Cartography M.Sc.

A Study in Node-Link Concept Map Visualization Enhancement

Thesis Defense for Cartography master of science degree
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Presentation outline

Defining concept maps

"Any node-link diagram in which each node represents a concept and each link identifies the relationship between the two concepts it connects" (Schroeder et. al, 2018, p. 431)

Typical use case is educational

Hierarchical–networked structured Novakian concept map

Based on (Canas Novak, 2008, p. 27). From "Evaluating a concept mapping training programme by 10 and 13 year-old students," by A. Habok, 2012, International Electronic Journal of Elementary Education, 4(3), 460. CC BY 4.0.

Motivation and problem statements

Universal problems and motivations

- While concept maps' capacity to facilitate learning is widely recognized, research on enhancing their designs to encourage learning is still rare (Krieglstein et al., 2022; Schroeder et al., 2018). Concept map designers lack guidance regarding how to best do their work.
- This research study seeks to identify principles for good concept map design, integrating the researcher's own ideas with ideas from other scholarship.

Project-specific problems and motivations

- The design of existing concept maps in UT-ITC's online publication *The Living Textbook* (LTB) may not be ideal for learning
- The design of these concept maps should be enhanced to encourage learning.

Research Objectives and Questions

RO1. Identify principles for node-link concept map design that facilitate learning

      (A) How do concept maps facilitate learning?

      (B) How can the design of concept maps be enhanced to facilitate learning?

RO2. Improve the visualization of node-link concept maps existing in UT-ITC's digital publication *The Living Textbook* (LTB) in alignment with identified principles of good concept map design

      (C) How can the designs of existing LTB concept maps be enhanced to facilitate learning?

RO3. Assess the learning utility of prototyped design forms for LTB concept maps

      (D) How can the learning utility of the prototyped new LTB concept map design forms created while answering question C be optimally evaluated?

      (E) What learning utility do the prototyped new LTB concept map design forms created by answering question (C) possess?
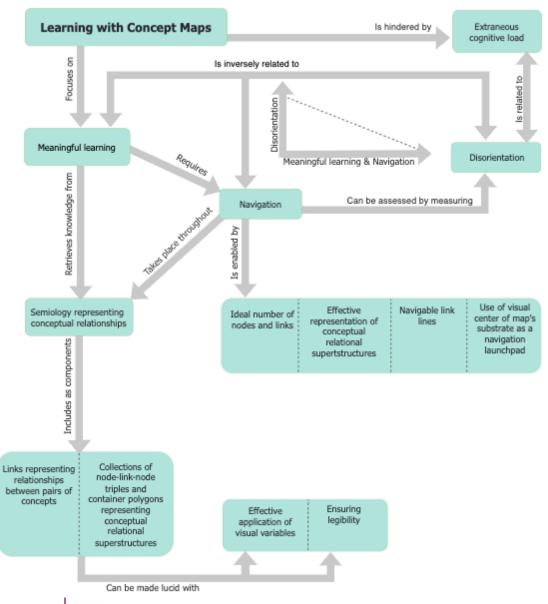
Research methodology

- Literature review to define "Concept Map," understand how learning with concept maps works, and how the design of concept maps can be optimized to facilitate learning

- Development of a conceptual framework for good concept map design integrating ideas from past relevant academic research about the topic and the researcher's own ideas drawn from what he's learned during his cartography studies

- Guided by the conceptual framework and usability protocol to enable good human centered design described in Nielsen (1992) and Nielsen (1993), improve two existing LTB concept maps. This involved three stages:
  - Needs assessment
    - Researcher compliance review
    - Needs assessment questionnaire gathering information from existing users and people with demographic profiles similar to existing users
  - Rapid prototyping of new visualization forms in alignment with assessed needs
  - User testing of new visualization forms to evaluate their learning utility
    - User test questionnaire
    - In-person user test

