

Cognitive Effects of Visualization on Learning Data Structure and Algorithms

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ABSTRACT

Education has the explicit task in society of developing cognition. This study has explored the cognition effects in four different aspects: The first is the psychological implications and effects of visualization applied to educational purposes and successfully guiding the learner to engage in cognitive processes essential for comprehension, the second aspect is prototyping data structure visualization platform, third aspect is implementation of prototype in real time environments like a classroom, the fourth and last impact is the feedback from students through a survey. Our research has showed the effectiveness of using visualization and animation techniques during lessons to engage people's attention towards cognitive learning. From the survey that we have conducted, we get to know that majority of people are unaware of the use of education visualization platform. All these observations motivate a critical look at visualization to facilitate learners in cognitive learning.

KEYWORDS

Visualization, E-Learning, Cognitive Learning, Human Computer Interaction

1 INTRODUCTION

During the last few decade new strategies in science, multimedia, technology, education and even learning processes have been developed. This paper presents an analysis and design study in the application domain of Computer Based Learning (CBL). CBL is a multidisciplinary field investigating the design of user-friendly computer learning systems. The term cognitive relates to psychology, it's all about mental abilities related to knowledge, decision making and problem solving [1]. There is a big relation between educational policy makers, teachers, general public and the parents, to analyze the important

factors that influence student achievement. For example, effectively delivered high quality professional knowledge can be a main factor to influence student outcomes [2]. For learning different things consciously we use cognitive abilities. Cognitive process use previous knowledge and learning to perform different tasks in practical life. In psychology the concept of cognitive directly relates to mental thoughts and intelligence [1]. So if we talk about learning then visualization is a very important term for better learning knowledge. Visualization or animations of different problems make the learning process easy and it affects cognitively on mental thoughts [1]. It is technique which enables people's consciousness, abilities, perceptions and motivates them to gain knowledge [5]. Graphic representations, such as pictures, graphs, charts and diagrams help people to get the meaning and understanding of information more easily and quickly [3]. Computers have been used for graphing, charting, animating and visualizing purposes in the last few decades.

Children show more interest during watching cartoons than reading story book [5], because it affects like a real time environment. Meanwhile it increases their learning process and builds their perception cognitively. As concerns to animation and visualizations, it works cognitively in analysis of exploratory visual data [11].

Animations can be developed in any field, for example in business for intelligent decision making [7], in education for better & easy learning and in medical for better treatment etc. But in our study, we took one very important course of computer science "data structure and algorithms". We developed and implemented a visualization prototype in real time environment

like classroom during lectures, to let students interact with this application directly. Animations provide an attractive environment for actively exploring algorithms and data structures [4]. Algorithm visualizations applications are widely viewed in technology as having the potential, for the major impact on computer science education, but the applications quality is highly variable [19]. However, in this area our research is concerned with the effects of instructional media and technologies that include computer screens, human interaction, learning cognitively, animations and survey about cognitive effects of visualization on education. The visualization platforms for different courses support education and provide the easy learning platform for students [3]. The possibility of creating an online educational visualization platform provides learners as well as instructors the best opportunities to improve the learning and teaching techniques. Visualization is a great step in the world of IT and most of the visualization software are open source and free of cost. [19]

2. REVIEW OF THE LITERATURE

After an extensive review of cognitive learning techniques and visualization technologies that make interaction with education, we have identified and explored many deficiencies in the current world of visualization. In the past decade, the high quality and graphical user interfaces have become a standard, especially in area of games. [5] We found that different kind of visualization platforms are helping people in different aspects of life. Data visualization is very important and hot research area in this decade [6]. There are some visualized tools in business intelligence fields, used by professionals for intelligence decision making [7]. And still there are bundles of visualization platform for students and for learners about different courses of science, administration and technology [19]. As you know currently the world is moving to E-Learning platforms and so as for it concerns HCI (Human Computer Interaction) which is focusing to facilitate teachers and student to provide them the

