Better Together? A Scoping Review of Integrating Knowledge Mapping Tools in Teaching and Learning

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\begin{abstract}
With rapid advances in learning technology, knowledge mapping tools have been claimed to facilitate teaching and have positive impact on learning. However, an important issue that has not been extensively investigated is the potential integrative uses of knowledge mapping tools. This study aims to explore the intersections of three major mapping tools: concept maps, argument maps, and topic maps. This scoping review provides researchers with an exploratory opportunity to conduct a preliminary mapping of existing literature. Selected papers were examined for their findings and suggestions regarding how different mapping tools can be used to complement each other. This scoping review may offer insights into the integrative applications of three knowledge mapping tools. We hope that these preliminary results across disciplines may serve for discussion basis to inform future studies in knowledge mapping tools and teaching.
\end{abstract}

\textbf{Keywords:} concept map, argument map, topic map, knowledge mapping, education


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1 Introduction

Concept maps, one of the most popular knowledge mapping tools, have been applied to teaching and learning in a wide range of domains (Nesbit and Adesope, 2006). The benefits of knowledge mapping tools on improving teaching and learning have been proven (Okada and Shum, 2006; Nesbit and Adesope, 2006; Davies, 2011). Nonaka and Takeuchi (1995) consider that visualization is a means of externalizing tacit knowledge. The key objective of knowledge mapping tools is to use visualization during knowledge management processes. However, most efforts in education literature focus on only one particular knowledge mapping tool. Little research discusses the similarities and differences among various knowledge mapping tools, not to mention exploring the potential to integrate multiple mapping tools for teaching and learning. Therefore, this study aims to tackle the following research question: what are the connections between different knowledge mapping tools in support of learning and teaching? From the perspective of knowledge management, this study initially delineates the notions of three knowledge mapping tools and how they can be used in education. Additionally, this study analyzes the characteristics of these three tools and maps them to Bloom’s Taxonomy and Webb’s Depth of Knowledge. These frameworks are used to evaluate learners’ cognitive processing.

2 Related Work

The scholars in education and information systems viewed mind maps, concept maps, and argument maps as knowledge mapping software tools or techniques (Davis, 2011; Balaid, Zibarzani, and Rozan, 2012). However, they analyzed three knowledge mapping tools from different perspectives. While Davis (2011) focused on multiple aspects of thinking architecture used to structure information/knowledge flow (Figure
1), Balaid, Zibarzani, and Rozan (2012) emphasized the knowledge sources (e.g., know-what, know-how, and know-why) (Figure 2).

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Structure</th>
<th>Level of abstraction</th>
<th>Nodes</th>
<th>Linking devices</th>
<th>Linking words</th>
<th>Language register and &quot;granularity&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept Maps: Relations between concepts</td>
<td>Hierarchical, tree-like</td>
<td>Medium generality</td>
<td>Boxes</td>
<td>Arrows</td>
<td>Relational phrases ('in relation to', 'is composed of', etc.)</td>
<td>Inferrerial linking words ('because', 'not', 'however')</td>
</tr>
<tr>
<td>Argument Maps: Inferences between claims (conclusions) and support (premisses)</td>
<td>Hierarchical, tree-like</td>
<td>Low generality</td>
<td>Boxes and lines</td>
<td>Lines, colours, shading</td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

Figure 1. Summary of the Differences Between Knowledge-Mapping Software: Excerpt from Davis (2011)

<table>
<thead>
<tr>
<th>Knowledge Technique</th>
<th>Description</th>
<th>Know What</th>
<th>Know How</th>
<th>Know Why</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept Maps</td>
<td>Concept map is a structured way to help groups to develop conceptual frameworks used in planning or evaluation. Starting from a question or phrase, in a 'tree' structured hierarchy ideas lie in layers (primary, secondary and tertiary ideas).</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Argument Maps</td>
<td>Argument map is considered relatively new to help in the analysis of legal arguments. This technique decomposes an argument into claims, reasons and objections. It is also used for preparing and presenting arguments and for developing critical thinking skills.</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Topic Map</td>
<td>Topic maps organize knowledge describes the relations between knowledge domains and links to knowledge resources. Topic Maps help to visualize information routing within organization.</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Figure 2. Knowledge Mapping Techniques: Excerpt from Balaid, Zibarzani, and Rozan, (2012)

