

# A Proposed Framework for Visualization to Teach Computer Science

Muhammed Yousoof, Mohd Sapiyan, and Khaja Kamaluddin

**Abstract**—Computer programming is considered a very difficult course by many computer science students. The reasons for the difficulties include cognitive load involved in programming, different learning styles of students, instructional methodology and the choice of the programming languages. To reduce the difficulties the following have been tried: pair programming, program visualization, different learning styles etc. However, these efforts have produced limited success. This paper reviews the problem and proposes a framework to help students overcome the difficulties involved.

**Keywords**—Cognitive Load, Instructional Models, Learning Styles, Program Visualization.

## I. INTRODUCTION

**V**ISUALIZATION of the programs is considered to help learners learn programming, as visual sense is considered to make powerful impact on the mental image created by humans. So many researchers have tried to develop visualization systems which are often based on the metaphors.

Some examples of such systems are:

- \* COLORS - developed to reduce cognitive load by increasing the germane cognitive load [1]
- \* BlueJ - used theatre metaphor to visualize programs
- \* JELIOT - used class diagrams to visualize the programs
- \* OGRE-3D - three dimensional visualization of programs

These efforts helped but did not suit all learners with varied learning styles. There is a need to customize the visualization tools on a common framework without neglecting the individual learning styles.

Other efforts like pair programming [5], reading programs method, learning by examples are also proposed. Nevertheless, the key challenge of fitting the individual users still remains.

## II. LEARNING MODEL FOR PROGRAMMING

Learning programming involves three main support components namely Learning support, Learning activities and learning content. Inclusion of appropriate elements of the above three areas is important.

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Program learning is often followed in the hierarchy of Bloom’s taxonomy to achieve learning objectives. Learning objectives are arranged in hierarchy which is Knowledge, Understanding, Application, Analysis and Synthesis of the problems. Each level corresponds to increased difficulty level for the learner. This is diagrammatically shown below where each circle represent the various levels of Bloom’s taxonomy starting with Knowledge through Synthesis. At each level three components are necessary namely learning support, learning activities and learning content.

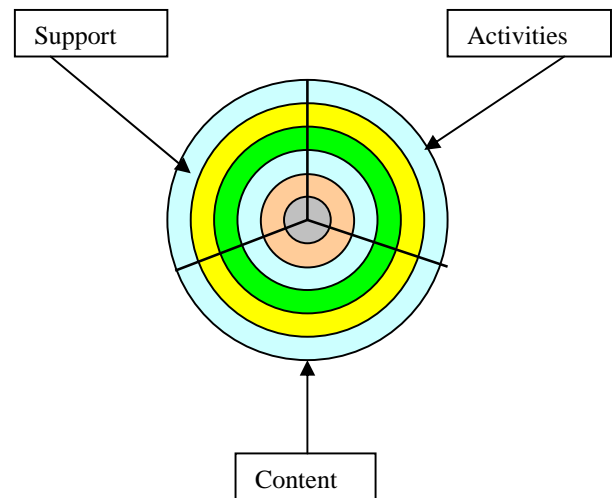


Fig. 1 Learning model for programming

In this model learning support has to be adequately planned to ease the process of learning. Otherwise it may result in increased cognitive load. As every human have limited working memory this memory could be best utilized by providing visual support or some motivator to help create mental image faster. Learners are usually provided with lecturers, notes, tutorials and lab sessions, supported with discussions and projects. Solving problems often requires the fusion of the mental image and external visual representation in the form of pictures or graphics. Mental image is formed based on the background of the learner, familiarity in the similar area, attention etc. So the impact of cognitive overload on learning programming differs from one person to another.

It is important to design the content and the activities involved in learning. The learning process is much influenced by the delivery framework or instructional methodology. The role of delivery framework is very important, as it motivates the learners to acquire knowledge and apply it in later stages in their carrier. If delivery framework is not

properly designed then it will lead to non achievable learning objectives.

IV. TAXONOMY ON CLASSIFICATION OF PEOPLE BASED ON COGNITIVE TRAIT

The proposed framework for visualization systems considers two main aspects namely learning styles and instructional format. Stereo typing of instructional design and delivery framework is avoided. When the students enroll for a computer science course, they should be identified into different groups based on their cognitive trait.