most interactive and user friendly platform [5]. The exciting new method and approach to the study of algorithms was done by Marc H Brown in algorithm animations [8]. In year 2003 Rainer Koschke conducted a survey on “software visualization”; this survey was designed and conducted through e-mails. The survey paper was sent to researchers, in software maintenance departments and reverse engineering [6]. These kind of surveys have been published also elsewhere [7], [17]. Keller and Bassil did the similar survey but this survey was about cost, quality and little bit focused on cognitive aspects of already available visualization tools [12]. In the background study of data structure and algorithm visualization, we found some visualized platform serving students in this course [9]. we have explored multiple visualization platforms some of them are O-Matrix, Algolist, David Galles (Visualization), Jeliot3, TRAKLA2, NZACDITT, John Morris (Visualization), CATAI, TANGO etc. [9]. Where NZACDITT is a platform [10], which is a collection of ppt slides, lectures animations, explanations and different visualization methods and comparison between them using different techniques especially about sorting algorithms. Another good website of Data Structure visualizations was developed by Duane Jarc in the university of George Washington [13]. A famous data structure and algorithms online visualization platform was developed by Professor David Galles [14]. There is another very famous and good learning environment tool TRAKLA2 for data structure and algorithms [15]. Through this a student can practice and do exercises simultaneously. Open DSA, a web application which provides, It’s an active e-book project to develop a complete online text book for DSA course [16]. During our study, analysis and survey, we found some short comings of these applications as listed below.

- The visualization level is very detailed that it made, it’s a little bit difficult to understand for a beginner student.
- In some platforms java applets also make trouble and every time asks to update, even after updating it displays the same error.

- The majority of the instructional web sites explored during our study are lack of interactive multimedia.
- Most of surveys were conducted through emails from professionals & engineers and participants in the field of computer science. [17]
- Sometimes extra code is needed for visualization of a specific algorithm, which is supposed to be inserted in the source code.
- In some platforms step by step working detail is not provided, so for some initial learners it's hard to understand some steps in detail.

3. RESEARCH METHODOLOGY

Here are several steps to describing our research contribution and methods we used for research.

3.1 Problem Statement

Working as a teacher assistant for the course of “Data Structure and Algorithm” at ZJUT, it was noticed that plenty of students were facing a lot of problems during the study of this course, so do the teachers in lectures. The course of “data structure and algorithm” is always considered a very tough course for beginner classes. Students spend much time on practicing different algorithms and doing a lot of practical work through coding to learn this course effectively. These types of courses are extremely difficult to learn by using static presentation media such as magazine, text book, and images or by lecture notes etc [3]. So to facilitate the learners of this course, we decided to create a visualization platform to enhance cognitive learning of students and make it easy for the teacher to illustrate more effectively by using the visual aids available [1]. We figured out that the development of a cognitive learning application is the only way to help out the students. By using visualization application for learning lesson, we can stop desperation of our mind and can fully focus on study [5].

The effectiveness of visualization has always been arguable [5]. It depends on the relationship between graphical representation and the mental

model. The cognitive theory also supports an active engagement of visualization and learning. The ideal situation of visualization is to fully automate and visualize the processes of the concerned problem [13]. To fully visualize a problem is a little bit hard, so during the visualization we should also keep in mind that what to animate and how to animate it and at which part we have to focus on more. Visualization and animations can successfully promote education because these are guiding for a learner to engage their cognitive sense to the goal of learning [11].

