

# Use of Visualization Techniques for Active Learning Engagement in Environmental Science Engineering Courses

Srinivasan Latha, M. R. Christhu Raj, Rajeev Sukumaran

**Abstract**—Active learning strategies have completely rewritten the concept of teaching and learning. Academicians have clocked back to Socratic approaches of questioning. Educators have started implementing active learning strategies for effective learning with the help of tools and technology. As Generation-Y learners are mostly visual, engaging them using visualization techniques play a vital role in their learning process. The facilitator has an important role in intrinsically motivating the learners using different approaches to create self-learning interests. Different visualization techniques were used along with lectures to help students understand and appreciate the concepts. Anonymous feedback was collected from learners. The consolidated report shows that majority of learners accepted the usage of visualization techniques was helpful in understanding concepts as well as create interest in learning the course. This study helps to understand, how the use of visualization techniques help the facilitator to engage learners effectively as well create and intrinsic motivation for their learning.

**Keywords**—Visualization techniques, concept maps, mind maps, argument maps, flowchart, tree diagram, problem solving.

## I. INTRODUCTION

THE extensive use of active learning strategies [1] has resulted in effective learning. Any activity that engages the learners actively in course-related content and context are termed as active learning. Visualization methods are used as approaches for meaningful learning as they demonstrate the understanding and reflection of the subject matter [2]. Visual information is processed must faster by brain [3]-[5]. Various visualization techniques are used to trigger lateral thinking and critical thinking among learners. Thus, the use of visualization techniques helps learners in classroom and develops their thinking process, problem-solving ability and improves learning [3].

Visualization techniques are used as approaches for meaningful learning in the classrooms [4]. Visualization techniques can also be used for brainstorming and develops their creative thinking ability. The prime reason for implementing visualization techniques is that; learners present the concepts visually and that triggers visual thinking among presenters and other learners in class learning. Visual thinking improves creativity and knowledge retention [5]. There are

Srinivasan Latha is with the Department of Chemistry, SRM University, India. (e-mail: latha.sr@ktr.srmuniv.ac.in).

Christhu Raj is with the University Learning Centre, SRM University, India. (Corresponding author: e-mail: christhuraj.m@ktr.srmuniv.ac.in).

Rajeev Sukumaran is with the Teaching Learning Centre, Indian Institute of Technology Madras, India. (e-mail: rajeev@wmail.iitm.ac.in)

many visualization techniques; (a) Mind map (b) Concept Map (c) Cognitive Map (d) Radial Tree (d) Semantic Map (e) Rhizome (f) Visual Metaphor (g) Tree structure (h) Argument map (i) Social Map.

Visualization techniques have been used in the educational domains of; science, technology, engineering and mathematics. Roth [6] proved that visualization techniques help learners in establishing the hierarchies, relationship among concepts, facilitate learners to introspect and reflect their learning. Nassi and Shneiderman [7] first proposed the idea of conveying a complex concept in a flow chart model. From then on, educationists have started implementing for different discipline. In the last decade, the use of information and computer technology has enabled information mapping to be achieved with far greater ease. Many software tools like Mindmaps, Mindmapper, Argunet, SNeps, Inspiration, etc., have been developed to meet the various needs and use of visualization techniques. Prabir [8] demonstrated the use of concept map in solving problem in structural analysis in civil engineering. Similarly, various visualization techniques have been used by learning facilitators for different concepts in education.

In this article, the authors present the use of different visualization techniques in enabling learners to create interest in the concepts of Bio-Diversity. The remainder of the article is organized as follows: Section II explains the taxonomy on different visualization techniques, Section III presents the methods used for explaining visualization techniques for learners, Section III explains the methods implemented for introducing visualization techniques followed by Section IV on the materials and software's used by learners for their preparation, Section V discusses the learner's presentation, Section VI presents the results, discussion and feedback obtained from the learners followed by concluding factors and future work.

