with issued based mapping. The goal being to highlight areas where information is missing and allowing for the creation of new domains. By assembling information and highlighting where there are holes or where there is a lack of solutions the map points out what is to be improved, even across domains. This is how the domain map aims to approach issue solving. By addressing underlying issues which build up to larger more complex wicked problems. The domain map grammar is intended to be flexible and non-restrictive. The goal is for the grammar so serve as a framing tool, but not to force the user into a set model which might not correlate to the idea that is being presented. The base grammar is what sets the general use, but allows for the creation of new types to be added as need be. In a sense the grammar is only the framework for the larger tool which is the domain map prototype.

Part of what makes up the grammar is how it is being created. The approach on how a node is made or how a link is established is a central part of how a user begins to think about the information. The creation of the grammar will also connect it more directly to the tagging and enable a more modular design of the domain map. The modular approach to information is how the loose frame of the domain map grammar approaches how information is to be treated within the

model. As moving, changing, interacting and evolving pieces of a constantly growing ecosystem and community of knowledge work and creators.

4.3.1 Nodes

A node object in the domain map is a piece of knowledge framed within a certain context. Nodes have types associated with them which give them a definition of meaning. The information inside the node is neutral without the context of the type. When switching view it is possible for the type of the same information object to be different depending on the connection that is made. Nodes can contain information in the form of plane text, images, video, audio, graphs and other forms of media which allow information to be shared from an individual to another. The information of an interview record, might be used as a positive argument as part of supporting a position in an argument or the same piece of information might be used to pose a question that was raised by the interview and which is being addressed. The information inside the node is defined in the context of the grammar and through the connection in which it is being used.

In order to understand how nodes function it is beneficial to look at how nodes are created by a user in the domain map prototype. Unlike in the debate graph application where a node is added to the graph and is then filled with information. In the domain map a node is first created as a neutral node outside of a map inside the inspector. The node is filled with information and the tags are applied automatically based on the formatting. If it is a longer text that can mean that every paragraph has a tag and thus will be a smaller node inside a spider structure of the node that is being created. Once a node is filled it can be categorized. If the node is note categorized it remains as neutral and has no properties of its own. Such nodes can be given context through the connection with other nodes or can be given a custom type by applying the appropriate tag. The tagged nodes that are created as part of the node inherit the typing of the node, but can independently be given new tags as they are being connected or incorporated as part of a new view. Each node is automatically tags the creator as the author.

The base grammar of the domain map includes several node types and are what makes up the framework for domain mapping. The node types are based on the IBIS centered notation from the debate graph (debategraph, 2019) and the experience of working with the notation to create the website test models (see 4.1). The notation renames, adds and/or removed elements from that notation based on the results of the test models.

The based nodes that make up the domain map prototype are:

Origin: The origin node is a starting point for a new map. The origin described the topics and ideas that are being addressed as part of the map. Each domain includes an origin point defining the domain. Trans-disciplines might have an origin or might emerge as the result of two maps connecting and overlapping greatly, in which case an origin can be create to define is specifically. The origin node is a way of orienting the reader similar to a wind rose on a map showing where north is.

Question: The question is the center of all problems. It is by asking questions that one can get closer to finding answers and solutions. The high level view of the domain map is centered on questions as with Issue mapping and the debate graph. A Question can stand on its own and does not require a response in order to be a valuable piece of knowledge. By having an unanswered question as part of a map one can learn as much if not more than with a simple piece of information.

Response: The response node is created connecting to question nodes. The response can be a positions to a question or it can be an extensive comment. The Reason the word response is used is to emphasis the idea of the dialog. The domain map is a collaborative effort in knowledge creation as much as it is an exploration of knowledge. By framing the grammar as a dialog the idea is to entice users to join in and be part of the solution. Responses can also additionally be classified as supporting or opposing the same way arguments are in the IBIS notation.

Supportive: Responses are building on the object that is being responded to. The supportive response is trying to add information or context to the element. A supportive response will typically be accompanied by additional information which can be integrated into the element.

Opposing: Responses are presenting information or positions which oppose the element that it is connected to. An opposing response is intended to present knowledge that undermines or disproves statements. The Opposing response should not present its own position. This should be done in from of a regular response.

Information: Information nodes are the central element that make up the lower level view of the debate graph. An information node can be many things, it is a manner of generic node type, but unlike the undefined node it contains a central piece of information. It contains one or more facts that are being presented. An information node could be something as simple as this description of the information node or it could be a complete essay on the complete agricultural history of a Tibetan village. Information nodes are enhanced through the connection that are made between them. An information node might require multiple information nodes to give a greater insight.

Idea: An idea node is intended as a conversation starter. Unlike the question node which poses a specific question which it wants answered, the idea node suggests a typically unfounded idea. The idea could come in the form of a solution or an invention. The idea does not inherently have to be supported by information or evidence. The idea is a space for exploration. Ideas can form into more specific information and generate questions, but cannot support any arguments or positions.

Actor: An actor node can come in several different variant. First it can be used to connect and attribute ideas and quotes to a person. This can come in the form of historical figures such as Einstein or in this case Engelbart. As papers are being cited the authors of those papers become integrated into the map. Second the actor can highlight an individual that is actively a factor of a question or positions. This

might come in the form of political figures. And third the actor is attributed to each user of the domain map. A user is linked to their actor node through the value matrix which stores information there (some visible and some not). The actor node is to give a face to the conversation.

Comment: When chatting on a topic the chat creates a series of minor nodes. Each node is generally not considered more than a note or a comment. These comments can be given a different context through new connection and linking. A comment might in a different view be used as an information node or it might spark an idea node. Comments are grouped inside a spider structure as part of a conversation node.

Conversation: A conversation node stores the exchanges that are made as part of one or multiple actors engaging in dialog. The dialog can be recorded through chat log or can come in other mediums such as video or audio.

Undefined: By default all nodes are set as undefined. Undefined nodes cannot be part of a map, buy can be connected privately to an actor. The nodes are defined once they are introduced into the domain map.

Custom: The custom node has its own type. All nodes that are defined outside the base grammar of the debate graph notation are considered custom nodes. The Custom node will be accompanied with a name such as for example ‘custom: Task’. The node includes a section which allows for a more detailed description of the node type that has been created and as part of what context. The custom node can be connected to any other node.

Creating custom nodes is an approach which is intended to give more flexibility and range to the domain map. If the grammar suggested is not extensive enough for the implementation of an idea or concept then the necessary nodes can simply be added.

Node Type:	Description:
Origin	Beginning of a new topic or domain for a map.
Question	A question which is posed.
Response	A Response to a question in form of a position or argument.
Supporting Response	Presenting supporting information.
Opposing Response	Presenting opposing information
Information	Presenting one or more facts.
Idea	An ideas to spark conversation.
Actor	Visual representation if individuals.
Comment	Comment or note.
Conversation	Collection of comments or recorded conversation.
Undefined	Not part of domain map yet.
Custom	Defined by user.

Table 1- List of Nodes that comprise the domain map base notation

The node types are visually separated and made distinct though the use of color to give a simple graphical view of the different types. Table 1 shows the colors that are attributed to each node type: Black for Origin, Blue for Question, Orange for Response, Green and Red for Supporting and Opposing Responses respectively, Yellow for Information, Pink of Idea, Lime for Actor, Grey for Comment, Dark Grey for Conversation, White for Custom and Undefined nodes.

4.3.2 Connections

Connections are the way that knowledge objects relate to one another within the domain map. In the metaphor of the map the connections are the roads that link places to one another making them reachable. Connection on their own do not have meaning of their own, they are given meaning by the two nodes that they are connected to, at the same time context is given to the nodes. Connections are how

a user explores the domain map, traversing between nodes along the connections. The connection can be as simple as connection one element to another such as in spider structures where the links are only intended to keep a sorted order. Such simple connections are a visual tool which bridges ideas. Connections can be far more complex, incorporating information of their own and other forms of medium as long as they give context from one node to another. The different connections are visually distinct to differentiate whether a connection is simple of complex.

Nodes and Connections can have much in common when only their content is examined instead of their role. While the information that is inside the different objects can be very similar the role they serve is different. A node stands on its own, conveying information and typically making a point of some sort. Connections cannot be made without nodes. The role of a connection is simply to give the information that is necessary to go from one node to the other, if no information is necessary then the node is a blank connection. Connections can however be used as nodes if appropriate by creating a link from a connection to a node. The connection will then be seen as a new node in the view which observes it. It will still remain a link, and be seen as such, from the view of the original connection.

When a node is introduced to the domain map it is done so through the creation of a new connection (Except of the Origin node of a map). A connection is by default a blank connection. This means that it has no inherent attribute other than to connect on node to another. Once a connection has been established the node can then be made more specific, whether that is through the addition of a designated type from the domain map grammar and/or to be filled with information which gives context to the connection. Figure 11 below shows how a created node is being connected to an existing map through a blank connection by dragging the node tag into the domain map. The nodes that have been created as part of the example node are automatically connected to one another through ‘previous’ and ‘next’ connections inside a spider stricture.