Conceptual Framework
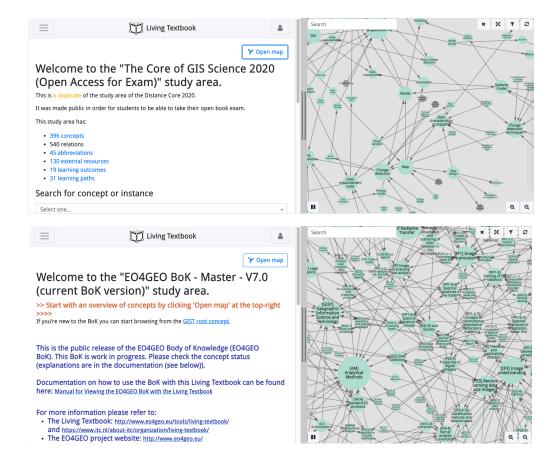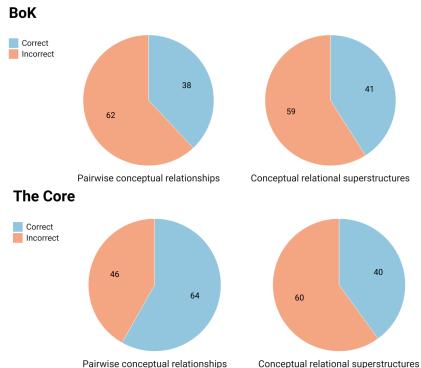
The Living Textbook (LTB) Concept Maps

Visualization Enhancement: Stage 1
Needs assessment

User needs assessment questionnaire:

Assessment of accuracy of retrieval of knowledge about conceptual relationships

BoK

Pairwise conceptual relationships

Conceptual relational superstructures

The Core

Pairwise conceptual relationships

Conceptual relational superstructures

Visualization Enhancement: Stage 1
Needs assessment

User needs assessment questionnaire:
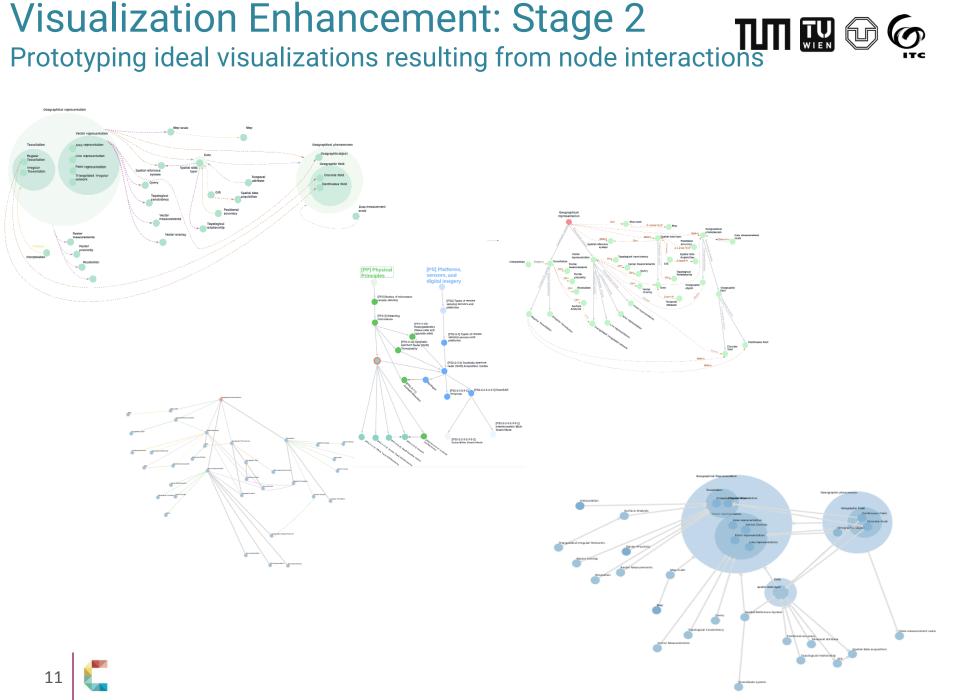
Navigability/Disorientation assessment

The Core

Legend: Strongly agree | Agree | Neither agree nor disagree | Disagree | Strongly disagree

Statement	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
I feel lost.		39	12	32	12
I feel like I'm going around in circles.	10	54	54	18	
It is difficult to find a node I have previously clicked on.		36	13	38	10
Navigating between nodes is a problem.		38	18	26	13
I don't know how to get to my desired location.		36	10	38	10
I feel disoriented.	10	28	15	26	18