Different instructional framework should be adopted for each category to fit their learning style and learning phase. This helps to ensure that the instruction adopts teaching strategies that suit individual learners.

According to [6] cognitive traits of all humans can be under any one of the four categories namely Sensory Thinker(ST), Sensory Feeler(SF), Intuitive Thinker(NT) and Intuitive Feeler(NF). People's learning style and ability differs much on the basis of the cognitive traits.

Research has also been conducted to study the association between mental models and cognitive traits and the results showed that Sensors learn depending on the senses namely which is ear, eyes, feeling, nose, tongue. Whereas the intuitive learners use visual memory to maintain information and recollect them. Thinkers work on facts and evidences for making decisions whereas feelers make decisions based on emotion or similar attributes.

ST prefer self learning and hence depends on the availability of learning resources. They also prefer to learn by solving problems. They can answer the questions if the answers are obvious.

SF prefer to learn by repetition. They can understand the once if the concept is presented in modular way. They prosper by experience and continual rehearsal. They tend to work well in groups.

NT prefers learning via the use of pictures or other visual aids. They learn better with the summaries.

NF prefers to learn by the fusion of existing ideas and to enhance them to new ideas. Visual representations are necessary for them to gain proper understanding.

TABLE I  
PROPOSED LEARNING STRATEGY FOR DIFFERENT LEARNERS BASED ON COGNITIVE TRAITS

Cognitive Traits	Learning Resource	Learning Activities	Learning Support
Sensory Thinkers	Complete information should be presented	Solve problems by writing programs based on worked examples.  The learners are presented with problems which are clear cut.	Worked examples of similar type  Visual aids
Sensory Feelers	Program Reading method is	Learn by reading the code	

	well adopted.  Parital code method may also be adopted  Group Assignments	Reinforcement of the idea by Self Assesment questions at the end of the each section	Visualization tools that can fit with co operative learning and repetitive tasks
Intutive Thinkers	Program visualization and concept maps to explain the concepts	Learners use their ability to visualize to understand and develop programs for the given exercise	Visualization tools  Concept Maps  Simulation of theoretical concepts
Intutive Feelers	Program visualization and concept maps to explain the concepts	Learners use their ability to visualize to understand and develop programs for the given exercise	Visualization tools  Concept Maps  Simulation of theoretical concepts

At the same time learning style also plays a vital role in learning by people as it is differs from people to people. So the teaching method should be student centered and help them in achieving the desired learning. Learning styles as classified by Felder [8] which has the following namely active/reflective processing, sequential/global understanding, sensing/intuitive perception, visual/verbal processing, inductive/deductive reasoning.

TABLE II  
CLASSIFICATION OF INSTRUCTIONAL METHODOLOGY ON THE BASIS OF FELDER'S CLASSIFICATION OF LEARNING STYLES

Felder's classification	Best Suitable Instructional Methodology	Cognitive trait suitable
Active/Reflective processing	Co-operative activites, Individual Study, Reading	ST,SF
Sequential/global understanding	Step by procedure and instruction	SF
Sensing/intuitive perception	Practical Lab Sessions	All categories
Visual/verbal processing	Flowcharts, Concept map, visualization	NT
Inductive/deductive reasoning	Traditional Lecture style Experimentaion, Discovery	NF

In the entire above example it is clear that learning through visualization can complement regular teaching. The proposed framework tries to customize the delivery and

instructional design in relation to the cognitive traits and learning styles of learners.

**V. COGNITIVE LOAD REDUCTION IN THE FRAMEWORK**

The proposed framework will try to overcome the two difficulty areas namely misconceptions of concepts and reducing cognitive load. A good learning support will help to overcome this problem. The proposed visualization will give the learning support appropriate for each individual learner. So it will result in ease of learning programming.

Many learners are unable to understand many concepts used in programming for the simple reason they are abstract. For all types of learners learning support should be given to understand the concepts. For examples abstract concepts like data encapsulation, information hiding etc. can be well understood with the visualization of concepts using simple examples. This approach leads to reduce cognitive load and also retain the ideas clearly.