Deleting a node results in all connection pointing to and from the node to be deleted as well. Similarly if all connection to a node are removed the node object is connected to the creator's actor-node where it is no longer visible to the domain map. Nodes and connections can be deleted only by the creator and authorized members of a domain.

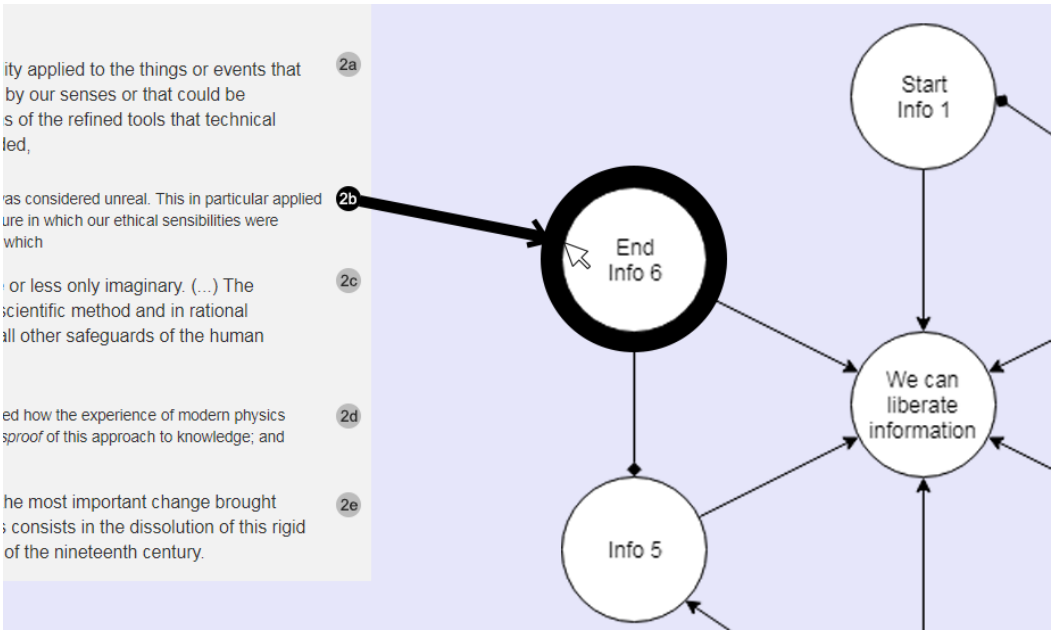


Figure 11 - Shows creation of connection between new node and map.

Connections are separated into defined types similarly to the way nodes are given types. The reason for the typing is to allow for common connections of significant to be preexisting requiring less work from the writer to create a simple connection. As connections can very much more broadly creating custom connection types is more encouraged than the creation of custom nodes. Connections have a second property which makes them distinct from nods. They can be directional. A connection is pointing from one node to another if it is directional. The visual representation of the direction is indicated by an arrow on the map. If the connection goes both ways it is considered non-directional, at which point the nodes are connected through a line.

The Connections that make up the domain map prototype grammar are:

Blank: The default connection. Contains no information. Is non-directional. Visually displayed as a simple black line.

Blank-directional: Same as Blank connection, but points from one node to another. Visually displayed as simple black arrow.

Citation: Citing a source is a cornerstone of academic writing and establishes credibility. By building on existing work the new work becomes validated and enhanced. The Citation connection is crucial to enable this in the domain map to validate information and to give credit. A citation is a directional node, pointing to an information node which contains the information that is being cited as part of the node. A Quote can be tagged and connected through citation node directly to the source of the quote. Citation connections are visually represented by a stripped black arrow.

Inform: Where the citation connection draws a direct reference to another piece of information the inform connection makes a more indirect connection. The inform connection is a way of tracking an idea or concept. It can also be used as way of building on a piece of information more directly than a blank connection would, but not as concise as a citation. The connation is represented visually as an arrow with a round dotted line.

Previous/Next: The previous and next connections are typically created by a spider-structure. It allows for connected to be sorted in an intended reading order. The connection will appear as a next connection from one node, once said node is being explored the connection will be splayed as a previous connection leading back to the original node. This is useful when one arrives to a node which is part of a series which is intended to be read in an order. The user can track back getting an understanding of the entire piece. When a chain of previous and next connections is made an icon will appear next to the node which leads to the beginning of the chain. This means that only one previous or next connection can exist for any

one given node. The previous and next connections are displayed as black solid arrow with a diamond shape at the beginning.

Custom: Connections that are established by the user allow for more precise and domain specific connections to be made. Rather than having to predict what would be necessary as part of the grammar the custom connection gives the power to the user. While the domain map grammar defined a hand full of preset connections, if a type of custom connection becomes popular within a domain, a domain administrator may add it to the domain list which will make it available to all working as part of the domain. A custom connection can be directional or non-directional as determined by the user, appearing as either a colored line or arrow respectively. The user is given a wide range of color to choose from when creating a custom connection allowing for varied visual distinction.

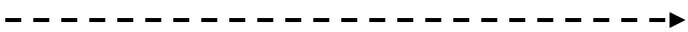
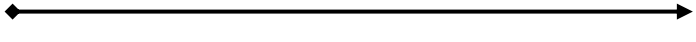
Connection Type:	**Visual**
Blank	
Blank-directional	
Citation	
Inform	
Pervious/Next	
Custom	

Table 2 - Visual representation of different connection types as displayed in domain map

The number of existing connection types has been kept deliberately low for two reasons. One in order to reduce the learning curve of using the domain map. With fewer elements to learn it becomes much easier to create maps quicker. Two in order to encourage connections to be made through custom connections which are more comprehensive than simple predetermined connection types would be. By having to define a connection it forces the user to thing about how

to elements relate to one another significantly, rather than checking what category the elements fall into and then connecting them accordingly.

4.3.3 Cross-linking

The term cross-linking was inherited from the debate graph application as a means of referencing connections that are made across maps and domains. Although the term originated from the debate graph application the domain map solution is much simpler and contains far fewer defined connection types. Cross-linking is a type of connection, but is different in its use rather than notation. The main difference between concretions and cross-linking is how it is done from the perspective of the user. The notation for cross-linking mostly retains the same types as the with the exception of the previous/next connection which cannot be created cross map.

The primary function of cross-linking is to generate new spaces and domains by connecting ideas and solutions from one domain into another to create new applications. By creation the relations ideas can start to organically form between disciplines in what knowledge federation called trans-disciplines. Cross linking is also the primary way citations are used as the information that is being used can often be located in different domain maps.

A cross-link connection is distinct from other notations in that the reader moves from one map to another. The transition of one map to another is visualized through a dot at the center of the connection that is being explored as well as through a symbol on the object that is being visited. The cross-connection shows information on what domain map is being accessed and allows for the reader to access the Origin node of the map simply by clicking the link that is displayed as part of the connection object.

Creating a cross-link is inherently no different than creating another connection. The location of the two nodes that are being connected is not located in the same place. As a result when creating a connection between such elements one much first locate the objects one wishes to create. There are two ways in which this can

be achieved in the domain map prototype. First the user can find the first node and lock it in the inspector, this will allow to keep track of it. Then the user can search for the object in the different domain map and once it has been located the connection can be stablished through drag and drop the same way as a regular connection. Second the user can mark the connection option on the tag on the node that is being connected. This will open a search box which allowed to find the desired node through the tag address of the object. Then the connection is stablished and can be further customized by the user.

4.4 Visual Representations

Knowledge mapping is a visual representation of a group's knowledge and ideas associated with an information topic. It acts as an inventory of knowledge, displayed as a visual medium. The visual nature of maps allows for certain properties which are only available through a model. The visual display allows for connections to be seen directly. Following the idea that an image can be worth more than a thousand words. The information is enhanced when it is combined with a visual model.

A knowledge community benefits from a large number of contributors and input from a large pool of options and minds. The domain map allows for the information to be organized in a structured methods and displayed to as many people as possible. To enable the accessibility of a large community the application has to be a convenient to use as possible to minimize people being becoming lost. By making the domain map a web application in the same vein as the debate graph it makes the application easily applicable to all who are connected to the web. It also makes integration into other application easily feasible operating on the same platform. The web based format also allows for all the desired features and layout which would be possible with other forms of software. The Limitations of the web are mostly related to user interaction. This is mostly minimized though the design of the interface and implementation of media.

The grammar serves as a means of conveying and understanding the domain map and learn how to interact with the map in a manner which allows for the creation and interaction of knowledge in a manner which enables the federation of knowledge. In order to prevent the user from being overwhelmed the grammar is kept as simple as possible while still being robust and allowing for specific notations. The learning curve of using the domain map is reduced to understanding how to interact with the interface, understanding the symbols which are used as part of the visual representation and knowing how different media may be implemented into a map element.