## II. VISUALIZATION TECHNIQUES – A TAXONOMY

The following section outlines the different mapping methods involved in visualization techniques

### A. Mind Map

Mind Map developed by Tony Buzan [9] provides a clear map structure for visual learners. The founder stress on the important message “Learn the way your brain learns”.

- **Key Features:** Mind Map is used to visually organize technical concept and content in an unstructured manner.

Mind map allows learners to explore relationships among concepts. It comprises of a network of connected and related concepts.

- *Advantages:* Mind maps are easy to learn and apply. It helps learners to improve their creativity. There are many open source software's that supports Mind map. Mind maps can be easily extended.
- *Disadvantages:* In some concepts, Mind maps become a complex tool for implementing because of its unstructured procedure. Individual Learners represent a concept in idiosyncratic manner that becomes hard for other learners to understand.

#### B. Concept Map

Concept map is a visualization technique developed over time [10]. It is more structured than mind map and follows a hierarchical model.

- *Key Features:* Concept maps are used to represent relations in topic using graphical presentation tools. It can be presented as a web diagram, where individual nodes act as a concept or idea and these ideas or concepts are interrelated to show relationship among various nodes. Nodes are connected using lines that describe their relation.
- *Advantages:* Concept maps can be used as a strategy to search out and analyze themes in qualitative research. Concept maps can be assessed through evaluation protocols.
- *Disadvantages:* Concept maps are not easy to apply and it needs extensive training for extending. The overall pattern does not necessarily assist memorability. Similar to Mind map, Concept Map tends to be idiosyncratic.

#### C. Argument Map

Argument map is visual representation of the structure of various groups of statements [11]. Argument maps typically includes unique components of the argument known as Conclusion or Premises. It is also refereed as contention and reasons.

- *Key Features:* Argument maps allow leaners to display the inferential connection between conclusion and premises. This feature enables argument maps to evaluate in terms of validity of argument structures.
- *Advantages:* Argument maps follow a hierarchical tree-like structure. Argument maps assist learners in developing critical thinking skills.
- *Disadvantages:* Argument maps have low level of generality and cannot be easily extended or modified.

#### D. Cognitive Map

Cognitive map is an overall mental image or representation of the space and layout of a setting, which means that the act of Cognitive Mapping is the mental structuring process leading to the creation of a cognitive map.

- *Key Features:* Cognitive Map is a visual representation that serves the learners to follow ACSRD model [12] known as Acquire, Code, Store, Recall and Decode information. Cognitive maps serve the construction and

accumulation of spatial knowledge allowing learners to visualize images in order to reduce their cognitive load.

- *Advantages:* Cognitive Maps are widely used, where other visualization techniques are not found suitable; Geography, Cartography, Education, Psychology, Landscape, Archaeology Architecture and Urban Planning.
- *Disadvantages:* Cognitive maps are not easy to understand and needs extensive training for higher concepts and there are very few researchers using this method. It is not widely used like other mapping techniques.

#### E. Social Map

Social mapping is an excellent learning tool and a very practical teaching tool in public health, especially when the researcher or health care provider has little knowledge about the fields practice area.

- *Key Features:* Social Map techniques are used to represent the cartographic and two-dimensional representation of social institutions projected on a plane [13]. It serves as a visual analysis of a digital identity of a person or brand or company.
- *Advantages:* Social maps are useful for Corporates and Software Firms than educational institutions. It is very effective and meaningful.
- *Disadvantages:* Social map needs authentic data and it's still a new and an unexplored or unusual methodology that is implemented in educational concepts in institutions.

#### F. Semantic Network

Semantic maps or graphic organizers are maps or webs of words. The purpose of creating a map is to visually display the meaning-based connections between a word or phrase and a set of related words or concepts.

