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Computer-assisted concept mapping: Visual aids for knowledge construction

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Abstract

Background—Concept mapping is a visual representation of ideas that facilitates critical thinking and is applicable to many areas of nursing education. *Computer-Assisted Concept Maps* are more flexible and less constrained than traditional paper methods, allowing for analysis and synthesis of complex topics and larger amounts of data. Ability to iteratively revise and collaboratively create computerized maps can contribute to enhanced interpersonal learning. However, there is limited awareness of free software that can support these types of applications.

Discussion—This educational brief examines affordances and limitations of Computer-Assisted Concept Maps and reviews free software for development of complex, collaborative malleable maps. Free software such as VUE, Xmind, MindMaple, and others can substantially contribute to utility of concept-mapping for nursing education.

Conclusions—Computerized concept-mapping is an important tool for nursing and is likely to hold greater benefit for students and faculty than traditional pen and paper methods alone.

Background

Concept mapping is a visual means of organizing information that promotes critical thinking and facilitates communication of ideas to others (Beel, Gipp, & Stiller, 2009; Novak, 1990; Pudelfko, Young, Lamarre, & Charlin, 2012). Use of concept mapping has been shown to produce deeper understanding of concepts and greater retention of knowledge compared to traditional teaching methods alone, such as reading texts, attending lectures, or in-class discussion (Dhindsa, Kasim, & Anderson, 2011; Nesbit & Adesope, 2006). Because of these advantages, concept mapping has been increasingly incorporated into nursing education. Examples of uses by nurse scholars include creating nursing care plans, conducting literature reviews, developing research projects, analyzing data, organizing and writing manuscripts, and designing courses and curriculum (Ackley & Ladwig, 2008; McDaniel, Roth, & Miller, 2005; St Cyr & All, 2009; Tseng, Sue, Su, Weng, & Tsai, 2007; University of Tennessee Chattanooga [UTC], n.d.)

Presently, many resources are available to learn specific concept mapping techniques (Berglund, 2015; Heinzeffry & Novak, 1990; Novak, 1990; Torre, Durning, & Daley, 2013).

However, awareness of free technological resources that can substantially increase overall utility of mapping is limited. Moving from pen and paper concept maps to **Computer-Assisted Concept Maps (CACM)** holds potential benefits for students and educators alike, bypassing many limitations of traditional paper methods. Specific disadvantages of paper maps are permanency, space constraints, and limited ability for sharing or collaboration. In contrast, CACM are flexible, less constrained, and readily amenable to both sharing and collaboration. The purpose of this brief is to examine the affordances and limitations of **CACM** versus traditional paper maps, and to review free software available for computerized concept mapping.

More flexible

A primary advantage of CACM is superior flexibility when compared with paper maps. On paper, when ideas are written down, there is limited ability to later modify content, size, location, shape, or priority. In CACM, ideas (called *nodes*) can be entered in rough form without initial regard for placement, then later modified repeatedly to refine meaning. Unlike with paper maps, nodes can be easily added, edited, deleted, or *iteratively* reordered by dragging and dropping to create a maximally intuitive, logical, and parsimonious structure. Graphical software features also allow users to modify node colors, shapes, internodal connectors, and fonts to enhance the visual structure and meaning of the map. While this may seem like play, visually organizing and reorganizing materials focuses attention on both content *and* structure, encourages analysis, fosters prolonged engagement with materials, and helps to define key vs. supporting or trivial content.

Less constrained

A second advantage of CACM is that they can be used to manage virtually unlimited information, whereas paper maps cannot. This allows for development of more robust, complex, and comprehensive conceptual models than is possible with traditional paper methods. In contrast to paper maps, where paper size and readability of text automatically limit how much information can be included, CACM can be expanded *ad infinitum*.