4.4.1 Interface

The visual layout of the domain map prototype is heavily based on the general look and feel of the debate graph as well as taking inspiration from general image manipulation software such as Adobe Photoshop and similar programs. The visual layout of the application is split into three major components; the map display, the interaction tools and the inspector.

The largest part of the screen revenue is granted to the visual representation of the map. As the map serves both as a navigation tool as well as being a means of visualizing connections and interactions of different ideas and problems. The map displays the nodes which contain information inside them as well as the connection which are med between them. Both elements can be viewed in more detail through the inspector. Simple symbols give some basic ideas of what the nodes and connection might mean displayed through color and shape as described the grammar section (see 4.3). Figure 12 shows a sample layout of what the visual layout of the domain map could look like, focusing on showing the elements in correlation to one another and highlighting the map portion as the largest area of the application.

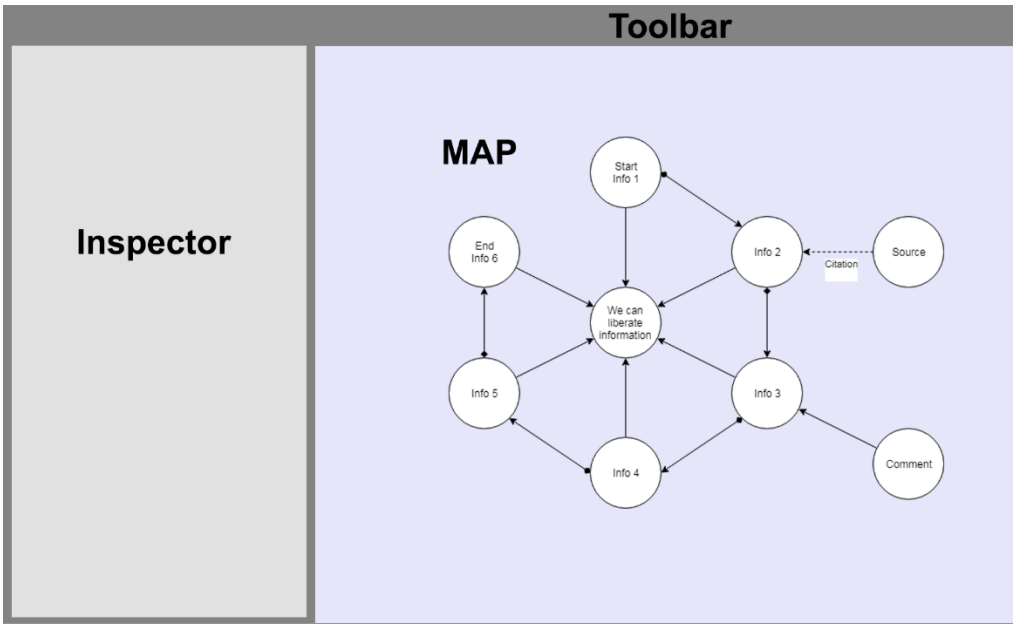


Figure 12- Potential layout of domain map prototype with emphasis on map.

The inspector is the way the user interacts with the knowledge that is stored inside the map. Through the inspector the information is displayed in a manner for the reader to interact with. The inspector also allows for an object to the edited (if authorized) or otherwise interacted with. When viewing an object through the inspector the user has the ability to leave feedback in form of a comment, which establishes a linking node, the history of the object can be accesses as well as a full overview off all the connection that are part of the object. The overview of all the connection show in what context and way the information is being used across the domain maps that it is part of. Upon clicking on of the connection the user will be transported on the map to the location of the interaction and displaying the connection in the context that is relevant to the selected interaction.

Administrative changes to an object are made through interacting with the object though the inspector. Such as enabling the level of access the object is given to what type of users. Connections can be made through the inspector by dragging the tags of the object or a sub-object (such as a node that is part of a spider structure) to another node inside the map that is being splayed (See figure 11).

The connection is set as a blank connection by default. But can be edited through clicking on it and editing it though the inspector. The inspector is separated by tabs which display different elements. One displays the information stored in the node and allows for it to be altered, as well as the type to be set or defined. A tab displays the history and administrative properties of the object and one displays the connections and views that the object is part of. Comments can be viewed as part of the connections section being separated from the other connections.

The final major component that comprised the interface of the domain map are the tools. The tools are inside the toolbar and are visualized with symbols. Highlighting the object will display a tool tip, giving better insight on how to use it. The tools are separated into two categories: the interaction tools and the navigation tools.

The creation tools allow for the manipulation of the domain map directly. The tools are: Create new node object, create connection, create cross-link, select objects, move object and delete object, export. The tools are in some cases shortcuts of what can also be done inside the inspector, but can be done quicker by directly interacting with the map.

The navigation tools allow the user to traverse the domain map. The nation tools are: display style, display depth, free drag, pointer and a search bar. The display style defines the visual esthetic that the map is displayed as, allowing for views similar to the other graphical notations such as argument mapping, web mapping and/or issue mapping (Okada, Buckingham, & Sherborne, 2008). This can also be observed in the debate graph (debategraph, 2019). The display style only shows how the information is displayed, it can still be interacted with in the same manner regardless of display style. Display depth described defines now many neighboring nodes are displayed for any given object that is being inspected. The limit how many can be displayed is based on the amount if objects that can be graphically rendered based on the limitations of web browser. By default the limit is 3 levels, as more information will likely result in information overload.

The search bar allows the users to search for a specific tag and have it be displayed. The toolbar can be also gives users access to their account and log in which is displayed through the website, but is not directly part of the domain map although it interacts with map through the actor node (See 4.3.1).

4.4.2 Symbols

With the intent of minimizing as much unnecessary text or explanations from the visual domain map there are some symbols employed as a means of making the key information and relations stand out. The use of symbols come in several different forms. The nodes are identified by colors as described in the node section (4.3.1) but will also include a simple icon identifying them allowing for images of the map to be used in black and white. The other two major uses of symbols are the connection arrows (4.3.2) and the use of special symbols to identify more properties of a node.

The arrows are visually distinct based the type of connection and change thickness based on the weight that is given to a connection. Each arrow has a default thickness value when it is being implemented then based on the rating from users the thickness will be impacted (the integration with the value matrix is described in 4.5.1)

Nodes can be tagged with special symbols which easily identify properties that the node has. In addition to a node type there are other attributes which can be highlighted for a node object. The domain map prototype identifies three attributes of requiring special symbols. Specific domains might require more and such would be implemented at that point. For a visual reference of the symbols see figure 13.

Figure 13 - Special symbols for domain map nodes

End: The first symbols identifies that the tagged node is the end node in a connection. This means that no more connections are made to the node.

Cross-domain: The cross-domain symbols identifies the node has a connection with one or more nodes of a map that is part of a different domain.

Number of Connections: A small number is next to the # symbol identifying how many connections are made with the node. This allows to identify how integral and entangled a node is with others, although it is not an absolute measurement only an indication. Comment nodes are not includes. While engagement is an important part of the domain map, measuring engaging levels in such a manner might encourage unconstructive comments to me made more frequently.

4.4.3 Media

Knowledge mapping methods and applications can often include the use of media other than text and images. The use of video and audio files can easily be incorporated by building in a function to display the given file types. Often however, like with the debate graph, the file only exist as part of a knowledge node. A major component of the domain map is the fact that every element is tagged. But in the case of objects other than text the tagging needs to be customized accordingly to gain as much flexibility and intractability. To support different forms of media the domain map attempts to incorporate them as strongly as possible.

Video and audio files have one thing in common which will make them able to be tagged as part of the domain map notation, they both have a run time. Having a quantifiable runtime allows for them to be broken up into smaller pieces the same way text can be. There are two primary methods of doing this. The first method is to divide the audio file into smaller chapters or topic as appropriate. In the case of an example it might mean separating the question and answer into tagged pieces. This requires the user incorporating the object into the map to divide the file as

they see fit. A node or connection would be made with one of the piece. The second way is to allow users to define a section using time codes. This would mean defining a start point and endpoint (or giving no end point at which point the remainder of the file is tagged). This method comes with a significant advantage and drawback. The flexibility of the being able to define the section by user gives more control of which section are used, this is especially useful in long files where the section might be minutes or hours long. The drawback is that many different but functionally identical nodes can be created from the same file. Since the time stamps are precise a one second difference in time stamp would result in a different tagged nodes. The amount of clutter that could be generated goes against the idea of simplifying the way one interacts with knowledge. Given the downside of the second method, the first method is used in the domain map. The time tags appear below the file allowing to tag either the entire node or a time interval.

External sources that are linked to the domain map are not strictly part of the map itself and are therefore not tagged, only the link itself would be tagged. In order to allow for external sources to be tagged there is the option of creating a tag list as part of the custom node. A tag list is a reference list of a source. The main node contains a reference point to the external source, wheatear it be a text document, a visual map or any other media. The tag list references all the elements that can be split up into nodes. The tag list could be splitting a published article into each of its section allowing connections to be made to specific part. The tag will then point back to the node including the original link to the external source.