BoK

Legend: Strongly agree | Agree | Neither agree nor disagree | Disagree | Strongly disagree

Statement	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
I feel lost.		36	7	43	14
I feel like I'm going around in circles.	9	35	21	23	12
It is difficult to find a node I have previously clicked on.	9	24	27	24	16
Navigating between nodes is a problem.		30	26	28	14
I don't know how to get to my desired location.	11	27	23	27	11
I feel disoriented.	7	30	18	27	18

Prototyping ideal visualizations resulting from node interactions
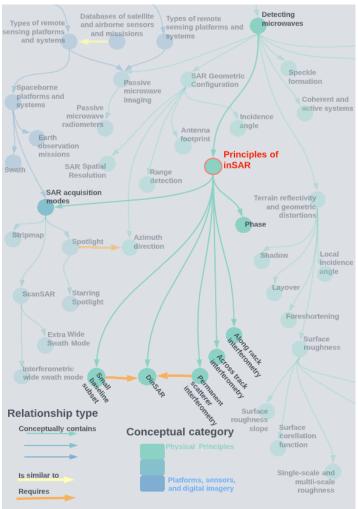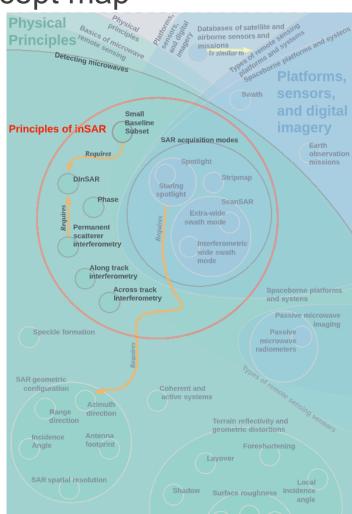

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Visualization enhancement: Stage 2

Selection of two visualizations with potentially strong learning utility to assess with user testing

BoK concept map

The two visualizations have semiology representing the same set of conceptual relationships. They vary in the way they represent hierarchical conceptual relational superstructures, a semantic focus of the BoK concept map.

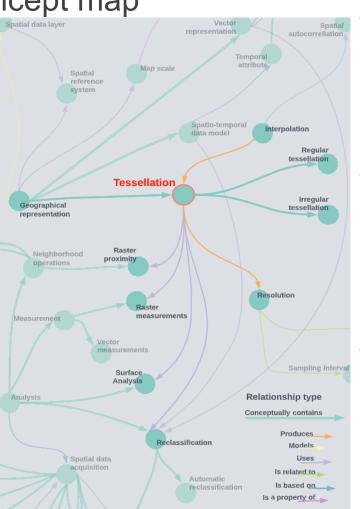# Design Enhancement: Stage 2

Selection of two visualizations with potentially strong learning utility to assess with user testing

The Core concept map
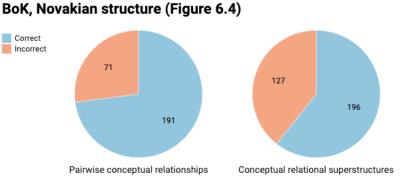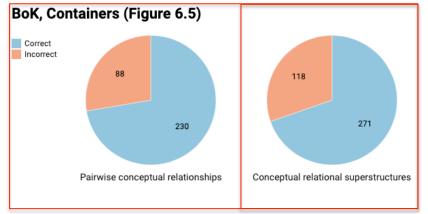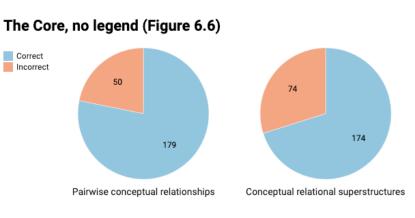
The two visualizations have semiology representing the same set of conceptual relationships. They vary in the way they represent pairwise conceptual relationships unrelated to conceptual hierarchy, a semantic focus of The Core concept map.
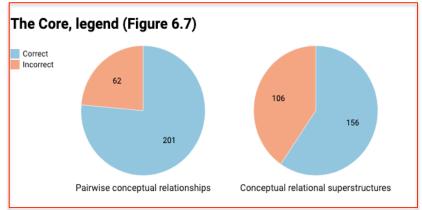
Accuracy of retrieval of knowledge about conceptual relationships assessment