While simultaneously maximizing quantity of information that can be included, CACM also allow users to control exactly how much data is managed at any given time. This is done by collapsing (i.e. hiding) individual branches, so as to focus only on desired content. For instance, students learning to do physical assessments might develop a comprehensive map of all main body systems (for example respiratory, musculoskeletal, neurological). Each node could then be *expanded* for study and editing, *collapsed* when not in use, and connections between systems indicated via internodal connectors. Thus, with CACM, students can move beyond analysis of *single* concepts to analysis and integration of *multiple interacting* concepts and systems, drilling down to finer detail, or stepping back to look at the bigger picture as needed.

Ability to share and collaborate

Lastly, because CACM are digital, they can be easily shared via email or online data repositories such as Dropbox, co-created/edited by multiple users, and sequentially revised in ways that paper copies cannot. This facilitates peer and faculty feedback and contributes

to interpersonal learning. The digital nature of CACM allows for *ongoing* evaluation and development of ideas throughout a course. Thus, maps that are devised within one learning module may later be resurrected, modified, extended, and serve as a building block for subsequent learning. This allows students and faculty to move beyond isolated exercises to use of CACM for systematic management of data within courses and across curriculum.

Discussion of Free Software for CACM

Presently, there are many programs available for computer-assisted concept mapping. These range from simplistic to complex multi-purpose programs that allow integration of digital data (web links, pictures, videos, articles) into the map. Some resources are free, whereas others are not. Following is a review of free software for CACM, based on the author's experiences with these programs. Other free programs are available which are not included in this review, as they were perceived to be more difficult to use, had fewer features, or were not cross-compatible with different operating systems (Wikipedia, 2016).

Virtual Understanding Environment (VUE) Version 3.1.2

(Compatible with Mac OS/Windows/Linux) VUE was developed for academic and educational purposes by designers at Tufts University. It is an intuitive and user-friendly program with a comprehensive online user manual. It has several nice features, such as: (a) rapid adding of nodes with connecting lines (*connectors*) in a variety of colors; (b) single or mass formatting of nodes (alignment, shape, color, fonts, lines) for both connectors and nodes; (c) easy labeling of internodal relationships; (d) ability to insert images and "lock" layers; and (e) ability to embed file pathways and URLs (audio/video/document/PDF). E-Figure 1 shows a free-form concept map of VUE features. The primary advantage of VUE over other programs, such as Xmind and MindMaple, is the ability to create maps in any shape desired (i.e. fully freeform). While other programs allow reordering and rearranging, they generally constrain within selected patterns, such as hierarchical (E-Figure 2) or radial arrays (E-Figure 3).

Clicking on hyperlinks within a VUE map will open the associated file or webpage—presuming the hyperlink has not been broken. *Moving* a linked file in any way (such as to a new folder) changes its address, breaking the hyperlink and making it impossible for the program to find or open the document. When sharing a VUE map, be aware that hyperlinks to documents stored on a personal computer cannot be accessed by others, as these are private files. For sharing purposes, free file export options include VUE files, PDF, JPG, and PNG. Despite noted limitations, this is a strong program with good potential for concept, course, and curriculum design. Registration is required to download this software, however, it is free to all (Visual Understanding Environment [VUE], n.d.).

XMind Version 3.4.1

(Compatible with Mac OS/Windows/Linux) This robust program has nearly all the same features as VUE, as well as a number of additional features. These extra features include pre-set templates, brainstorming capability, ability to drag-and-drop external files/images into the map, *automatic* organizing features, and easy keyboard shortcuts, all of which

dramatically speed up mapping. E-Figure 2 displays one section of a right-branching hierarchical concept map constructed using Xmind. While much easier to use, Xmind is less flexible than VUE for freeform mapping, as it uses preexisting templates and constrains node placement into evenly distributed layouts (e.g. right branching, hierarchical, radial). This is generally a minor limitation, as within any selected pattern, nodes can still be ordered or prioritized as desired. A second disadvantage of Xmind is that labeling of internodal relationships is more difficult than with VUE, requiring use of *two* lines (one unlabeled, one labeled). Despite these limitations, Xmind is an excellent program. It contains multiple aesthetically pleasing and easy to use templates to choose from, as well as auto-formatting features that make room for new nodes as they are added, which VUE does not. Xmind also allows attachment of notes (hidden comments) to nodes, which is very useful.