The domain map is intended a shared collaborative working tool. When the domain map needs to be used in other media or referenced directly visually there are a number of way of doing so. First exporting a domain map or a section of a domain map (if only partial all nodes are selected) as a formatted document. As with the debate graph the ability to convert the information of the map into an article form allows for the conversion of new media to traditional media. Audio and video files are only references linking to the original file. Second exporting as a map model with supporting text. This is a non-interactive representation of the

domain map. Showing the domain map model as images in the form of the selected display form. The information contained in the nodes is then listed separately similar to the article form. The final way of exporting a map is by sending a time-stamped link to the domain map. This will show a map in the state it was in at the sent date, allowing for references of object that might be constantly evolving and changing in the domain map application.

4.5 Rating

Ensuring the quality and accuracy of the domain map requires for information to be curated and reviewed. The curation is done in conjugation between human actors and automated systems. The human element when reviewing and understanding knowledge is as of yet unmatched my machines. The algorithms and systems that are in place serve as a means of contextualizing information quantifiably and using said information in a manner which is valuable to the maintenance of the system as a whole. The domain map prototype is as much as collection of people as it is a knowledge platform and a problems solving tool. The user is crucial to allowing the domain map to grow and adapt to new environments, ideas and problems. It is through systems innovation that the domain map prototype aims to achieve its full potential and being to complete the unfinished revolution.

4.5.1 User

Every used of the domain map (anyone aiming to interact with it directly) must create a user profile. By default a user profile simply allows the user to be incorporated into the domain map and take part in exploring and discovering ideas and information that exists in the map. In order to contribute to a map user must register themselves as part of the domain and confirm their identity. The gatekeeping might deter some users, but it reduced the amount of bad actors that have influenced similar knowledge platforms such as Wikipedia (Magnus, 2008). To

confirm ones identity the prototype suggests verifying someone's phone number. This might be altered depending the practical implementation and usage.

Domains are curated by what are called domain experts. A domain expert serves as a knowledge source being an expert in the domain that is mapped as well as serving as an administrator for the domain. Approving major edits and creating empty nodes with holes that need to be filled. It is important to note that the expert id not required to approve every user and surveil every action. The experts is simply an authority in the domain. Experts are appointed though knowledge federation throughout multiple domains. The expert appoints administrators to oversee certain areas of the map and to handle minor issues. The experts can be contacted though their actor node which is linked to the domain origin node.

Every user has an actor node connected to their user. The actor node displays all connections and nodes that have been contributed by the users, as well as all comments the user has made. The node also contains the value matrix object of the user which is used in determining the credibility and trustworthiness of a user. Through the actor node it is easy to see the contributions of an individual as well as gain an understating how who the person is, as he actor node is customizable through the account profile site.

Users have the ability to subscribe to desired feed in order to receive any updates that are made. A user can subscribe to a domain though the domain origin node, a user can subscribe to a topic or to a tag, getting email updates of any changes. Users also have the ability to subscribe to other users by following their actor node. The information will appear in log form on the user's profile (only visible to the user) as well as being sent to them via email. By subscribing to an idea it allows for users to stay up to date with new development within their field as well as new problems which might present themselves. It also allows for communities to develop within domains as well as across multiple different disciples.

4.5.2 Value Matrix Implementation

The value matrix prototype is an integral part of the domain map validation system. The value matrix is where the values for relevance and impact are being generated to then inform the domain map. The accuracy of the domain map is heavily reliant on a functioning value matrix. While administrators and exerts serve to curate the maps within the given domains, the potential scope and interconnectivity of the maps will require information to evaluate date objectively as well as critically. The matrix allows for the generation of value scores which can then enable the visual representation of the impact of certain objects.

Each tagged object inside the domain map has a value score associated with it which is a measurement of its overall contribution to the map. By taking into account the three key parameter highlighted in the matrix (see 2.7) the overall score is determined. The rating system inside the domain map is weighted by user contribution. Every object has a value attributed to it, this includes the actor nodes that are part of the user account. The contributions of a user in regards to trustworthiness and weighted impact on rating are determined by the value score of the user, which in turn is determined by the impact of their contributions. Through weighted arithmetic means a median of all ratings is achieved which makes up an objects rating. The more valuable insights a user contributes the more weight they will carry for the evolution of information and connections. An important factor is that the contribution is not cumulative or quantitative. Meaning that more contributions will not arbitrarily inflate a score. By the same means a new user can gain a high score through few contributions if the impact of the contributions is significant.

The impact of the rating on the domain map can be observed visually in the domain map as well as more suddenly throughout. The connections which are represented though lines or arrows have the lines grow thicker the higher rated an object is (new objects are set to a default value). The visual impact is that the connections that are bigger are more important. This is in one sense a way of seeing what is considered valuable information. It does however also serve the

point of showing what areas might be lacking and inform what new research might be needed within a domain. The same way the a domain expert can create an empty object to show an area that is ripe for exploration the absence of valuable objects within a topic can show the need for new solutions. This ties into the learning and exploration aspect of the domain map. Serving to guide task oriented education. A student could use the domain map to find a research question to write a thesis by finding objects that are lacking as well as by finding connections which are entirely missing. Subtlety the domain map shows what areas on the map are easily reached. If a mountain needs exploration but lacks a strong road, then a different route might be taken or the route might need to be rebuilt.

4.5.3 Road Map

Using the domain map as an educational tool poses the question of how does one measure the progress that an individual is making? The answer is the road map. The road map is a way of seeing what information a user has been exploring and engaging with. What connections that have been explored and what have been ignored. In the metaphor of the map it is the equivalent of traveling a red line across every road and town one has visited as part of the journey. The road that is formed is the sum of the knowledge one as gained.

The road map serves as a means of evaluating the progress that has been made in exploring the domain map. It informs what information a person has been exposed to and should have gained an understanding of. In the context of education it is providing a way of evaluation the progress and learning outcome of a student. The roadmap allows for a customized leaning experience in conjunction with traditional education. The road map can also show how an insight has been reached. By tracing what path someone takes to reach a certain understanding or conclusion the same process might be reproduced. If many people find that a path yields the best learning outcome then their road map could serve as a navigational aid for people less likely or willing to explore. It can give a way of approaching a task by highlighting the steps that have lead others to a solution.

The implementation of the road map is rather simple as the ground work for enabling such an approach is already in place. There are two methods of creating a road map.

The first approach is by manually tracking the road map. Each map object has a small button which allows it to be tracked as part of the current road map. The user simply navigates the object and adds every new object to the map by clicking the button. This gives the user control over the road map, but might be inconvenient for some users. Some users might forget to track every node or omit important steps.

The second approach is based on the exploration history of a user. Each user has a history of each tab they have explored (within a certain time frame) and in what order. The list appears as a list of every tag in order of having been explored, if the user backtracked this is also recorded. In order to create the road map the user simply export the list of nodes as a road map. The road map is then generated and can be explored similarly to a slide presentation. Allowing to move forward and backward in steps.

4.6 Analysis

In order to find out if the method outlined in the approach chapter was successful at creating a prototype which fulfils the desired requirements the model must be analyzed. Looking back at what was set up as part of the approach chapter and seeing how well the results matched the expecting will give an indication of the success of the prototype. The approach methodology was rooted in the approach of wicked problems which was highlighted. Choosing to pursue a cooperative strategy. As the role of the domain expert in the domain map became clearer the model moved more towards a hybrid incorporating elements from an Authoritarian strategy.

The vison of the prototype which was described as part of the approach chapter (see 3.1) was realized as well as refined in several areas. The grammar which was developed does fit the requirement that were set out beforehand. The visual nature

of the application was addressed as well (see 4.4) which was not part of the original approach strategy, although suggested. In order to truly see how well the domain map prototype has been able to achieve its aspirations, one has to put it to the test. Testing a theoretical model will be done by seeing how well it can enable what originally was set out to design. In this case that is the model of the knowledge federation website. The domain map prototype should be capable of mapping the website in a manner which upholds all the attributes and functionality which was desired.

Looking at the construction of the knowledge federation website there are the five major parts which need to be addressed in order to map the website successfully. The five parts as highlighted in the approach chapter (see 3.4) are the main introduction page, federation though images, through stories, through applications and through conversations. Each of the major elements needs to be mapped in a manner which does not lose any of the information and context that is present on the website, while simultaneously allowing for addition information and context to be generated. The website does also link to addition pages located on the website which are not part of the core five pages. This is naturally integrated as the domain map is built in the idea of connection information, taking inspiration in the hyperlinking concept invented by Doug Engelbart (See 2.4.1).