BoK, Novakian structure (Figure 6.4)

Legend: Correct, Incorrect

Pie 1 — Pairwise conceptual relationships: 71, 191
Pie 2 — Conceptual relational superstructures: 127, 196

BoK, Containers (Figure 6.5)

Legend: Correct, Incorrect

Pie 1 — Pairwise conceptual relationships: 88, 230
Pie 2 — Conceptual relational superstructures: 118, 271

The Core, no legend (Figure 6.6)

Legend: Correct, Incorrect

Pie 1 — Pairwise conceptual relationships: 50, 179
Pie 2 — Conceptual relational superstructures: 74, 174

The Core, legend (Figure 6.7)

Legend: Correct, Incorrect

Pie 1 — Pairwise conceptual relationships: 62, 201
Pie 2 — Conceptual relational superstructures: 106, 156

User test questionnaire

Navigability/Disorientation assessment

BoK, Novakian structure (Figure 6.4)

Legend: ■ Strongly agree ■ Agree □ Neither agree nor disagree ■ Disagree ■ Strongly disagree

Statement	Strongly agree	Agree	Neither	Disagree	Strongly disagree
I felt lost	10	17	14	22	
I felt like I was going around in circles	8	15	8	29	5
It was difficult to find a node I had previously viewed.	8	20	12	17	8
Navigating between nodes was a problem.		19	17	21	6
I didn't know how to get to my desired destination.	6	14	10	24	9
I felt disoriented.	7	21	11	22	4

BoK, containers (Figure 6.5)

Legend: ■ Strongly agree ■ Agree □ Neither agree nor disagree ■ Disagree ■ Strongly disagree

Statement	Strongly agree	Agree	Neither	Disagree	Strongly disagree
I felt lost	11	25	14	22	8
I felt like I was going around in circles	10	24	11	27	6
It was difficult to find a node I had previously viewed.	8	19	17	28	8
Navigating between nodes was a problem.	8	19	13	33	6
I didn't know how to get to my desired destination.	8	16	17	28	11
I felt disoriented.	14	20	13	19	14

The Core, no legend (Figure 6.6)

Legend: ■ Strongly agree ■ Agree □ Neither agree nor disagree ■ Disagree ■ Strongly disagree

Statement	Strongly agree	Agree	Neither	Disagree	Strongly disagree
I felt lost		13	14	26	4
I felt like I was going around in circles	11	10	27		5
It was difficult to find a node I had previously viewed.	3	13	11	22	7
Navigating between nodes was a problem.	3	11	10	27	7
I didn't know how to get to my desired destination.		7	11	29	10
I felt disoriented.	3	18	10	19	6

Created with Datawrapper

The Core, with legend (Figure 6.7)

Legend: ■ Strongly agree ■ Agree □ Neither agree nor disagree ■ Disagree ■ Strongly disagree

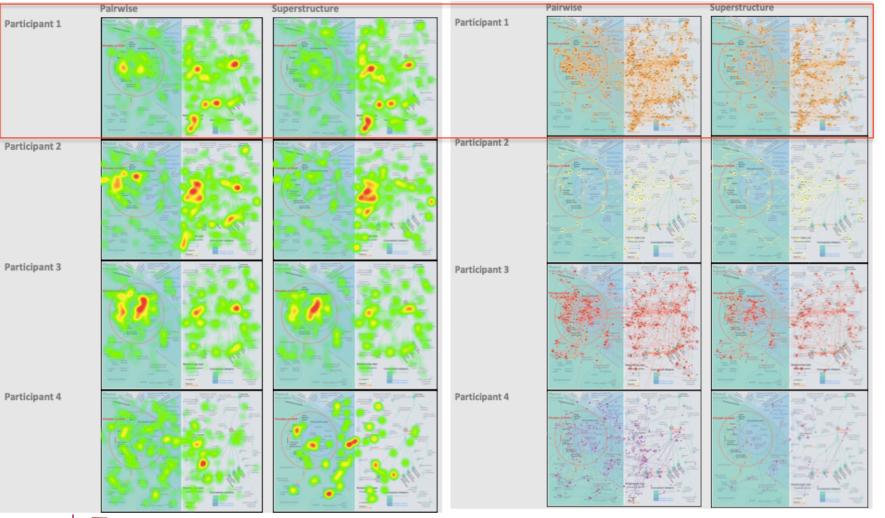| Statement	Strongly agree	Agree	Neither	Disagree	Strongly disagree
I felt lost	4	23	15	19	4
I felt like I was going around in circles	4	23	15	19	4
It was difficult to find a node I had previously clicked on.		20	22	21	
Navigating between nodes was a problem.	4	23	15	21	4
I didn't know how to get to my desired destination.		19	14	27	
I felt disoriented.	3	25	16	17	4