Overall, XMind has superior resource management capabilities compared with VUE: documents can be added as hyperlinks *or* the entire document can be embedded into the map, thus eliminating the problem of broken hyperlinks that can be so problematic in VUE. However, *embedding* large amounts of external data (as opposed to linking) can result in very large files that are hard to share, except by exporting to a flash drive or uploading to an online data repository, such as Dropbox. One of the biggest drawbacks to Xmind is that free export options are limited to Xmind files, image files (JPG) and cumbersome plain text files. The free version contains no PDF or other presentation option. It is important to note that Xmind may be unable to export JPG images of larger files. In these circumstances, screen shots (PNG) can be used instead. Xmind offers fee-for-upgrade versions with additional features, including direct recording of audio notes and multiple additional export formats (PDF, Word document, Excel, PowerPoint, CSV). In all versions, files can be shared privately or publically. No registration is required to download the free version (XMind, n.d.).

MindMaple Version 3.4.1

(Compatible with Mac OS/Window/iPad iOS/iPhone iOS) MindMaple is an outstanding newer program that has all features of Xmind, with the added advantage of smartphone and iPad applications—permitting users to concept-map on the go. As with Xmind, branches in maps can be completely collapsed (E-Figure 3), expanded in sections (E-Figure 4), or completely expanded (E-figure 5) for easy data management. MindMaple can import files from Xmind and other mapping software. Exported files can be emailed, saved to Google Drive or Dropbox, and accessed from multiple computers. Another major advantage over Xmind is that there are *multiple* easy and free export options, including PDF, JPG, TIFF, GIFF, and text files. Text files convert maps into outlines, minus images or embedded documents. The biggest disadvantage of MindMaple is that while internodal relationships can be indicated with lines or arrows, they cannot be labeled, although there are options to add hidden notations. Despite this limitation, if choosing only one concept/content-mapping software, this program may be the best choice (MindMaple, n.d.).

Cmap, Version 6.01.01

(Mac OSX/Windows/Linux/Solaris/iPad IOS 7) Cmap was designed by the Institute for Machine and Human Cognition. Downloading and using the software is free, however,

registration is required. CMap has many of the same features as VUE and XMind, but seemed less flexible, less intuitive, and more time consuming to use. Like VUE, map layout is entirely unconstrained without any preset templates. While good for certain applications, this can also be problematic, as entering additional data requires manually moving nodes around to make room for the new ones. Creating branches and editing nodes takes significantly more effort than with other programs, requiring constant manipulation of the mouse, as there are no convenient keyboard shortcuts or rapid prototyping features. Embedded file pathways and video links open into a separate side box, requiring an additional step to access files. Some auto-formatting features are available to help decrease the effort of reorganization, although fewer than available in Xmind or MindMaple. Like MindMaple, CMap now supports use on iPad (Cmap, n.d.).

Prezi

(Compatible with Mac OS/Windows) While intended as presentation software and not specifically created for concept mapping, Prezi does have features that can be used to concept map at a basic level. Presentations are built just like maps, and allow for integration of pictures, video links, and documents. Relationships between items can be labeled, albeit the process is laborious and time intensive. The advantage of Prezi over other programs is the outstanding presentation format for easy dissemination and sharing of ideas. Note that the free version of this program stipulates all presentations will be posted online and publicly shared (Prezi, n.d.).