Mapping each aspect of the knowledge federation website comes with unique challenges. The different parts of the website have a focus on different elements. The mapping for the main page is the most straight forward approach. The main page build the concept of knowledge federation up through a series of vignettes. The key feature for the main map is that it is supposed to be read sequentially for it to have the desired outcome. For this purpose the domain map has introduced the spider structure. The whole of the main page will be considered one node which is part of the knowledge federation domain. This introductions node can then be zoomed in revealing the inner nodes which make up the larger structure. Inside the structure are nodes which make up the vignettes that the page is built up from. The nodes are ordered as part of the spider structure. Most vignettes

contain enough information that they warrant their own spider structure as well. Reducing the information of the page into single information snippets. As the main page refers to other sites within the website domain a connection is made between the information node containing the information and the node containing the information from the referenced page.

Federation through images is centered on images and models being able to convey information more concisely in some context. In the context of the domain map this aspect is mapped in a similar manner as the main page. The overall structure of the page remains the same. What is notably different from the images page is that each vignette is centered on an image. The image is at the center of the structure and each connecting node surrounds it. An image can have different meanings depending on different context. The map reflects this by allowing the image to be part of multiple spider structures. New conceptions are simply made to the image node. The image stays the focal point allowing for information to be introduced to emphasize it.

Federation though stories has one key attribute which needs to be taken into account when mapping it as part of the domain map. The vignettes which make up the stories of the page are notably longer than the other vignettes. Contrary to intuition this results in the information likely being split into fewer pieces. As the stories are more long form text which is necessary as a whole to generate information. This highlights an attribute of the domain map. The fact that information can be split into as small pieces as one desires, but the language for the domain map encourages to structure the information in a manner which contributes to understanding and insight.

Federation through application presents prototypes and applications in the context of how they serve knowledge federation. The domain map is versatile enough in its design to allow for both the description of an application to be mapped as well as the application itself. Taking the value matrix prototype as an example which is described on the webpage. The value matrix can be mapped though its functionality inside the grammar of the domain map. Examining in the concepts and

features, and citing the origin of some concepts. Or a simple vignette can also server to introduce the application into the domain map. It is the second approach that is the result of mapping the website rather than mapping the prototype itself. The domain map is capable of mapping both.

Federation though conversions is the perhaps least clearly defined section of the website as it incorporates several concepts. Regarding the elements which can provide the need for a different approach as part of the domain mapping the feature which stands out is recording dialog. Conversations can be captured in many different forms. The domain map aims to allow for all forms of dialog to be integrated into a model. Comment nodes which allow for every branching conversations to be recorded allows for the most direct way of interacting with information. Each comment creates a node which in turn can be commented on. The connections between nodes can then highlight which branches of conversation are productive, based on the rating, and worth pursuing. The domain map also allows for recorded conversation such as video or audio from a conference to be mapped and tag in a manner which makes it intractable directly. The different mediums can even be interacted with across medium. A comment can be made on a section of a video and responded to through a link to and audio interview. The conversation section is also a special case because while being an application, the domain map directly addresses the ideas of the conversation section. The domain map is an enabler for conversations and community.

The domain map prototype has the capability to map the contents of the knowledge federation website. This makes it a tool which can be used to explain the concepts which are part of knowledge federation and serve as a way to engage people to interact with wicked problems. As people are engaging with the problems through the map this will lead to insights and solutions to the problems.

5 Discussion

The process of developing the domain map prototype has yielded as number of insights and raised a number of questions and ideas. Being a prototype the work that has been done as part of the thesis is a step towards building a more complete application and community which enables the federation of knowledge on a global scale, guided through the experts of different domains both academic in nature as well as not. This chapter aims to discuss and highlight the major insights and development gained as part of the development of the thesis.

5.1 The Prototype

The domain map prototype is an application in the larger domain of knowledge federation. As such it is positioned in a place where it serves to both federate the ideas presented by knowledge federation as well as inform the creation and evolution of ideas within the knowledge federation domain. The prototype is positioned in a matter which allows it to work as an improvement mechanism as well as being part of the mechanism itself. This loges it firmly in the bootstrapping category highlighted by Doug Engelbart (see 2.4.1). The development of the prototype has led to a series of insights in regards to its own development as well as raised new questions and issues.

The spider structure was an unexpected solution which developed naturally as part of the implementation of the test maps into the debate graph. The problem of how to split up larger information was one of the biggest hurdles when attempting to introduce information into a map. The structure emerges as a result of splitting an object while rating its context as a whole. The spider structure is the only structure component introduced as part of the prototype, as it seemed the only necessary structure for the implementation of the website into the domain map. In a different

domain there might be a need for different and more complex structures. Exploring these could yield in interesting new development of future prototypes or applications.

The grammar was built on the basis of issue based mapping as well as the notation used in the debate graph application, but also introduced new elements as deemed necessary. The new grammar that developed as a result is notably different in several areas and borrows some general ideas of concept mapping while introducing its own notions which were deemed appropriate for a domain map within the scope of knowledge federation. The development of the grammar is heavily influenced by the website's structure and what was required to map the information on it, as well as on personal bias while developing the grammar. The grammar is on one hand very subjective, but its development is reproducible. A different developer might approach the problem differently, but following the same steps and test case a similar notation would likely be reached. The naming of the grammar is result of the works at knowledge federation as well as the IBIS notation and might be different in other versions, thought it would likely function similarly.

The domain map grammar sets a heavy emphasis on customization and user activity. What became clear when working on the test maps was that developing a grammar which accurately would represent any domain accurately and satisfactorily would be highly unlikely if even possible at all. Instead of making the notations purposefully vague or more general the decision was made to stick to the language and tools which are useful for the knowledge federation domain and allow for new grammar tools to be introduced by the users of different domains through customization tools. One could argue that the introduction of custom nodes makes the need for a grammar immaterial. However giving a set of basic tools, which are proven to work in other models such as issue mapping, as well as introducing some new tools into the tools box allows the user access to the necessary general tools. The custom tools can then be made more specialized for specific fields. The idea being that giving everyone a hammer and wrench might be a good start, providing enough to start remodeling the house, even though one

might eventually need a drill down the line. Rather than letting someone start without tools, providing the basic ones, but still allowing for more to be added. The ability to create new custom nodes and connections will likely result in a naturally growing and developing notation which grows as the result of actual users' needs rather than attempting to predict what users might need in all given domains and fields.

Transforming the display of the domain map from the debate graph required fewer changes than originally expected. The general layout of the two applications are very similar. This is because the same general needs are present for both projects. The map portion requires more space to visualize all the information. Examining the information through an inspector object which shows the information of the objects seems very intuitive as well. The major changes that were implemented come in the form of the tool bar and the display symbols. Implementing a toolbar more akin to image editing software suggests that the user is intended to interact and change the map actively. This choice was the result of feeling that the debate graph was difficult to interacting with initially having a steeper learning curve than desired. More in regards to the learning curve is discussed in Section 5.4.1. The choices of symbols was a late addition when finding that there were numerous shared properties for the different nodes that could be highlighted to give the map more information without adding clutter. There are more symbols which could be employed such as the * º ´ symbols and properties from the debate graph. The symbols used are a result of deliberate choice of what information was valuable to an implementation of the website information. For instance knowing whether a connection was leading to a different map seemed relevant, whereas knowing if an information node contained information was not as important as the expectation is that the nodes contain some information. Unlike in debate mapping where a single word might summarize and argument.

A crucial element to making the domain map prototype function as described is the functionality provided by the value matrix prototype. The heavy reliance on

another prototype which has not been extensively tested or implemented is dangerous. It adds a risk factor which would compromise the prototype externally. Why take the risk? There are two main reasons why the value matrix prototype was used.

First, both prototypes are part of knowledge federation, meaning that if one prototype does not function then another prototype can help find weakness of the other than that will have provided added value to the overall system. The idea is to bootstrap using the value matrix prototype.

Second, the value matrix was designed to work with a tool similar to the domain map (Karabeg & Johansson, Boundary Objects for Online Knowledge Management, 2012). This means it fits ideally with the specifications of the model.

The use a value matrix prototype was the approach chosen for a ranking system, but the question does pose, why use a rating system at all? The reason why a rating system is useful is because it allows to compare information and to help make guided decision. It also allows to show what information is being engaged with more. A fear of using a rating system is that is generates a system which can inherently be gamed to achieve ones purpose. The argument against that is that the alternative would be to have every object be unlisted which would result in less information to be gained. The argument that a system can be manipulated is true of most systems. The way the debate graph attempts to minimize this is by making the scores hidden where possible. While the map is influenced by the ratings visually, the numbers are not visible to the users. The user's weight and ratings are not visible either.

The user score does present the danger of making a certain few have more power inside the domain maps of certain fields. This is however intentional. The reliance on experts should be utilized. Systemic innovation requires that there be a guiding force behind decision making, allowing for guided evolution of the system rather than simply relying a the free market ecosystem (see 2.3). It is for the same reason

that there are experts as part of the domain map and administrators. Using human insights informed by algorithm rather than relying entirely on the rating values.