3.2 System Development Methodology

After identifying, analyzing and exploring the system complexity, the available resources and considering all risks, the most suitable and appropriate methodology for this project was prototyping. By finding out the difficulties in teaching of data structure course, we decided to introduce and aware the students the concept of visualization and animation during lectures. It may be very interesting to determine whether using visualization and animations enables students to understand the efficiency or functionality of an algorithm. One of the key requirements was developing a learning platform which is easy to use and attractive. Animations don't let a learner loose his contact with the problem, the learner fully concentrates on it starting to make his own perceptions about it [5]. Currently, we have visualizations for the following data structures and algorithms:

- Data Structures (Queues, Arrays, Lists, Stacks,)
- Searching (Trees and algorithms)
- Sorting and Selection (Insertion Sort, Merge, Heap, Bubble, Shell Sorting etc...)
- Graph Algorithms (BFS, DFS etc...)
- Tree based Heap Data Structure
- Factorial of Numbers

The focus was to develop an online education visualization platform, which can be accessible all over the world through the internet. And find the importance of visualization in cognitive learning. To achieve this goal first we designed

the prototype of data structure and algorithms course for the students of ZJUT China.

Here are some snapshots of visualized data structure and algorithms developed application.

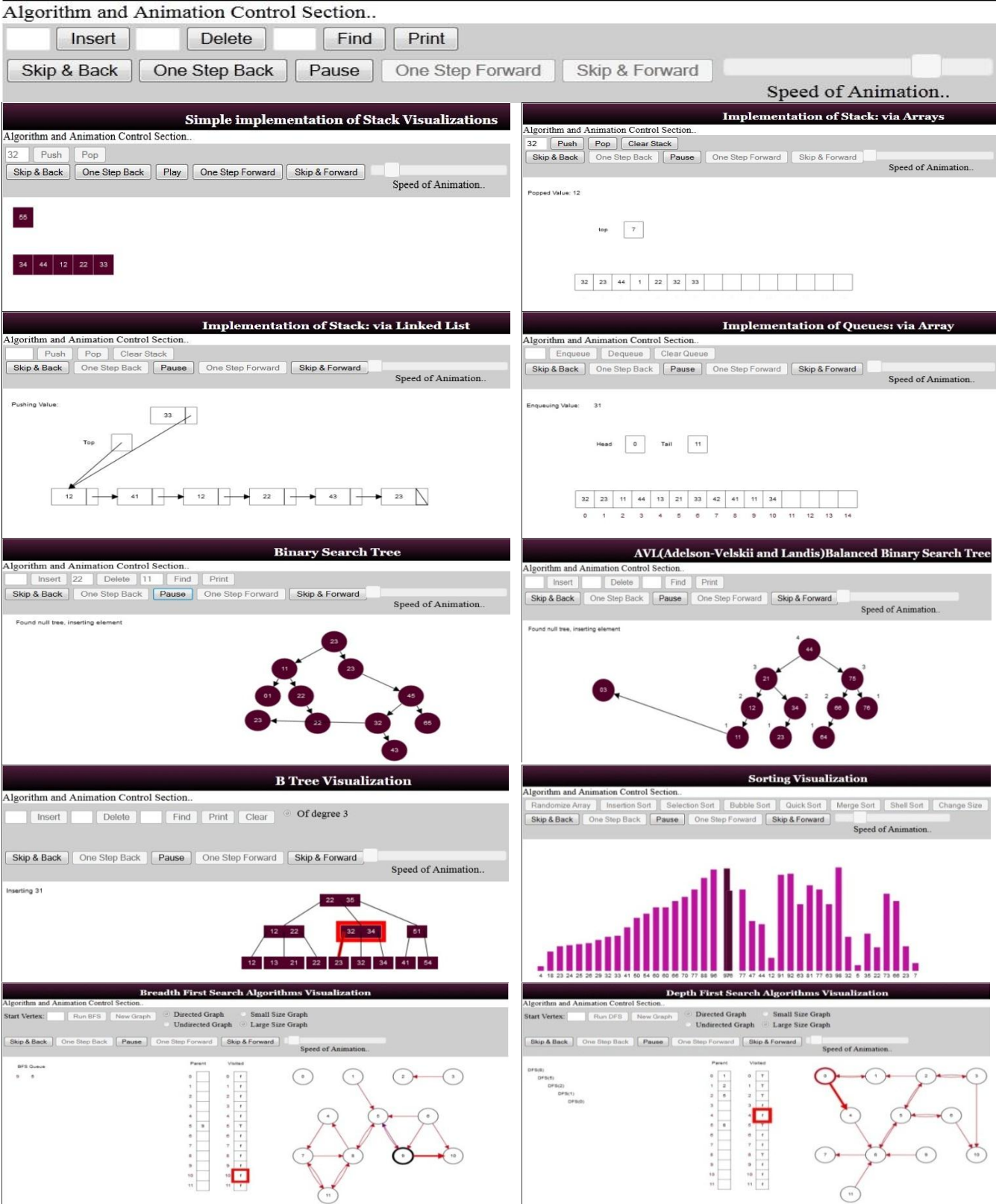


Figure.1 Selected data structure and algorithms snapshot

There were multiple options and factors that were needed to be before development of this application; like time, cost, amount of effort, risks, bugs, security and user friendly interface. Finally HTML5 and java script was selected to develop this prototype application.

3.3 Implementation Considerations

During the development process we delivered some lectures and taught students, different content of the course by using visualization and animations. We implemented our developed prototype application in real time environment. Because our developed prototype application hosted on the web, so all students were having full access to this application to learn different contents of the course “data structure”.

3.4 Conducting a Survey

To know the importance and value of visualization and interactive education system we adopted the survey methodology. We designed a questionnaire consisting of about 20 different questions. This survey was conducted only from international students studying in different departments. The questionnaire was organized into three parts as explained below.

Part-1: In this section mostly questions were about student’s background of visualizations. Whether have they ever used the visualization or animation applications before?

Part-2: This Section was our main concern, which described that visualization can improve the learning process of learners. And it can make learning more effective and cognitive.