- *Key Features:* Semantic Network maps represents semantic among relation and concepts. Unlike other maps, Semantic maps comprise of directed or undirected graph consisting of vertices that represents concepts and graphs [14]. Semantic Maps can aid the learners to understand the concepts to great extent.
- *Advantages:* Semantic network technique is used when one has knowledge that is best understood as a set of concepts that are related to one another.
- *Disadvantage:* Semantic network techniques are not applicable for all topics and it cannot be extended for higher end level concepts.

#### G. Radial Tree

Radial Tree is a method of displaying concepts in a tree structure. There are 42 types of radial tree methods that can be implemented. Radial tree techniques are mostly used in courses like Data Structures, Networks, Database Systems

- *Key features:* The radial tree techniques are used to display the concept in a tree like structure. It expands outwards and radially [15].

- *Advantages:* Radial tree techniques have mind mapping systems such as Mind manager and Mind Mapper that can make radial-like layouts for easy understandability for learners [16]. Spicy nodes approach enables to visualize the hierarchy and mobility among nodes for better reading.
- *Disadvantages:* The main drawback of the system is that Radial tree is difficult to extend for analytical concepts. Radial tree method is more suited for computer and storages oriented concepts and topics.

#### H. Conceptual Diagram

A conceptual diagram is a systematic depiction of an abstract concept in pre-defined category boxes with specified relations. Conceptual diagrams are typically based on a theory or model.

- *Key features:* It is based on specified relationship, typically based on theory or model. It helps learners to analyze a topic or situation through proven analytic framework.
- *Advantages:* Conceptual diagram provides a hierarchical structure and reading directions is either from left to right or from top to bottom [17]. It structures a topic into systematic building blocks.
- *Disadvantages:* Conceptual diagram follows a fixed diagram shape and the level of difficulty ranges from medium to high. Conceptual diagram technique is not applicable to any topic at hand. It does not foster creativity and critical thinking when compared with other techniques like Mind map and Concept map.

#### III. METHODS FOR VISUALIZATION TECHNIQUES

The study was conducted for 72 students of first year engineering who have registered for the course on Environmental Science. It was found from learners' interactions and assessments, that learners often show disinterest in the learning modules. As the course contains a lot of information that are only conceptual, it was decided to implement active learning strategies to engage them in meaningful learning practices. Visualization techniques were introduced to learners along with their respective software's such as; Mindmaple, Inspiration, Argunet and SNeps.

The topic for this experimental learning study is Biodiversity. The technical content and depth for the topic are decided with appropriate tools and technologies that are needed for implementing visualization techniques.

Based on the grouping theories [18], the learners were grouped into nine teams with 8 learners per team. Each team was assigned an unique topic; (i) Biodiversity (ii) Terminologies (iii) Values of Biodiversity (iv) Classification of Biodiversity (v) Threats to Biodiversity – Environmental Conditions (vi) Threats to Biodiversity – Biological Competition (vii) Anthropogenic activities (viii) Conservation-In-Situ (ix) Conservation–Ex-situ. The Key roles and accountabilities for every member of every team were assigned to ensure that all learners have some role to perform and learn. The individual teams have chosen

appropriate visualization tools for presentation of the concept to all the other teams.

#### IV. MATERIALS FOR VISUALIZATION TECHNIQUES

Tony Buzan's Mind map and Novak's Concept map were shown high interest among the learners. The facilitator requested the learners to choose atleast five visualization techniques. Learners opted for Mind Map, Concept map, Argument Map, Radial Tree and Visual metaphors. Experts from the SRM University Learning Centre aided the learners along with the facilitator in preparing visualization techniques. There are similarities and differences among the concepts. Each individual group started preparing for the presentation. Learning rooms are equipped with Wi-Fi Connectivity and this made task much easier for learners and facilitators for the preparation. Fig. 1 shows the sample Mind map for Biodiversity concepts.