2.1 Concept Maps

Developed by Dr. Novak, concept maps are designed to improve learning and teaching in science education through identifying a set of concepts and their relationships with linking words (Novak, 1981; 1998). The relationships between concepts have to be explicitly described in concept maps. Figure 3 presents a concept maps about concept maps. CMap, introduced by Florida Institute for Human & Machine Cognition (IHMC), and Visual Understanding Environment (VUE) by Tufts University are two major open source concept mapping applications.
Conventional concept mapping presents limitations and challenges for supporting complex problem-solving reasoning, in particular, for externalizing the cognitive processes of structuring problems (Wang, Wu, and Kirschner, 2016). A dual-mapping approach was proposed to integrate both problem-solving and knowledge-construction perspectives and make cognitive processes accessible to learners when working with clinical problems (Wang et al., 2013). A recent study suggested extending concept mapping and explored a computer-based cognitive-mapping approach to problem-solving and knowledge-construction gaps problems (Wang, Wu, and Kirschner, 2016).

2.2 Argument Maps

Concept mapping tools may be used to draw argument diagrams; however, they are not meant for representing the structure of arguments (Dwyer et al., 2013). Argument maps consist of two major elements to visualize the lines of reasoning: color-coded boxes indicating propositions (e.g., reasons, objections, and rebuttals) and arrows with semantic cues annotating the relationship between the propositions (e.g., but, because, and however). Figure 4 shows an example of an argument map.

![Figure 4. An Example of an Argument Map (Dwyer et al., 2013, p.12)](http://cmap.nlm.nih.gov/docs/img/CmapAboutCmapsLarge.png)

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1 Source: http://cmap.nlm.nih.gov/docs/img/CmapAboutCmapsLarge.png
As an “efficacious methodology for learning and teaching” (Dwyer et al., 2013), argument maps have been around more than 200 years and have been applied to multiple domains, including law, policy, philosophy, education, and computer science (Buckingham-Shum, 2003; Reed, 2007). While Rationale (https://www.rationaleonline.com/editor/) is one of the commercial software tools for argument mapping, Argunet Editor, created by Karlsruher Institut für Technologie (Betz, G. et al., 2013), and iLogos, developed by CMU, are two open source argument mapping alternatives. Learners can benefit from the visualization of arguments, which enhances their critical thinking abilities (Okada and Shum, 2006) and facilitates subsequent memory and comprehension (Dwyer et al., 2013). Argument maps are used to illustrate legal or policy problem structures and critical reasoning, which can actually fill the gaps of other mapping tools.

2.3 Topic Maps

The expansion of concept maps serves as an ontology, which can be represented as topic maps. Topic maps require mapping the conceptual structure of a knowledge domain and making the topics easy to navigate/browse. The construction of topic maps has become an ISO standard (ISO/IEC 13250:2003), in which the processes of aggregating information resources from multiple sources have been defined. Similar to concept maps, topic maps entail topics, associations (denoting relationships between topics), and occurrences (referring to the grouping of information objects relevant to the topics) (ISO/IEC 13250:2003). Unlike concept maps, topic maps use a database to organize and connect information resources on the themes. Wandora, an open source knowledge management application, can be used to construct topic maps (Wu, Lehman, and Dunaway, 2015). It is worth mentioning that Wandora is equipped with a collection of information extractors, like Twitter extractor and Facebook graph extractor, for incorporating external information from social media and associating it with a topic map.

Below is a screenshot of a topic map (Figure 5).

Figure 5. An Example of a Topic Map on Enterprises, Knowledge and Change

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2 Source: http://www.grahamwideman.com/gw/xm/index.htm
The idea of integrating concept maps and topic maps is not new. Garrido and Tramullas (2004) proposed an interesting question, “Is topic maps an alternative or a complement to concept maps?”, and analyzed the complementary nature of concept maps and topic maps. While concept maps feature knowledge creation by employing the conceptual structures between concepts, topic maps serve as a knowledge organization tool to enhance information retrieval and findability (Wu, Lehman, & Dunaway, 2015).

3 Methodology: Scoping Review

The Canadian Institutes of Health Research define scoping reviews as “exploratory projects that systematically map the literature available on a topic, identifying the key concepts, theories, sources of evidence, and gaps in the research” (Grimshaw, 2010). The exploratory nature of scoping reviews responds to the concern that insufficient literature exists. Therefore, scoping reviews provide researchers with an opportunity to conduct a preliminary mapping of the literature tailored by the researchers’ inquiry, which helps evaluate if undertaking a full systematic review is feasible or worthwhile (Arksey & O’Malley, 2005; Paré et al., 2015). The primary purpose of scoping reviews is to identify effective interventions. The scoping question of this study focuses on: what are the connections between different knowledge mapping tools in support of learning and teaching?