The current approaches to visualization have tried to use visual metaphors to illustrate the different areas of program. In some systems the animation of the program is shown. But in the proposed framework visualization of the program visualization can be done in many ways like UML notations, Concept Maps, Partial coding, Program reading etc. This multicentred approach in visualization will cater to each individual user's ability. This can help the learners to progress by their own phase and style. In short customizing the visual support on the basis of cognitive trait is the strength of the system.

**VI. PROPOSED VISUALIZATION FRAMEWORK**

The diagrammatic representation of the proposed framework is shown in the Fig. 2.

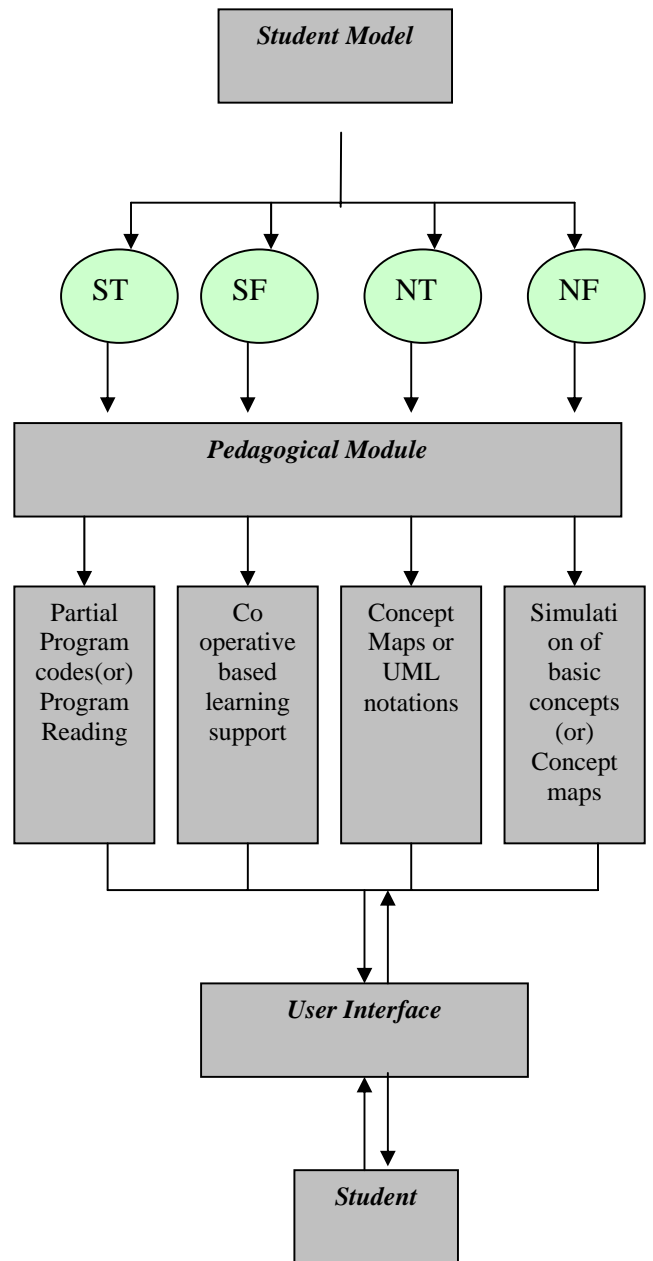


Fig. 2 Proposed framework for visualization

In the proposed system we have included the student model in which the information about the cognitive trait is stored. Depending upon the classification of the cognitive trait the learning support in the form of visualization is varied by the pedagogical module to suit the individual learner's learning style. Thus program visualization is customized to foster the learning process.

**VII. DISCUSSION AND FUTURE WORK**

The proposed framework for program visualization will help to overcome the barriers the learning programming. Two key difficulties of learning programming namely cognitive load and misconceptions about the programming language concepts can be overcome. It is possible as this framework

helps the learner to progress in their own phase by providing learning support appropriate for individual learner Learning support given to one individual may not be helpful for another as individual differences exist between users. Customizing the instructional methodology and delivery framework will certainly help in achieving learning outcomes. The proposed framework needs to be implemented and tested to evaluate the expected outcome i.e. reducing the difficulty in learning programming.

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