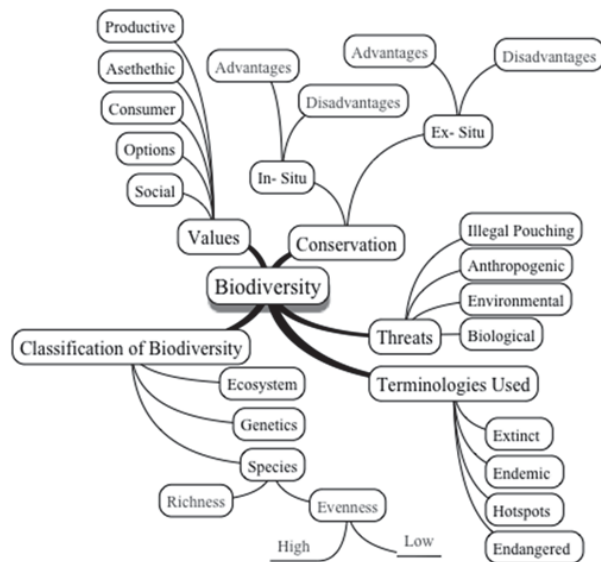


Fig. 1 Biodiversity Concepts using Mind Map

#### V. LEARNERS PRESENTATION

Learners were given time to prepare their individual learning's of the assigned topics. Each team was given specific slots to present their findings. Students have created a series of mind maps, concepts maps and argument maps, which implicitly focus on concepts of learning. When an individual team is presenting, other teams needs to understand the concept. The presenting team is given full freedom to assess the learning amongst members of the class. They have used either summative or formative techniques to access and verify the learning.

#### VI. RESULTS AND DISCUSSION

Learners had presented the concepts in biodiversity module using visualization techniques. A questionnaire was prepared to collect feedback from the learners. The motive behind collecting feedback was to determine and ensure the

usefulness of visualization techniques in class learning. The major parameters included in the survey show how the Visualization Techniques helped learning of the module. Table I shows the parameters of nine statements for learners. The scale determines the values; 1-Strongly disagree (SD), 2-Disagree (D), 3-Neutral (N), 4-Agree (A), 5-Strongly agree (SA).

TABLE I  
LEARNER'S FEEDBACK ON VISUALIZATION TECHNIQUES

Statement	Responses from Learners					Disagree %	Agree %	Neutral %
	SD	D	N	A	SA			
Creative Thinking	6	5	12	32	17	16%	67%	17%
Simplifying Complex Concepts	7	3	18	27	17	15%	60%	25%
Ease of understanding	5	8	21	28	10	18%	53%	29%
Big Picture of learning	2	6	22	18	24	11%	59%	30%
Interesting and Engaging	4	8	19	21	20	16%	58%	26%
Revision before Exams	9	6	16	26	15	20%	58%	22%
Future Class Implementation	5	9	21	21	16	19%	52%	29%
Construction of own maps	6	8	16	20	22	19%	59%	22%
Linkage between concepts	7	3	16	26	20	14%	64%	22%

Visualization techniques help students to learn the key concepts and their relations. Enhanced student's learning through clear conceptual understanding was observed in interactions and in the formal assessments. Facilitator then discussed the Visualization techniques drawn from various team presentation. Learners were active and attendance was 100%. Table I explains the overall support for implementing visualization techniques ranges around 55%-85%. Therefore the use of visualization techniques has aided students in thinking creatively for their presentation. Similarly other questions show positive feedbacks from learners for implementing the visualization techniques. Thus the use of visualization techniques was found to be useful for engaging for the learners.

Nearly 80% students agreed to continue the mapping techniques for other classrooms lectures also. Improvements in the performance of students in the class interaction and assessments were observed. This further supports the use of visualization techniques for learning reinforcement, motivation and improvement. Furthermore, the facilitator was able to implement the higher order thinking style in the Bloom's Taxonomy. The results show that visualization techniques help improve learning and also help achieve the learning outcomes of the individual sessions. Feedback shows

that active learning strategies were generally seen as useful learning techniques in the classrooms. Table II explains the feedback obtained from the learners regarding various visualization techniques.