It is hoped that the preliminary scoping review opens the discussions from diverse disciplines that have shared interests in adopting knowledge mapping tools in teaching and learning. Additionally, this initial effort may clarify the concepts of knowledge mapping tools used in the literature of different domains to inform decision-making on the selection of knowledge mapping tools.

4 Preliminary Findings

Different knowledge mapping tools have both strengths and weaknesses. What they have in common is not only their usefulness in visualizing ideas, concepts, and thoughts in a way that is easy to perceive and communicate but also in reducing the human cognitive load. Each knowledge mapping tool also has its unique strength to counter the difficulties in creating, organizing, and communicating tacit knowledge. Regarding which knowledge mapping tools work better, scholars tend to concur with each other that a sole knowledge mapping tool is not perfect. They suggest that one mapping tool can become more powerful either by extending the functions of the existing mapping tool (Wang, Wu, & Kirschner, 2016) or by integrating it with other mapping tools (Garrido and Tramullas, 2004; Davies, 2011).

To support developing topic maps, concept maps and argument maps can facilitate building the data models and defining rules based on human cognitive reasoning. For this reason, the representations in concept maps and argument maps complement each other by bringing together critical thinking and problem-solving processes. It is not always easy to disentangle concepts and relevant contentions or cases associated with the concepts while constructing concept maps. Argument maps can help the learner focus on identifying, structuring, evaluating, and communicating arguments.

As shown in Table 1, while the revised Bloom’s Taxonomy (Anderson et al., 2001) indicates six levels of cognitive skills, Webb’s Depth of Knowledge (1997) focusing on curriculum evaluation describes four increasing levels of cognitive processing (i.e., thinking), consisting of recall and reproduction, skills and concepts, strategic thinking, and extended thinking. Perkins (2008) aligned the revised Bloom’s Taxonomy with Webb’s Depth of Knowledge, which serves as a quality assessment framework in education. This study utilizes such a framework to map three knowledge mapping tools to the matching knowledge levels in Table 1.
<table>
<thead>
<tr>
<th>Level</th>
<th>Web’s Depth of Knowledge</th>
<th>Revised Bloom’s Taxonomy</th>
<th>Knowledge Mapping Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Recall and Reproduction</td>
<td>Remembering</td>
<td>Concept Maps</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Understanding</td>
<td>Concept Maps</td>
</tr>
<tr>
<td>2</td>
<td>Skills and Concepts</td>
<td>Applying</td>
<td>Concept Maps</td>
</tr>
<tr>
<td>3</td>
<td>Strategic Thinking</td>
<td>Analyzing</td>
<td>Concept Maps + Argument Maps</td>
</tr>
<tr>
<td>4</td>
<td>Extended Thinking</td>
<td>Evaluating</td>
<td>Concept Maps + Argument Maps</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Creating</td>
<td>+ Topic Maps</td>
</tr>
</tbody>
</table>

Table 1. Mapping Knowledge Mapping Tools with Levels of Thinking in Bloom’s Taxonomy and Webb’s Depth of Knowledge

Adopting concept maps alone would be appropriate when learners possess the entry-level knowledge (i.e., recall and reproduction) or are in the process of studying new skills and concepts. As their knowledge level reaches the strategic thinking level, adopting both concept maps and argument maps seems to be beneficial to their critical reasoning and problem-solving abilities. Once the learners advance their knowledge level and further extend their knowledge utilization to other domains, adopting topic maps plus concept maps and argument maps can connect teaching and learning resources in the knowledge network.

5 Conclusions

Our preliminary results indicate that concept maps help specify the relationships between concepts; argument maps are conducive to delineating the lines of reasoning, as the concepts entail multiple perspectives, particularly contrasting viewpoints; topic maps feature information/knowledge organization and connect the teaching and learning resources created by using concept maps and argument maps. This scoping review may offer insights into the integrative applications of these three knowledge mapping tools as well as challenges encountered by instructors when choosing tools. It is hoped that these preliminary results may serve as a basis to facilitate future research design on learning and teaching using knowledge mapping tools in an innovative combination.

6 References


