



Figure 2. Interface. (a) Depicting a citation network to show the evolution of interests and knowledge. (b) Displaying the distribution of cited and published articles.

Knowledge flows through the citation network without constraint. Scientists can publish in several areas, and thus be involved in different knowledge flow networks. This enables knowledge to flow through knowledge networks in different areas to promote interdisciplinary research.

An important characteristic of knowledge flow is its reachability—knowledge of author A's article can reach C when C cites B's article and B cites A's article.

The development of a large knowledge flow network involves certain special roles shown in the accompanying table. Different roles contribute differently to the development of an area. A researcher can play different roles in several areas.

THE KNOWLEDGE FLOW SPIRAL—A KNOWLEDGE HYPERCYCLE MODEL

Knowledge flow spirals are formed when knowledge flows in a network. A knowledge node (scientist) can deliver knowledge to its peers by forwarding knowledge it has received (for example, forwarding an answer to the node that forwarded the query), or by passing on knowledge it generates (for example, send the answer to the querying node directly). The

received knowledge inspires a node to generate new knowledge. Knowledge passing can take the form of broadcasting or query routing. Figure 1 depicts a knowledge spiral, comprising nodes and two types of flow:

- *External knowledge flow*—knowledge flowing between nodes, and
- *Internal knowledge flow*—knowledge arising within a node as the result of processing.

The functioning of the knowledge spiral is very similar to that of the hypercycle model [8]. The self-replication and catalytic-support arcs in the hypercycle correspond to the external knowledge flow and internal knowledge flow of the knowledge spiral. There are two differences: self-replication happens in the nodes of hypercycles while external knowledge flow is between nodes of a knowledge flow spiral, and catalytic support happens between nodes while internal knowledge flow is within individual nodes of a knowledge flow spiral. A knowledge flow spiral can generate and generalize knowledge during the processing and recycling of

The knowledge flow network implicit in the citation network consists of KNOWLEDGE FLOWS BETWEEN NODES THAT PROCESS KNOWLEDGE, including reasoning, fusing, generalizing, inventing, and problem solving, by authors and co-authors.