Conclusion

In summary, concept mapping can promote a wide variety of nursing educational goals through visually explicit delineation of ideas, which facilitates critical thinking. Use of computer concept mapping software allows for the development of more complex and comprehensive maps than traditional paper methods, and can therefore increase the utility and relevance of concept mapping for nurse scholars. While concept mapping has demonstrated efficacy as a learning tool, it is worth noting that prior studies have evaluated traditional pen and paper, not computerized mapping methods (Daley & Torre, 2010; Nesbit & Adesope, 2006). Although it is likely that CACM will hold similar benefits, research is needed to demonstrate this.

Second, given the relative novelty of this approach, it is unknown which individuals this technique is most likely to benefit. It is quite possible that CACM may be more useful to technologically inclined or visually oriented learners, as opposed to those who are not. Furthermore, while traditional methods have been successfully used in both graduate and undergraduate education (West, Pomeroy, Park, Gerstenberger, & Sandoval, 2000), some evidence exists that graduate students have not benefitted as much as undergraduate students (Nesbit & Adesope, 2006). It is unclear whether the same will hold true for computerized mapping, or whether the added affordances of CACM will render it useful to a wider range of students and faculty.

Third, is also unclear in what contexts CACM will be most useful. Traditional methods have been successfully used for a variety of knowledge assessment, problem-based learning, and

critical thinking exercises (George, Geethakrishnan, & D'Souza, 2014; Hung & Lin, 2015; Mok, Whitehill, & Dodd, 2014). Similar to prior applications, the author has personally used CACM for diverse studies (pharmacology, pathophysiology, statistics) as well as conducting literature reviews, developing research projects, managing weekly content of individual courses, analyzing data, and preparing manuscripts (Chen, Liang, Lee, & Liao, 2011; Henige, 2012; Qadir, Zehra, & Khan, 2011). Given the added affordances of CACM for data management, it is likely that concept mapping may be suitable for many other areas as well. Research on use of computer-assisted concept mapping is needed to understand not only the benefits and burdens of this technique, but also for whom and under what conditions it is most likely to be useful.

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References

- Ackley, B.; Ladwig, G. Nursing diagnosis handbook: An evidence based guide to planning care. 8th. St. Louis: Mosby; 2008.
- Beel, J.; Gipp, B.; Stiller, J. Information retrieval on mind maps—What could it be good for?. Paper presented at the Proceedings of the 5th International Conference on Collaborative Computing; Washington, USA. 2009. Retrieved from <http://www.sciplore.org>
- Berglund A. What's in a Word? Concept mapping: a graphical tool to reinforce learning of epidemiological concepts. *Journal of Epidemiology and Community Health*. 2015; 69(12):1232–1236. DOI: 10.1136/jech-2014-205068 [PubMed: 25987721]
- Chen SL, Liang T, Lee ML, Liao IC. Effects of concept map teaching on students' critical thinking and approach to learning and studying. *Journal of Nursing Education*. 2011; 50(8):466–469. DOI: 10.3928/01484834-20110415-06 [PubMed: 21524017]
- Cmap. (n.d.). Version 6.01.01. Retrieved from <http://cmap.ihmc.us/download/>
- Daley BJ, Torre DM. Concept maps in medical education: An analytical literature review. *Medical Education*. 2010; 44(5):440–448. DOI: 10.1111/j.1365-2923.2010.03628.x [PubMed: 20374475]
- Dhindsa HS, Kasim M, Anderson OR. Constructivist-visual mind map teaching approach and the quality of students' cognitive structures. *Journal of Science Education and Technology*. 2011; 20(2): 186–200. DOI: 10.1007/S10956-010-9245-4
- George A, Geethakrishnan R, D'Souza P. Concept mapping: a child health nursing practical exercise. *Holistic Nursing Practice*. 2014; 28(1):43–47. DOI: 10.1097/HNP.0000000000000001 [PubMed: 24304630]
- Heinzefry JA, Novak JD. Concept mapping brings long-term movement toward meaningful learning. *Science Education*. 1990; 74(4):461–472. DOI: 10.1002/Sc.3730740406
- Henige K. Use of concept mapping in an undergraduate introductory exercise physiology course. *Advances in Physiology Education*. 2012; 36(3):197–206. DOI: 10.1152/advan.00001.2012 [PubMed: 22952258]
- Hung CH, Lin CY. Using concept mapping to evaluate knowledge structure in problem-based learning. *BMC Medical Education*. 2015; 15:212.doi: 10.1186/s12909-015-0496-x [PubMed: 26614519]
- McDaniel E, Roth B, Miller M. Concept mapping as a tool for curriculum development. *Informing Science: International Journal of an Emerging Transdiscipline*. 2005; 2:505–513.
- MindMaple. (n.d.). Version 1.2. Retrieved from <http://www.mindmaple.com/Products/Features/>
- Mok CK, Whitehill TL, Dodd BJ. Concept map analysis in the assessment of speech-language pathology students' learning in a problem-based learning curriculum: a longitudinal study. *Clinical Linguistics & Phonetics*. 2014; 28(1):83–101. DOI: 10.3109/02699206.2013.807880 [PubMed: 23837405]