The road map function of the domain map is a way to give a more educational way of using the domain way. The emphasis of the domain map is on knowledge federation trough exploration. The road map was the result of attempting to back-track what nodes have been visited and through which connections. Utilizing the information for education and evaluation purposes were a late addition to the prototype functionality. The function is non-intrusive to users meaning is optional to use without taking up much screen revenue. The function can also be used as originally intended to review how a conclusion was reached and to get an idea of a bigger picture by seeing the explored information in order.

Viewing the completed design of the domain map prototype the question arises of the reproducibility of the project. Is it possible to arrive at the same or similar version of a domain mapping prototype. Many of the ideas that are implemented and used as part of the prototype have been around for a long time, dating back to the 60s and even further back. Knowledge mapping is being used across many fields and the debate graph application is a similar application only with a different focus. The foundation for the prototype has been in place a long time. What was required is to put the pieces together and to address issues that arise by doing so, as well as designing the now public knowledge federation website (Karabeg, Knowledge Federation Prototpye, 2019). All the information and technology is publicly available, making it reasonable for anyone with the understanding of knowledge federation to reproduce the prototype. The results are in part informed on experience and trial and error, and different conclusion might be reached based on the modeling that is done.

5.2 Realization of Prototype

The prototype of the domain map is designed as a means of establishing the grammar and functionality needed to develop a fully functioning domain map. Given more time a working prototype of the application could be made. Having a strong

theoretical foundation for the prototype does however create a solid foundation as well as an outline for the development and testing of a fully-fledged functioning prototype in the future.

In order to create the prototype the need for some form of testing environed becomes immensely valuable. In the case of the domain map prototype having access to the debate graph allowed for a much better feel and visualization of the prototype. As the two applicators are similar in the technical functionality that is required it allowed to create the test models which informed the design of the final prototype. It is fair to say that the approach of this thesis would have required a far greater amount of modeling and physical prototyping such as with sticky notes and strings in order to visualize the map. Another advantage of having access to a similar piece of mapping tools is that by modeling the website in the debate graph everything that was not possible to map inside the debate graph and everything which needed to be changed became more visible. The creation of the models inside the debate graph resulted in a positive result in regards to getting a vision of the full prototype. The needs for what needed to be altered and implemented were made visible through trial and error of the models. The major challenge came from having to translate the information from the website into the grammar of the debate graph which was not intended for this purpose. The use of the debate graph might also highlight some areas which could benefit the debate graph. Some of the features such as predefined structures and modes of the connections and symbols might be interesting additions to the debate graph.

From a technical standpoint the implementation of the domain map should be feasibly doable. The Base architecture for an application such as the domain map already exists in the debate graph, although not open source. An alternative which could be implemented is building a mod on top of the debate graph which translates information from the domain map grammar into the debate graph as well as keeping track of all new features such as the implementation of the value matrix. This would also be very doable by introducing the new notation of the domain map into the debate graph which is easily done according to co-founder Davis

Price. Alternatively the application could be built from scratch allowing for the features to be build and integrated from the ground up with an architecture that is fully build on the idea of tagging and the value system. The application will result in a large amount of small objects which are only loaded in memory when displayed. This would also make it browser friendly.

5.3 New World

The metaphor of the traditional map has served to describe many phenomena in the thesis. It would seem appropriate to continue it while discussing the process of developing the domain map. In order to create the mapping language for the domain map the basis was taken in the test maps developed in the debate graph based on the website. The maps were mapping what was there to be mapped. Adding the objects (mountains and towns) that were necessary for the knowledge federation domain. But what if the map was of the wrong continent. What if, like Columbus, the wrong continent is being named inaccurately? Mapping a different domain could result in a very different map with very different objects on it. Perhaps the domain map does not have a tool which integrates metaphorical deserts into its map. The addition of custom nodes and connection elevate the potential of missing information but the question dose pose. Would a different domain have been a better approach for the creation of the domain map grammar?

The choice of the prototype domain informed much of the design decisions. The debate graph was built on the idea of facilitating debate and organizing information gathered from debate into a readable map. The purpose of the domain map is to serve as a way of facilitating knowledge as a means of addressing problems across trans-disciplines which exists across domains. The choice of using the website of knowledge federation is therefore a natural selection. In essence, mapping the contents of the website is akin to the domain map mapping itself as a means of creating itself. While the map is not of the domain map itself, it is of what has led to its inception. It would now in retrospect be possible to create a map of the

domain map inside the domain map. This could serve to introduce the functionality of the domain map to new users. Mapping knowledge federation brings with it the advantage that it is a domain that emphasizes the sharing of information. It serves as a way of exploratory education which makes it an ideal first domain to map, as once a map is in place which can teach users how to use it, the other domains can be created as the result of the learning gained from the base domain.

Developing the test models allowed for a wide amount of experimentation and exploration of the mapping tools. Each test model was addressing a specific need and came with similar challenges. The challenges where mostly a result of the grammar disconnect between the two projects. Once the nodes and connections where re-contextualized, how to split up information became the major obstacle. With unlimited time each test map would have included every element of the website as a means of understanding how the objects interact in relation of one another. Narrowing in on one task at the time did however make each test more focused. The results of the test maps where very positive.

5.4 Alternate approaches

When deciding on the approach to address the problem statement there where a number of factors which determined which direction to take. Wicked problems can be tackled in different ways, and choosing an approach in regards to the three approaches highlighted by Nancy Roberts (see 2.2.2). The focus was places on a collaborative strategy, which is very much a mantra of the knowledge federation movement. While this approach was highlighted there were also elements which are more akin to an authoritative approach. Through the introduction of experts and the suggestion of domains being curated by individuals which undoubtable have authority within the system this becomes a hybrid approach of the two methodologies.

The hybrid approach is also supported by the idea of systemic innovation and the idea of bootstrapping as part of the development. Making a system which improves itself as a part of development. The emphasis was placed less on the

improvement methods however and more on the collaborative integration if information into a system as a whole. Focusing more on the ABC approach outlined by Engelbart (See 2.4.3) could result in interesting new features to a domain map.

The approach chosen was dictated by the problem statement which was focused on designing a prototype which would enable a domain map. A more common approach might have been to attempt to build a prototype. The reason that the thesis focuses on design rather than development is a matter of time allocation. The approach of solving wicked problems is dictated by ones understanding of such problem. In order to fully comprehend the full scope of such a problem requires a large time investment. The development of the grammar and prototype if done extensively is also a time intensive matter. In order to build a prototype one needs to familiarize oneself with the tools, design what is to be implemented and then develop it with the likelihood of many unexpected problems. Given the timeframe of the thesis. Both designing and developing a prototype would likely have resulted in a subpar result. Focusing on designing allowed to explore the grammar more thoroughly. The hope is that creating a solid framework for a domain map is a better step towards the unfished revolution than a limited functioning application would have been.

5.4.1 Onboarding

When exploring the debate graph as part of developing the test maps for the domain map one thing that became apparent as a new user to the mapping tool was the steep learning curve that is experienced. The learning curve for a new user was steeper than would have been expected looking at the grammar and general mapping design of the application. The domain map prototype in a similar vein does not have a proper onboarding process for new users in regards to functionality. The initial introduction is given through an information section which explains the notations and how they are to be used, but the user does not experience learning process. The focus of the design was on conveying the concepts and connections that are part of knowledge federation and to gain and understanding

of the information. In order to create a learning tool for new users there are a number of onboarding strategies which could be explored (Cook, 2019).

An approach that could be explored as a means of onboarding is the exploration of a domain map which maps the domain map. By creating a map of the domain map notation one could use the map itself (with a limited view and scope) to explain how it is intended to be used. The connectivity aspect of the map would then allow to bridge from a tutorial map into the full domain map. This is an approach which could generate new ideas and features in the future.

5.5 Unfinished Revolution

The unfinished revolution is what knowledge federation refers to as Doug Engelbart's unrealized vision of how technology could be used to improve the collective human capability. Realizing the unfinished revolution could be described as the task of the century. Engelbart describes an OHS system as part of the solution to raise collective intelligence (see 2.4.2). Realizing a completely functional system of the scale which he described would allow for the collective IQ across all fields and domains to be enhanced. When Engelbart was asked how much of his vison had been achieved he answered that only 2.8 percent had been achieved. The domain map aims to be a step closer to realizing the vision. The prototype is the next step in realizing the 97 percent that were missing during his lifetime.

Developing a tool which enables the open collaboration, sharing of ideas and lifelong explorative education is what needs to be in place for the unfinished revolution to be tackled. The application requires to have a set number of properties as highlighted as part of the OHS (see 2.4.2). Comparing the domain map prototype to the three categories and seeing how it approaches these issues can provide an insight in how it could be used for this purposes. The properties fall into three categories: Internal attributes, key features and additional features.