Word clouds showing 50 words most frequently found in answers to write-in questions

Design Enhancement: Stage 3
User test questionnaire

Word clouds showing 50 words most frequently found in answers to write-in questions

Eye-tracking data, BoK figures

In-person user study

Eye-tracking data, The Core figures
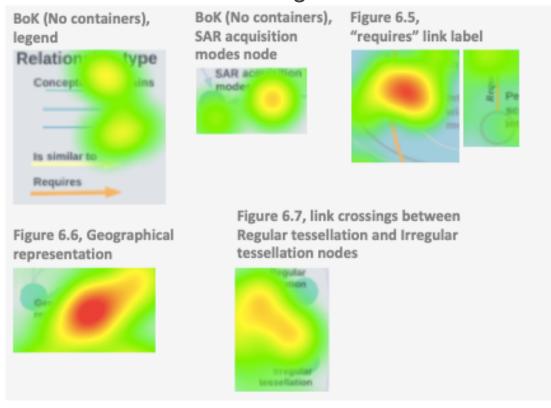
Notable locations of gazes

Research limitations and opportunities for further research

Limitation	Relevant further research
Exclusive use of lucid representation of conceptual relationships and navigability as metrics for concept map learning utility.	Consideration of other relevant factors such as, for example, learner motivation and memory, as well as relevant associated metrics such as, for example, aesthetics and memorability
Exclusive reliance educational psychology literature to identify visualization principles relevant to enhancing the design of LTB concept maps	Using information and knowledge access and retrieval literature to identify such principles
Performing user tests on enhanced LTB visualizations after altering the designs of multiple components of these visualizations' semiology	Performing user tests after changing the design of individual components of these visualizations' semiology in isolation from each other

Thank you very much for taking the time to listen to my presentation.

I welcome any questions you have.

Design Enhancement: Stage 3
In-person user study

Answers to the following questions:
- Which concept map was more helpful for retrieving knowledge about conceptual relationships?
- Which concept map concept was more navigable?

BoK		Container polygons	Novakian structure
Conceptual relationships	Participant 1		X
	Participant 2		X
	Participant 3	X	
	Participant 4	X	
Navigability	Participant 1		X
	Participant 2		X
	Participant 3	X	
	Participant 4		X

The Core		No Legend	Legend
Conceptual relationships	Participant 1		X
	Participant 2		X
	Participant 3	X	
	Participant 4	X	
Navigability	Participant 1		X
	Participant 2		X
	Participant 3	X	
	Participant 4		X

Design Enhancement: Stage 3
In-person user study

Notable comments made during think-aloud

"I really like it. It is like playing a game." (Referencing the user study generally)

"For some questions I preferred this map, for others I found the other more helpful." (Referencing the figures associated with The Core concept map)

"The right image is easier to navigate because there is less text. It is easier to find the keyword." (Referencing the figures associated with The Core concept map)

"Sometimes the arrows go from right to left, but we read left to right. Adapt the position of the concepts as much as possible to enable reading appropriately when users select a certain concept to focus on." (Referencing the figures associated with The Core concept map)

"The one on the left requires way too much time to digest the principles behind the visualization. I think personally that we should not try to visualize everything in one view but enable a simple selection of different views in much much simpler structures are visible. If you want to show the overall complexity, the left one does it perfectly, but it does not help a user. My preference is the right one, but I actually do not like both." (Referencing the figures associated with the BoK concept map)

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