Part-3: The last section was about finding out if visualization is an intelligent step in the world of education? And in the future what kind of visualization application students would like to have in the education department. The questions about future trend of animations, visualizations, e-learning and online education platforms for cognitive learning in different areas.

The most important thing to note is that in questionnaire, all the answers was predefined and

consist on MCQ’s from which the student just have to select an option. The survey was conducted in three steps to collect the data from the students of three different universities. More than 130 students participate in this survey, in which 70 questionnaire forms were filled by the students of course “data structure and algorithm” at ZJUT.

3.5 Data Collection and Analysis

Students from different departments participate in this survey but especially from the computer science department. The survey was conducted in three stages. The first stage was before the implementation of data structure and algorithms web application prototype. The second stage was after the prototype application presented in classroom during lectures. In the final stage around 80 questionnaire papers were filled by students of different departments, schools, and programs (BS, MS, and PhD).

All data was collected through questionnaire papers and then transferred into the computer for statistical analysis. After transferring to computer we divided all data into three files for separate analysis of each type of data. For statistical analysis we decided to use SPSS as an analysis tool, we have analyzed the collected data and values. We have applied standard statistical techniques, pie charts for analysis of all data. After getting all the required results from these three data sets, we performed comparison and evaluation of these results as shown in figure 2.

3.6 Survey Results and Comparison

This section displays the results of our survey and we will do some comparison between these results. Basically the comparison will be done in groups of students who were studying the courses of data structure; to know that how do they consider our provided prototype application for learning data structure course through animations. During demo classes of this application the feedback from students was 100%; students were showing fully interest in visualization, meanwhile

we noted that teaching with visualized tool, the students pay more attention on concerned problem and learn more attentively. Let's see some statistical results of different questions.

Note: In every column there are three graphs, the detail and title has mentioned down. The first two graphs shows the results of bachelor students of ZJUT, to whom we developed a visualization application of course "Data Structure" as a

prototype, and in these two graphs the first one is *before the demo classes* and the second is *after the demo classes*. It is stated that third graphs shows the result of *General survey* (all kind of students). In General survey the participants were from different departments, schools and of different ages. Let's see some selected questions results in the form of pie charts and then do comparison between these results.