TABLE II  
LEARNER'S SPECIFIC FEEDBACK

No	Technique	Advantages	Suggestions
1	Mind Map	1. Ease of use 2. Implementable 3. High level of understanding	1. Need to be implemented for all concepts
2	Concept Map	1. Easy to Understand 2. Increased creativity 3. Useful for revision of content during exams	1. Software need to be developed for better User interface
3	Argument Map	1. Interesting group work 2. Understand the big picture.	1. Need experts for introducing techniques 2. Need to be explained for higher concepts. 3. Bit confusing techniques.
4	Radial Tree	1. Increased problem solving techniques. 2. Develops confidence	1. Time consuming 2. Need for specific Software's to explain 3. Difficult to understand
5	Visual Metaphor	1. Understanding the overall picture	1. Time consuming 2. Difficult to draw the concepts 3. Need experts working in Visual Metaphor

The experts from University Learning Centre enquired learners for specific feedback about individual visualization techniques. The consolidated report was generated and presented in the above table. It clearly shows that learners were comfortable with Mind Map and Concept maps. Table III shows the taxonomy of various visualization techniques.

## VII. CONCLUSION AND FUTURE WORK

This article presents a study on using visualization techniques in first year course on environmental science. The learner's consolidated report shows that visualization techniques were generally seen as effective tool for learning and retention of concepts. Visualization techniques make students learn concepts and their relationship with ease. This is because visualization techniques were more helpful in learning to grasp the big picture and develop confidence. This study can also be used for other courses because complex topics through visualization techniques can be made simple. This better understanding of concepts and basics can drive the engineering students to take up individual or group research work and publish solutions for many socially related issues.



TABLE III  
VISUALIZATION TECHNIQUES – A TAXONOMY

No	Parameters	Argument Map	Cognitive Map	Concept Map	Radial Tree	Semantic Map	Social Map	Tree Structure	Mind Map
1	Definition	Visual representation of the structure	Spatial representation of the outside world that is kept within the mind, until an actual manifestation	Top-down diagram Showing the relationships between concepts Including cross Connections among Concepts, and their Manifestation	Radial Tree is a method of displaying concepts in a tree structure	Semantic map is a network to represent semantic relations between concepts	Social Map technique is used to represent in the cartographic and two-dimensional representation of social institutions projected on a plane	Tree structure is a way of representing the hierarchical nature of a structure in a graphical form	Mind map is defined as a visual, non-linear representations of ideas and their relationships
2	Features	Encourages Creative thinking	Association of ideas.	It is systematic proven approach to provide overview of concepts	Learning retention.	Overview of Concepts	High level of usage in corporates.	A tree structure is conceptual, and appears in several form	Encourages Critical thinking, creativity.
3	Benefits	Top down approach	Used for high level of understanding	Shows systematic Relationships among Sub-concepts relating to one main concept	Tree structure can be used in explaining topics effectively in Data structures	Semantic map used for research oriented topics	Social Maps can be used in Location Tracking Concepts.	Tree structure can be used in explaining topics effectively in Data structures	Show sub-topics of a domain in a creative and seamless manner
4	Graphical Elements	Boxes, Arrows	Arrows, Box	Boxes/bubble with Text and labeled Connector arrows	Triangle, Circle, Dots	Directed Arrows	Directed Arrows	Nodes, Leaf nodes, end Nodes, Leaves	Text within visual structure, sometimes connected through arrows
5	Reading Directions	Bottom-Up	Based on Human Imagination	Top-down	Centre outwards	Based on Directed Arrows, Centre Out	Based on Directed arrows	Top-Down	Centre-Out
6	Level of Difficulty	Medium to Low	Medium	Medium to Low	Medium	Medium	Medium	Medium	Low
7	Extensibility	Very Limited	Open	Limited	Limited	Open	Open	Open	Open
8	Typical Software	Araucaria, Argunet	Mind Maple	Inspiration	Mind manager	SNeps, MultiNet	Similar to Google Earth Maps	Mind Mapper	Mind Maple
9	Structure	Hierarchy Structure	No defined structure	Hierarchical, Treelike, Spider Bubble	Triangular, Circular.	Non-Linear	Two Dimensional	Hierarchical	Non-Linear
10	Understandability	Medium	High	High	Medium	High	Medium	High	High