The internal attributes that where highlighted as part of examining the idea of the OHS were, that each object must be tagged automatically and can be tagged by the author. This is a core attribute of the domain map build on the concept that

every object is tagged. The tag also includes a time stamp and a log of what user updated the object as part of the tag. This is another intern attribute which is desired for an OHS which the domain map has implemented. The final key attribute which was highlighted was that the system should encourage user to structure objects naturally. This is a somewhat subjective manner, however given the vignette structure and the splitting according to natural writing (the forming of paragraphs) this also can be deemed executed as part of the domain map.

The key features which should be in place for an OHS are numerous. The five that where highlighted where all implemented to some extent as part of the domain map. Objects are linked and can be jumped to freely though different views. The domain map allows for both a top down view as well as a contained focused view and access over the view is given to the user as part of navigating the map. Additionally the domain map differentiates between high-level concepts and simple information pieces. It does this though the used of grammar which encourages objects to be viewed differently based on the connection which is being observed. The messages system is realized more as the ability to post comments and to start comment chains which are integrated as conversation inside the map. Email alerts are integrated as part of the subscription functionality which allows the message to be forwarded to the user, but only on desired elements and parts of the map.

In regards to the further support attributes which are described the domain map does also address the majority of them. The application prototype allows for seamless transition between exploring and editing of the map. Simply by interacting with the object that is being viewed. The information is gathered as part of domains. This is somewhat different then what was described as journals or libraries, but served the inherently same purpose of grouping information in a logical manner. The subscription function is realized. Each object is tagged uniquely which makes it clearly identifiable.

The areas which are not realized are in regards to the direct integration of video conferencing. While the tools can be used in conjunction with conferences the domain map is not designed to provide the direct integration. A conference can be

recorded and then integrated into the map. The idea of recording is strongly encouraged and the implementation of live communication is a feature which could be addressed in the development of the prototype. There is also no direct email support as part of the domain map. Integrating email support into the grammar could provide a new structure to be created. Finally the UI should be highly customizable as part of an OHS. The domain map prototype has a very simplistic UI with only three main components. Making the UI customizable was not a focus for the initial prototype. This could be explored as part of developing the application.

The domain map prototype does fulfil a large amount of functionality and properties which was desired by Engelbart. It realizes one aspect of what Engelbart saw as part of his vision. With the tool in place the Cultural Revolution can be enabled. But it will require the ideas to be developed, tested and implemented for Engelbart's revolution tot truly be complete and for Collective Intelligence to be enhanced.

5.6 Problem Statement

At the beginning of the thesis work the problem statement was defined to insure that the work would be guided towards accomplishing a single goal. The problem statement was defined as:

Design a mapping tool prototype with a grammar enabling knowledge federation across multiple domains.

The problem statement has been the guiding force behind the decision made in the thesis. Being the steering force of the thesis makes it pivotal. Each aspect of the statement was made deliberately.

The Focus was from the beginning on creating the language and approach for a domain map application. The prototype as needs to be in place in order for an application to be built which support the key features and attributes that have been highlighted as part of the thesis. The thesis would have been completely different

if any part of the problem statement had been changes and other approaches would have resulted from that.

Changing the design aspect to ‘develop’ would have shifted the focus on the technical implementation of a design. This would also have raised the question of testing the application which would have taken focus away from developing the necessary language which could enable a domain map. Having the focusing scope be different from knowledge federation would also have resultant in a different approach as different features might have become more important. Different structures would have become more relevant as a result as well.

A desire that existed before the problem statement was even conceived was to federate the need for a domain map. Doug Engelbart was often quotes as saying “You just don’t get it”. This thesis hopes to show that someone got it.

6 Conclusion

The goal of this thesis was to design a domain map prototype in order to address the means by which wicked problems are being approached and how knowledge mapping can be employed as a tool towards solving global issues. Through the design of a prototype with grammar based on the IBIS notation (See 2.5.2) and other mapping techniques (2.5.1), specialized for the purpose of knowledge federation as a means of generating understating of problems as a means of solving them. The thesis is part of the knowledge federation infinitive, which aims to enable a new approach to knowledge work by presenting information in new ways (See 3.3). This means changing how information is presented and allow for new ways of interacting with knowledge (See 2.3). This in turn allows for major wicked problems like global warming and education systems to be approached from a new side.

The design of the domain map prototype is built on the vision by Douglas C. Engelbart of collective intelligence achieved through tools such as the DKR (See 2.4.3), incorporating mapping tools and techniques (Such as IBIS and Concept mapping) as part of the design. The creation and launch of the knowledge federation was the first step of contributing to this vision. Through the design of the website, the information was presented and organized in a traditional manner. The domain map prototype then serves as a tool to federate the content in a systemic manner (See 2.3). It does this through a grammar which was designed specifically for this purpose as part of this thesis. The grammar incorporates methods from other modeling languages and tools (such as the debate graph notation) modified to the needs of the domain map.

The approach to designing the domain map prototype once the completion of the website had been completed was heavily tied to the use of the debate graph application. Through the use of the application, test maps were created (See 3.5 & 4.1) to discover which features would need to be implemented and was used to create

a better understanding of the features needed for the domain map prototype. The prototype also makes use of the value matrix prototype (See 2.7). The value matrix is integrated into the domain map prototype and serves as the basis of information evaluation which the domain map provides as a means of organizing and presenting information.

This thesis presenting the domain map prototype aims to federate the ideas of using knowledge mapping as a means of tackling wicked problems. The prototype is an invitation to collaborate and create new knowledge work. Through the implementation of the prototype and through the use of the language that this thesis provides as part of the domain map grammar.

6.1 Future work

Closing out this thesis with a look into the future of the project and different approaches what can make domain mapping more robust and get closer to Doug Engelbart's vision. The domain map prototype falls in as one of the applications that make up knowledge federation and as such serves to advance the overall goal of a paradigm shift. The domain map prototype is only a small piece in a larger puzzle. With every new application that gets added to knowledge federation, the puzzle becomes more whole. The closer the image that Doug Engelbart envisioned becomes wholly visible.

The next step in regards to the domain map prototype is the implementation of the grammar and design into a functioning application which can then be used as part of knowledge federation as well as other domains. This will enable more effective testing than a theoretical prototype is capable of, using only approximation tools such as the debate graph. Once the domain map reaches the hands of users the domain map should begin to generate a feedback loop. The loop between user need and domain-specific issues enable the growth and change of the domain map in a dynamic manner.

Areas which are subject to change and evolution in the domain map are in regards to structures. The domain map prototype only introduced the spider structure as a

way of organizing fractioned sequential information in a manner which is able to create logical connections while meaning the integrity of an information piece as a whole. Different domains will likely have new needs and new structures could accommodate these needs. The idea of implementing a structure for email integration seems a likely first approach in regards to introducing new elements. However, there are likely many more to be explored.

The rating system introduced in conjunction with the value matrix prototype is likely to be the subject of revision. Once the application is developed and is being used by a large number of users the need for the rating system to adjust are highly likely. The ratings will have to be adjusted to the actual way that users are interacting with the information. There is likely an interesting analysis thesis possible in regards to investigating the effectiveness of the value matric in conjunction with the domain map as well as the results of the rating system. The adjustments and evaluation can only happen once data has been gathered however.

The design of an onboarding section for the domain map could also result in a possible subject for the development of a thesis. The specific methodology of creating an onboarding process which teaches the user to utilize the domain map through the use of the domain map would be a valuable tool and addition to the domain map prototype. Such an onboarding process could be made regardless of which domain the user approaches, but could result in the users being navigated through a domain map of domain maps in order to orient themselves and find the information that is most useful to them and allow them to begin exploring using the map as a guide.

The debate graph has been an invaluable tool for the testing and experimenting of different ideas, implementations and concepts. It has served as the basis for many design decisions that were made in regard to the domain map. The hope is that through the design of the prototype some areas are highlighted which might benefit the debate graph as well. Allowing for some features to be implemented into

the debate graph. As knowledge federation the goal is to create and share information to change how knowledge is used. The debate graph has been a valuable asset and will hopefully benefit from the research in this thesis as well.

7 Bibliography

About An Open Hyperdocument System (OHS). (2019). Retrieved from The Doug Engebart Institute : http://dougengelbart.org/content/view/156/88/

About Bootstrapping. (2018). Retrieved from The Doug Engelbart Institute: http://www.dougengelbart.org/content/view/226/269/

About Dynamic Knowledge Repositories. (2019). Retrieved February 15, 2019, from The Doug Engelbart Institute: http://www.dougengelbart.org/content/view/190/163/

Ausubel, D. P. (1963). *The psychology of meaningful verbal learning.* New York, Grune & Stratton.

Bloom, B. (1956). *Taxonomy of Educational Objectives: The Classification of Educational Goals.*

Bush, V. (1945). As We May Think. *The Atlantic Volume 176, No. 1*, 101–108.