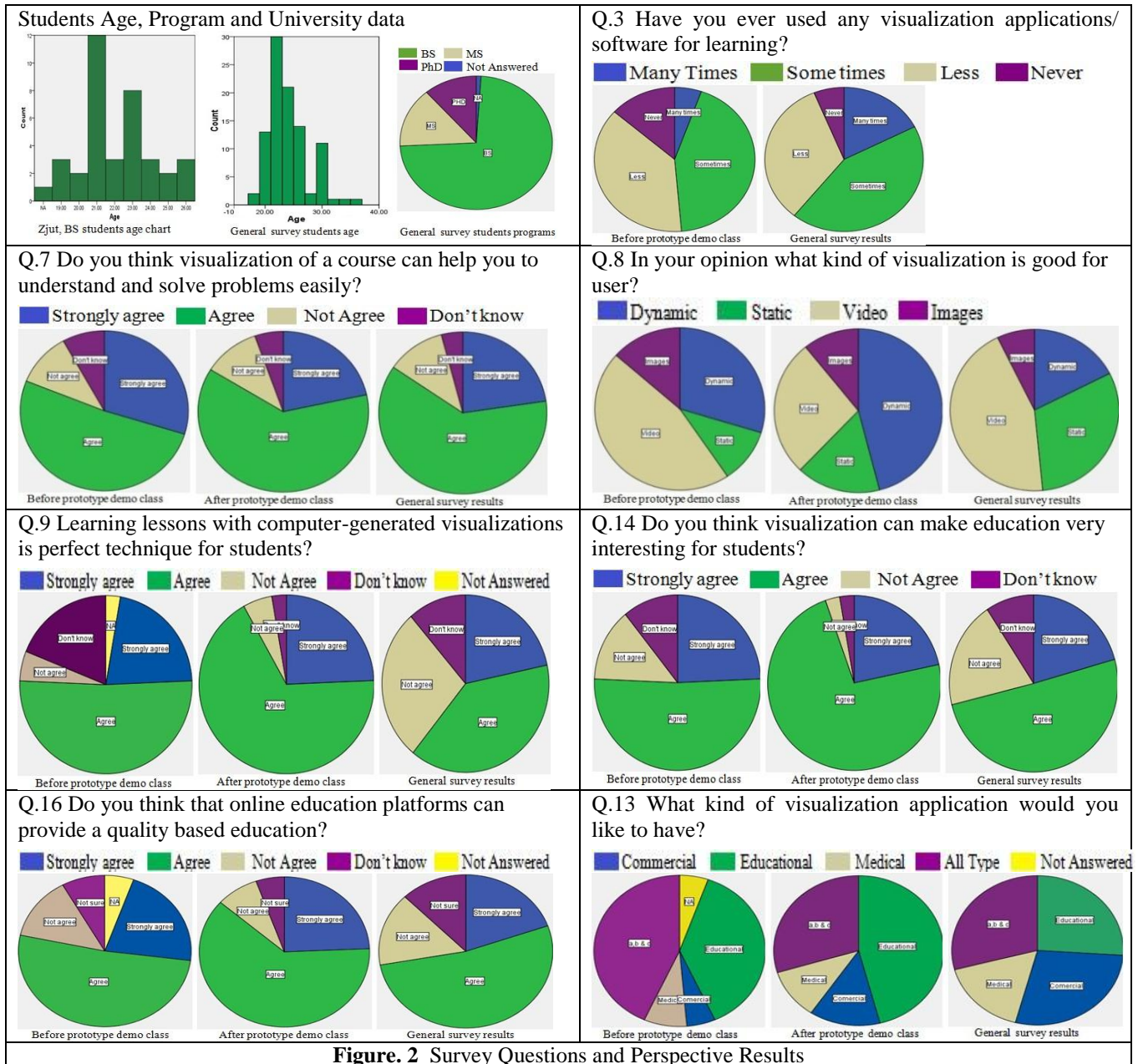


Figure. 2 Survey Questions and Perspective Results

After collecting all these results we reached the point to do comparative study. As you can see the results after demo classes of visualization prototype application are totally different from same students. During analysis there were two main reasons came to know, the first is that most of the students were never used visualization application for study and the second is: it was very hard for students to learn course of “Data Structure” by old teaching method i.e. Blackboard or PowerPoint slides. For these kinds of students animated learning platform was totally new and very attractive. So their response after the demo classes was totally different. This shows that they got the awareness from this survey to use animated and visualized learning platforms to clear their concepts and build the logics. Most of the students appreciate our prototype application and ask for to develop this kind of application for other computer science courses. Most of the students also support online education platforms, where they can attend classes online through video conferencing and all course materials are provided online. In the response of question “future visualization applications” many students checked the option to have visualization in all department of education.

If we consider overall results of the survey then we can say that, mostly students are in favor of visualization application, because it helps them in study, learning lessons, practice, understanding problems and in homework. In this survey almost 70% participants were Bachelor students and almost 23%, 22% were Master and PhD students respectively.

From the survey, the students also have suggested to include several more features as written bellow.

- To enhance the information written during the running animation, so that user can have better understanding of running code.
- To provide other language options of instruction to explain the steps,
- To add some games and sounds as attractive element for learning different contents of coursework.

4. Cognitive Effects of Animated Visualization