- Nesbit JC, Adesope OO. Learning with concept and knowledge maps: A meta-analysis. Review of Educational Research. 2006; 76(3):413–448. DOI: 10.3102/00346543076003413
- Novak JD. Concept mapping - A useful tool for science education. Journal of Research in Science Teaching. 1990; 27(10):937–949. DOI: 10.1002/Tea.3660271003
- Prezi. (n.d.). Retrieved from <http://prezi.com>
- Pudelko B, Young M, Lamarre P, Charlin B. Mapping as a learning strategy in health professions education: A critical analysis. Medical Education. 2012; 46(12):1215–1225. DOI: 10.1111/Medu.12032 [PubMed: 23171264]
- Qadir F, Zehra T, Khan I. Use of concept mapping as a facilitative tool to promote learning in pharmacology. Journal of the College of Physicians and Surgeons of Pakistan. 2011; 21(8):476–481. doi: 08.2011/JCPSP.476481.
- St Cyr SK, All AC. Concept mapping: A road to critical thinking. Journal for Nurses in Staff Development. 2009; 25(2):70–74. DOI: 10.1097/NND.0b013e31819e1082 [PubMed: 19346829]
- Torre DM, Durning SJ, Daley BJ. Twelve tips for teaching with concept maps in medical education. Medical Teacher. 2013; 35(3):201–208. DOI: 10.3109/0142159X.2013.759644 [PubMed: 23464896]
- Tseng SS, Sue PC, Su JM, Weng JF, Tsai WN. A new approach for constructing the concept map. Computers & Education. 2007; 49(3):691–707. DOI: 10.1016/J.Compedu.2005.11.020
- University of Tennessee Chattanooga [UTC]. (n.d.). Concept mapping and curriculum design. Retrieved from <http://www.utc.edu/walker-center-teaching-learning/teaching-resources/cm-cd.php>
- Visual Understanding Environment [VUE]. (n.d.). Version 3.1.2. Retrieved from <http://vue.tufts.edu>
- West DC, Pomeroy JR, Park JK, Gerstenberger EA, Sandoval J. Critical thinking in graduate medical education: A role for concept mapping assessment? JAMA. 2000; 284(9):1105–1110. [PubMed: 10974689]
- Wikipedia. List of concept and mind mapping software. 2016. Retrieved from http://en.wikipedia.org/wiki/List_of_concept-_and_mind-mapping_software
- XMind. (n.d.). Version 3.4.1. Retrieved from <http://www.xmind.net>

E-Figure 1.
Free form concept map of VUE software

E-Figure 2.
Right branching hierarchical course content map (Xmind)

E-Figure 3.
Completely collapsed radial pattern data analysis map (MindMaple)

E-Figure 4.
Partially expanded radial pattern data analysis map (MindMap)

E-Figure 5.
Fully expanded radial pattern data analysis map (MindMaple)