Camillus, J. C. (2008). Strategy as a Wicked Problem. *Harvard Business Review (may).*

Cañas, A. J., & Novak , J. D. (2008). Concept Mapping Using CmapTools. In A. Okada, S. Buckingham Shum, & T. Sherborne, *Knowledge Cartography: Software Tools and Mapping Techniques.*

Cañas, A. J., & Novak , J. D. (2008). Concept Mapping Using CmapTools. In A. Okada, S. S. Buckingham, & T. Sherborne, *"Knowledge cartography." Software Tools and Mapping Techniques.*

Cañas, A. J., Hill, G., & et al. (2004). *CmapTools: A Knowledge Modeling and Sharing Environment.*

Celebrating the 30th anniversary of Doug's 1968 Demo. (2018). Retrieved from The Doug Engelbart Institute: http://dougengelbart.org/content/view/223/000/

Chang, K., Sung, Y., & Chen, S. (2001). Learning through computer-based. *ournal of Computer Assisted Learning 17*, 21-33.

Conklin, J. (2003). Dialog Mapping: Reflections on an Industrial Strength Case Study. In B. S. Kirschner P.A., *Visualizing Argumentation. Computer Supported Cooperative Work.* London: Springer.

Conklin, J. (2005). *Dialogue Mapping: Building Shared Understanding of Wicked Problems.* Wiley .

Conklin, J. (2005). *Dialogue Mapping: Building Shared Understanding of Wicked Problems.* Wiley.

Cook, M. (2019). *UX Flows: How to Turn Onboarding into an Amazing First Date with Your User*. Retrieved April 28, 2019, from Telepathy: https://www.dtelepathy.com/blog/design/ux-flows-onboarding

Culmsee, P., & Awati , K. (2008). The Map and the Territory: A Practitioner. In A. Okada , S. S. Buckingham , & T. Sherborne , *"Knowledge cartography." Software Tools and Mapping Techniques.*

Daul, B. (2013). Bill Daul interviewed by Martin Wasserman. (M. Wasserman, Interviewer)

debategraph. (2019). *Help*. Retrieved August 15, 2018, from debategraph: https://debategraph.org/Stream.aspx?nid=61932&vt=rgraph&dc=1

Derbentseva , N., Safayeni, F., & Cañas, A. J. (2006). Concept maps: Experiments on dynamic thinking. *Journal of Research in Science Teaching*, 448–465 .

Douglas, E. C. (1995). Dreaming of the Future. *Bootstrap Institute*.

Doug's Strategic Vision - A Human Endeavor. (2018). Retrieved from The Doug Engelbart Institute: http://www.dougengelbart.org/content/view/309/313/

Engelbart, D. C. (1992). Toward High-Performance Organizations. *GroupWare '92*.

Groetker, R. (2008). Visualized Problem Structuring for Stakeholder Consultations. In A. Okada , S. S. Buckingham , & T. Sherborne , *"Knowledge cartography." Software Tools and Mapping Techniques.*

Hyerle, D. (2008). Thinking Maps®: A Visual Language. In A. Okada, S. S. Buckingham , & T. Sherborne , *"Knowledge cartography." Software Tools and Mapping Techniques.*

Implemented Hypermedia in the '60s. (2019, April 28). Retrieved from Doug Engelbart Institute: http://www.dougengelbart.org/content/view/158/90/

Karabeg, D. (2003). Information design - a new paradigm in creation and use of information.

Karabeg, D. (2019). Retrieved April 15, 2019, from Knowledge Federation Prototpye: http://kf.wikiwiki.ifi.uio.no/Main_Page

Karabeg, D. (2019, March 01). Retrieved from Knowledge Federation Protoype: http://kf.wikiwiki.ifi.uio.no/Main_Page

Karabeg, D. (2019). *A paradigm*. Retrieved from Knowledge Federation: http://kf.wikiwiki.ifi.uio.no/Main_Page

Karabeg, D. (2019, 04 01). *Federation through applicaiton*. Retrieved from Knowledge Federation: Prototype: http://knowledgefederation.org/APPLICATIONS#Value_Matrix_object

Karabeg, D., & Johansson, B. (2012). Boundary Objects for Online Knowledge Management.

Knapp, R. (2008). Wholesome Design for Wicked Problems. *Public Sphere Project*.

Lachica, R., Karabeg, D., & Rudan, S. (2008). Quality, relevance and importance in information retrieval with fuzzy semantic networks. *Subject-Centric Computing - 4th International Conference on Topic Maps Research and Applications, TMRA 2008. 12.*

Landau, V. (2009). *The Engelbart Hypothesis: dialogs with Douglas Engelbart.* NextPress; 2st Edition edition.

Landau, V. (2018). How Douglas Engelbart Invented the Future. *SMITHSONIAN MAGAZINE*.

Larkin, J. H., & Simon, H. A. (1987). Why a Diagram is (Sometimes) Worth Ten Thousand Words. *Cognitive Science Volume 11 Issue 1*, 65–99.

Lehtman, H., Engelbart, D., & Engelbart, C. (1998). TECHNOLOGY TEMPLATE PROJECT OHS Framework. *ALLIANCE,980*.

Lyman, P., & Varian, H. R. (2003). *How Much Information?* University of California.

Magnus, P. (2008). Early response to false claims in Wikipedia. *First Monday, Volume 13 Number 9*.

Marr, B. (2018). How Much Data Do We Create Every Day? The Mind-Blowing Stats Everyone Should Read. *Forbes*.

Midgley, G., & Lindhult, E. (2017). What is Systemic Innovation?

Novak, J. D. (1998). *Learning, Creating, and Using Knowledge: Concept Maps(tm) As Facilitative Tools in Schools and Corporations.* Routledge.

Novak, J. D., & Gowin, D. (1984). *Learning How to Learn.* New York: Cambridge University Press.

Noveck, B. (2009, June 5). *Open Government Brainstorm: Collaboration in Action*. Retrieved November 30, 2018, from The Whitehouse: president Obama: https://obamawhitehouse.archives.gov/blog/2009/06/05/open-government-brainstorm-collaboration-action

Nuclear 2010: NPT Review . (2011). *Nuclear debategraph*. Retrieved November 30, 2018, from A: The National Archieves.

O'Brien, T. (1999, February 09). From the archives: Douglas Engelbart's lasting legacy, 1999. *San Jose Mercury News*. Retrieved from

https://web.archive.org/web/20130707130924/http:/www.siliconvalley.com/ci_23592605

OHS-Like Tools. (2019). Retrieved 02 14, 2019, from The Doug Engelbart Institute: http://www.dougengelbart.org/content/view/193/388/

Okada, A., Buckingham, S. S., & Sherborne, T. (2008). *"Knowledge cartography." Software Tools and Mapping Techniques.*

Price, D. (2009). Mapping the path to peace in the Middle East. *The Independet*.

Rittel, H. (1972). On the Planning Crisis: Systems Analysis of the 'First and Second Generations. *Bedriftskonomen*.

Rittel, H. W., & Kunz, W. (1970). Issues as Elements of Information Systems. *Working Paper 131*.

Rittel, H., & Weber, M. (1973). Dilemmas in a general theory of planning Policy. 155-169.

Roberts, N. (2000). Wicked problems and network approaches to resolution. *International public management review, 1(1)*, 1-19.

Shum, S. B. (2003). The Roots of Computer Supported Argument Visualization. In B. S. Kirschner P.A., *Visualizing Argumentation. Computer Supported Cooperative Work.* London: Springer.

Stavru, S. (2014). A critical examination of recent industrial surveys on agile method usage. *Journal of Systems and Software, Volume 94*.

Takey, S., & de Carvalho, M. M. (2016). Fuzzy front end of systemic innovations: A conceptual framework based on a systematic literature review. *Technological Forecasting and Social Change*.

Tarté , G. (2006). Conéctate al Conocimiento: Una Estrategia Nacional de Panamá basada en Mapas. *CMC 2006 Concept Maps: Theory, Methodology, Technology.* San José, Costa Rica: CMC: International Conference on Concept Mapping.

The MIT/Brown Vannevar Bush Symposium. (2018). Retrieved from The Doug Engelbart Institute: http://dougengelbart.org/content/view/258/000/#2

The unfinished revolution. (2000, April). Retrieved from Dougengelbart: http://www.dougengelbart.org/colloquium/colloquium.html

To enable a conversation over the world's knowledge. (2019). Retrieved from hypothes.is: https://web.hypothes.is/about/

Weick, K. E. (1995). *Sensemaking in organizations.* SAGE.

Wrenn , J., & Wrenn , B. (2009). Enhancing Learning by Integrating. *International Journal of Teaching and Learning in Higher Education Volume 21, Number 2*.

Wright, A. (2007). *Glut: Mastering Information through the Ages.* Joseph Henry Press.

Zeiliger, R., & Esnault , L. (2008). The Constructivist Mapping of Internet. In A. Okada , S. S. Buckingham , & T. Sherborne , *"Knowledge cartography." Software Tools and Mapping Techniques.*