Concerning the cognitive effects of visualization tool, we realize that, in order to generate specific results of computer based learning, it would have been necessary to have more visualized applications and tools [1]. From this survey we can tell that current online visualization tool is very helpful form of learning cognitively. We came to know many benefits over the old teaching method. We have also confirmed that interaction with animated visualizations is an essential part which let users attend class fully attentively. Algorithm animations can develop a number of valuable and useful contributions: it can describes models for software engineers for creating animations, for end users interacting with the animations, for "script writers" creating and editing dynamic documents, and for "script viewers" feed backing and directly interacting with these dynamic documents [11].

The present study is based on cognitive orientation to learning and on the constructive visualized model, which enables students to take an active role in their learning to provide a quality based education [3]. Some modern teacher used animated effects to enhance their lectures in class and the outcome it produced was really great, they illustrated the main structure of their lecture while giving supporting arguments to their main point. They used the visual aids to converge the observational attention of students on a practical ground so that their imagination might take them to the point where they can see a thing happening in front of them [18]. The student present during the class were able to access their self-efficacy power by taking their mind on to the state of imagination, where they see every word coming out from their teacher mouth was going in a practical phase.

As per the survey conducted on the students before and after taking the demo classes with cognitive learning support, the following results were obtained. We are here by discussing the results of Q.17 and Q.20 graphed under. It has been asked to the students that weather they support the idea of traditional learning methods

or by applied other teaching methods like Blackboard, PPTs Video Tutorials and Computer visualization. The survey conducted before the class came out with the results of 45% students were in favor of video tutorial and about 25% students opted out for computer visualizations, 20% students went for PPT and 8% among them were supporting the fact that we should go with black board. But after taking class with visualization-

application prototype, the results were dramatically changed and a large number of students supported computer visualizations. the results of survey stated that the 70% of students opted out for cognitive learning and pupils in favor of video tutorial were lessened to 15% and PPT went on to take 10% and 5 % of students still remain in favor of blackboard .The results in the form of graphs are showed down.