## REFERENCES

- Turns, J., Atman, C.J. and Adams, R., "Concept maps for engineering education: a cognitively motivated tool supporting varied assessment functions", *IEEE Transaction. on Education*. Vol. 43, No.2, pp. 164-173 2000.
- West, D. C., Pomeroy, J. R., Park, J. K., "Critical thinking in graduate medical education: A role for concept mapping assessment", *The Journal of the American Medical Association*, Vol. 284, No.9, pp. 1105-1110, 2000
- Burkhard R, "Knowledge Visualization--The Use of Complementary Visual Representations for the Transfer of Knowledge. A Model, a Framework, and Four New Approaches". Swiss Federal Institute of Technology (ETH): Zurich, 2005
- McClure, J.R., Sonak, B. and Suen, H.K., "Concept map assessment of classroom learning: reliability, validity, and logistical practicality", *Journal of Research in Science Teaching*, Vol. 36, No. 4, pp. 475-492 1999.
- Markham, K.M., Mintzes, J.J. and Jones, M.G., "The concept map as a research and evaluation tool: further evidence of validity", *Journal of Research in Science Teaching*, Vol. 31, No. 1, pp. 91-101.
- Roth, W.M., "Student views of collaborative concept mapping an emancipatory research project", *Science Education* Vol.78, No. 1, pp. 1-34, 1994.
- Nassi, I., and Shneiderman, B "Flowchart techniques for structured programming". *SIGPLAN Notices*, Vol. 8, No.8.
- Prabir K Sarker, "Use of Concept Maps for problem-solving in engineering", *Global Journal of Engineering Education*, Vol.17, No. 1, pp. 29-33, 2015.
- Mento, A., Martinelli, P and Jones, R. M, "Mind mapping in executive education: Applications and outcomes", *Journal of Management Development* Vol. 18, No. 4, pp. 390-407, 1999.
- Novak JD. "Learning, Creating, and Using Knowledge: Concept Maps as Facilitative Tools in Schools and Corporations". Lawrence Erlbaum Associates: Mahwah, NJ, 1998
- Twardy, C, "Argument maps improve critical thinking", *Teaching Philosophy* Vol. 27, No.2, pp. 95-116.
- Kitchin RM. "Cognitive Maps: What Are They and Why Study Them?" *Journal of Environmental Psychology* Vol. 14 No.1, 1994.
- Wu, Wentao, "Probbase: A probabilistic taxonomy for text understanding." *Proceedings of the ACM SIGMOD International Conference on Management of Data*. ACM, 2012.
- Steyvers, M.; Tenenbaum, J.B. (2005). "The Large-Scale Structure of Semantic Networks: Statistical Analyses and a Model of Semantic Growth". *Cognitive Science*, Vol. 29, No. 1, pp. 41-78.
- Yee, K.-P, D. Fisher, R. Dhamija, & M. Hearst. "Animated Exploration of Dynamic Graphs with Radial Layout". *Proc. Information Visualization*, pp. 43-50, 2001.
- Douma, Michael, Greg Ligierko, Ovidiu Ancuta, P. Gritsai, and S. Liu. *Spicy Nodes: Radial Layout Authoring for the General Public*. InfoVis. Atlantic City, NJ. October 2009.
- Farrand P, Hussain F, Hennessy E. "The efficacy of the mind maps study technique", *Medical Education*, Vol.5, pp. 426-431, 2002
- Van der Laan, S and Dean, G. "Assessment to Encourage Meaningful Learning in Groups.", *AAFANZ SIZ*, Wellington, 2006.