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Enhancing Large Educational Node-Link Concept Map Design for Optimal User Learning

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Keywords: Map Use, Usability and Cognition; Concept Map; Body of Knowledge

Abstract:

The body of knowledge constituting cartography and the geosciences comprises a large number of concepts, sharing relationships with each other at multiple levels of conceptual hierarchy. Becoming aware of these relationships can likely help people in their studies of these disciplines in multiple ways. Educational node-link diagrams *(Figure 1)*, which are often called concept maps, have the potential to provide such an understanding to people who interact with them. Sharing with traditional cartography, a synoptic communication style, concept maps include points called nodes, representing concepts and lines representing relationships between the concepts associated with the nodes they connect. Arrows often append the linking lines, indicating directional relationships between the concepts. (Nesbit & Adesope, 2006; Novak, 2011; Kriegelstein et al., 2022; Schroeder et al., 2018).

Figure 1. Concept map about Raptors
From Schroeder et al. (2018, p. 432), Copyright 2017, by Springer Science + Business Media

Significant empirical evidence supports the educational effectiveness of concept maps. Schroeder et al. (2018) meta-analysed 63 studies that experimentally compared learning with concept maps to learning with other instructional forms. Various forms of learning with concept maps was found to be more effective, with moderate to large effect sizes, indicated by Hedge's g values, than learning with lectures, discussions, prose texts, lists, or outlines. These findings corroborate those of a previous similar meta-analysis carried out by Nesbit and Adesope (2006).

The relative utility of a concept map as an instructional tool likely depends on the salience of conceptual relationship semantics communicated by the map. A concept map in which this salience is poor due to poor visual communications design may not be effective for learning relative to other instruction forms. Unfortunately, research on how to design concept maps that enhance learning is still rare (Kriegelstein, 2022; Schroeder et al., 2018). Educational concept map designers lack significant empirically tested guidance regarding how to best do their work.

This research project will investigate the design of concept maps, particularly with regard to the representation of conceptual relationship semantics, which can be enhanced for optimal understanding of the information the map communicates. Efforts will be made to improve the designs of large node-link concept maps found in The Core of GIScience 2020 and EO4GEO Body of Knowledge (BoK) sections of the online educational publication *The Living Textbook* (LTB) *(Figures 2, 3)*, which is managed by the University of Twente, Faculty of Geo-Information Science and Earth Observation (ITC).

Figure 2: The Core of GIScience 2020 Concept Map

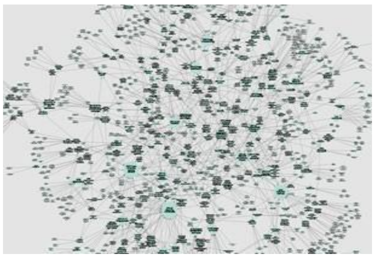

Figure 3: E04GEO BoK Concept Map

https://doi.org/10.5194/ica-abs-5-23-2022 |

These concept maps may also be considered knowledge maps, node-link diagrams in which all links represent relationships belonging to a fixed set of relationship types (O'Donnell et. al, 2002). Knowledge maps can be considered a specific type of concept map (Schroeder et. al, 2018). Knowledge maps can be distinguished from their close cousins knowledge graphs by their information visualization primary use case: The primary use case of knowledge graphs lies in data storage (Rhem, 2019). The LTB concept maps visualize relationships existing among a large number of concepts in the geo-information science and earth observation domains (Lemmens et. al, 2018). Each node represents one unique concept. Nodes are connected with directed links, each representing one of several relationship types.

These concept maps' current representation of conceptual relationship semantics may be considered poor. A student using the concept maps to learn may have difficulty discriminating different relationships belonging to individual concept-relationship-concept triples: All relationship types are represented with the same link symbology, and, in many locations in the maps, links cross each others' paths. Additionally, the map does not clearly communicate information about conceptual relationship superstructures, to which multiple node-link-node triples may belong. For example, several node-link-node triples in the EO4GEO BoK concept map are relevant to the broad topics of cartography and geovisualization. However, the map's current design doesn't lucidly communicate the close semantic relationships shared among these node-link-node triples. The design improvement work taking place during the thesis research will focus on remedying these representation shortcomings of the maps' conceptual relationship semantics.

Suitable design optimizations will be identified following reviews of academic literature regarding cognitive processes involved in learning with node-link concept maps and principles of good information visualization; solicitation of opinions of students and teachers who make use of the concept maps regarding the strengths and weaknesses of their current designs; and an examination of similar large, online node-link concept maps whose designs are considered optimal. Design optimization work will likely draw on information visualization and cartographic theories regarding appropriate use of visual variables and visual hierarchy.

The improved designs will then be evaluated during a qualitative user study involving UT-ITC students who use the LTB in their educational and professional pursuits. During the user study, students will likely be asked to complete spatial analysis questions similar to those they are often required to complete during their studies. Effectively answering the questions will require interaction with the redesigned concept maps. The effectiveness of proposed design optimizations for learning will be evaluated with participant observation, think aloud, and questionnaire methods.

Proposed design optimizations evaluated to be conducive to learning may be permanently implemented in the concept maps following the completion of the thesis project. Information gained from the thesis research could be used to guide future design optimizations of similar node-link concept maps used for instruction about a variety of subjects, including cartography and beyond.

Acknowledgements

We would like to thank in advance all of our questionnaire and user study participants for their help.

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https://doi.org/10.5194/ica-abs-5-23-2022 |