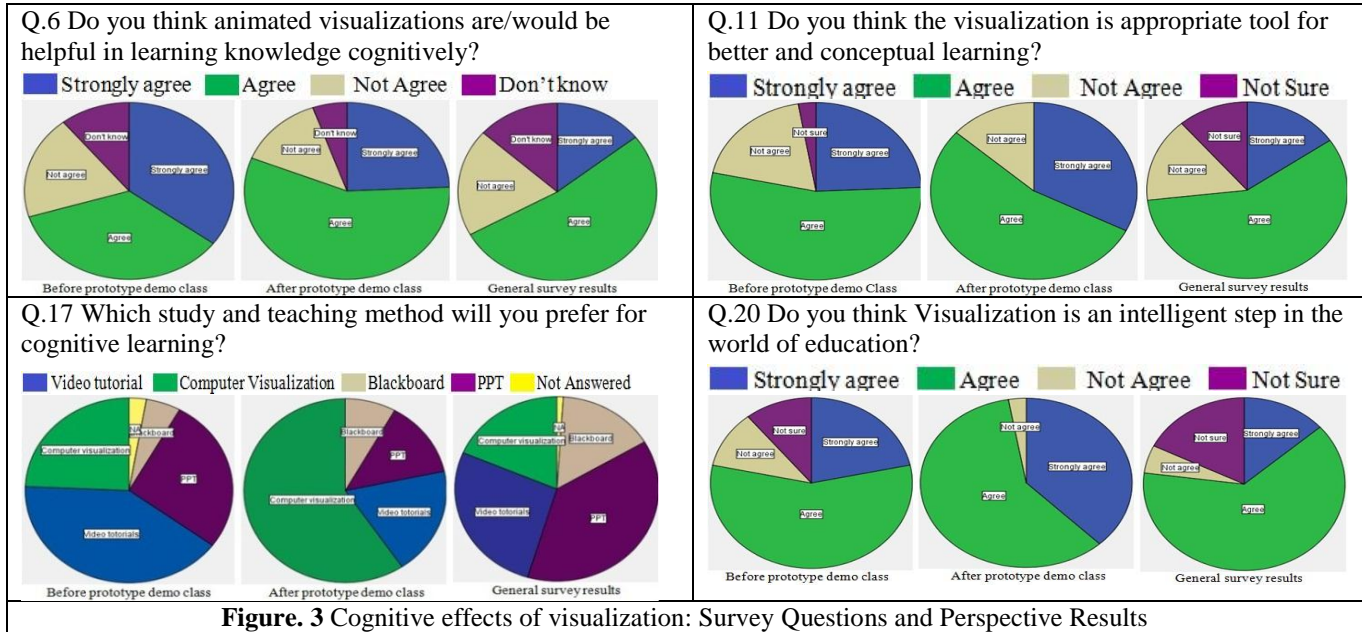


Figure. 3 Cognitive effects of visualization: Survey Questions and Perspective Results

5. Conclusion and Recommendations

We have developed a prototype visualization application for the course of “data structure & algorithm” and we have implemented it, in a real time environment like a classroom. After implementation we have conducted a survey from two groups of students in the form of questionnaire. The first group used that prototype during lessons and the second group was consisted on some random students from different schools and departments. As concerned about results, mostly students appreciated this prototype application and showed full interest during lessons. Our work has answered a set of primary questions about the effectiveness of using visualization applications and animations techniques during lessons. Starting with the most important course of “data structure and algorithm”

We are looking forward to visualize some other courses of computer Science. While analyzing the results of surveys conducted before making this visualization platform, we learned that the most of the pupils were unaware of the cognitive learning and visualization.

This particular application emphasis on the giving visual aid to the teacher while explaining his lecture in class. It also provided an online platform for the students to access the required visualization about course and a practical practice of Data Structure contents. We are strongly thinking that this particular application is going to boost a new era of revolution in the fields of mathematics and engineering [1].

These kind of visualization platforms can do a great job in hospitals and in other different risk management issues. We have all these ideas in our mind and we are ready to take our research as

further as we can. We think of visualization as the interface between mind, perceptions, ideas, learning and the way to understand. Here are some recommendations we would like to make. From the survey that we have conducted, we get to know that the majority of people were unaware of the use of education visualization platforms, so are the teachers. Some teachers are also unaware of the fact that use of visualization applications during lectures can help students in cognitive and

better learning. They should use advance teaching methodologies like visualization applications in their lectures, so the best solution for an advance learning method is to make users aware of cognitive learning methods and provide all the learning applications on web. These applications should be free and be at easy access to everyone. It is strongly recommended of making visualized applications for different educational courses comprehended using the cognitive ways [11].

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