

USING LEARNING THEORY IN A HYPERMEDIA-BASED PETRI NET  
MODELING TUTORIAL

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**Title**

Using Learning Theory in a Hypermedia-based Petri Net Modeling Tutorial

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## **ABSTRACT**

The primary aim of this paper is to examine the dominant schools of thought in relation to educational theories and learning styles and in what manner various hypermedia technologies can be integrated into educational theories to enhance the design and delivery of educational content. The specific focus of this paper is to create teaching material for Petri net modeling fundamentals.

Guided by the principles of Bloom's revised taxonomy, a tutorial on Petri net Modeling Fundamentals is developed and implemented. The material in the tutorial is designed specifically to accommodate the lower-order thinking levels of Bloom's revised taxonomy and the various learning styles proposed in the Felder-Silverman learning style model.

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## **1. INTRODCUTION**

### **1.1. Petri Nets**

Petri net is a well-known mathematical formalism used for the modeling and analysis of concurrent and distributed systems. Petri Nets are applied to several areas such as manufacturing systems, work flow descriptions, and recently in telecommunication systems and communication protocols. A distinctive advantage of Petri nets is the fact that Petri nets have the ability to bring together different types of analysis techniques for concurrent and distributed systems. The analysis techniques range from detailed mathematical models to informal techniques such as animations.

Therefore, it is evident that Petri nets should be an integral part of the computer science curriculum. Academia has long realized this and Petri nets have been introduced in courses such as Simulation Models, Formal Methods of Software Engineering, and Computer Networking in institutions of higher learning.

Educators face the challenge of having a well-structured course readily available for teaching Petri net modeling fundamentals. From a learner's point of view, it is difficult to learn to create complex models without being familiar with the fundamental knowledge on which the complex models are based.

### **1.2. Learning Theories**

Learning theory based approaches to education have had a proven track record in providing a framework for setting up the learning objectives and how information is absorbed and retained during learning [3]. Learning theories provide a clear demarcation between the various levels of understanding and how these levels can be achieved and assessed while designing a course.

### **1.3. Objectives**

The three main objectives of this paper are:

- a. To examine the pedagogical requirements established by learning and educational theories and to identify appropriate technologies that can be applied to satisfy those requirements.
- b. To present educational content and assessments for the purpose of teaching Petri net modeling fundamentals in a structured and efficient manner.
- c. To specifically relate the educational content and assessments to satisfy the principles of a learning theory. Guided by the principles of Revised Bloom's taxonomy, we wish to structure our tutorial in such a way that the tutorial satisfies the learning objectives established by various levels of the Revised Bloom's taxonomy.

### **1.4. Document Outline**

This chapter has set the stage for the paper. The chapter has outlined the need for a well-structured Petri net fundamentals course that can be used by educators as a part of their modeling classroom. The chapter also outlined the need for a sound assessment of learning theories before design and creation of any course content. The rest of the chapters describe the topics given below.

Chapter 2 provides a brief discussion on Petri nets and the current state of Petri net education in Computer science curricula. A summary of learning theories and learning styles is provided and an introduction to Bloom's taxonomy of learning objectives is given. The effectiveness of hypermedia in enhancing course content creation and delivery is discussed

Chapter 3 describes a summary of various Internet and Multimedia technologies that can be combined to form a hypermedia-enhanced learning environment.

Chapter 4 provides an outline for a hypermedia-enhanced Petri net Modeling Fundamentals tutorial that is based on the Revised Bloom's Taxonomy.

Chapter 5 presents a set of conclusions drawn from the experience gained from creating the tutorial and the limitations of this work are discussed. Recommendations for future work are discussed.

## **2. OVERVIEW OF TOPICS AND LITERATURE REVIEW**

In this chapter we begin by providing an overview of Petri Nets, their applications and advantages. We provide a review of the state of Petri net education within computer science curriculum.

The chapter moves on to providing an examination of learning theories and learning styles and significance of incorporating learning theory into instructional course design

The chapter ends with a review on the current state of the art in web-based education and significance of web-based course content delivery.

### **2.1. Petri Nets**

We provide a detailed overview of Petri Nets in this section followed by an examination of current state of Petri Net education in institutes of higher learning.

#### **2.1.1. Petri Nets Overview**

Petri nets are a graphical and mathematical modeling tool which finds application in many systems. One of the special advantages of Petri nets as a modeling formalism is how the concepts of concurrent systems can be identified and analyzed both graphically and mathematically.

The concept of Petri net finds its origin in the Ph.D. dissertation of Dr. Carl Adam Petri submitted to the faculty of Mathematics and Physics at the Technical University of Darmstadt, West Germany in the year 1962 [5].

Structurally a Petri net is a directed bipartite graph consisting of places and transitions, wherein places are modeled by circles and represent conditions, and transitions are modeled by rectangles and represent events. Directed arcs connect places

to transitions or transitions to places. Figure 1 shows the three basic Petri net modeling elements we described above.



Figure 1: Petri Net Modeling Elements

Places can contain tokens, which are modeled by black dots, and these tokens represent the specific value of a condition [4]. A specific distribution of tokens across all the places in a Petri net is called the marking of a Petri net [4]. The system begins with an initial arrangement of tokens called the initial marking of the Petri net [4]. Figure 2 shows an example that demonstrates the basic structure of a marked Petri net.

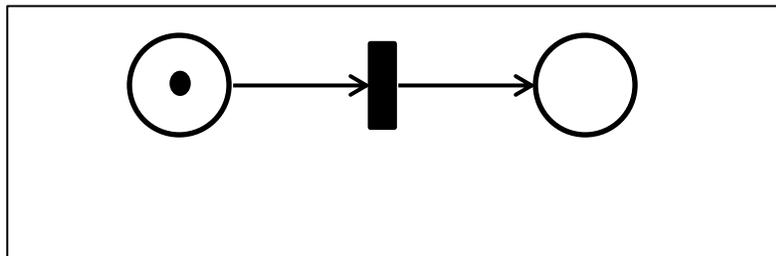


Figure 2: A Marked Petri Net

Based on the position of the arc with respect to transition, an arc can be classified as an input arc (arc directed from a place to a transition) or an output arc (arc directed from a transition to a place). Multiple (input or output) arcs between places and transitions are allowed [4] and instead of showing multiple arcs, a single arc is shown and is labeled with a number specifying the multiplicity. Hence, an arc labeled with a weight

'k' can be interpreted as the set of 'k' parallel arcs [5]. As a norm, if the arc weight is unity then the arc is not labeled and it is inferred that the arc weight is 1.

A transition is said to be an enabled transition in a particular marking if each of the input places hold at least as many tokens as the weight of the input arc [4]. An enabled transition can fire. A transition fire is an action that removes one token from all the input places of the transition and generates one token in all the output places of the transition. Figure 3 illustrates the state of a Petri net before and after a transition fires.

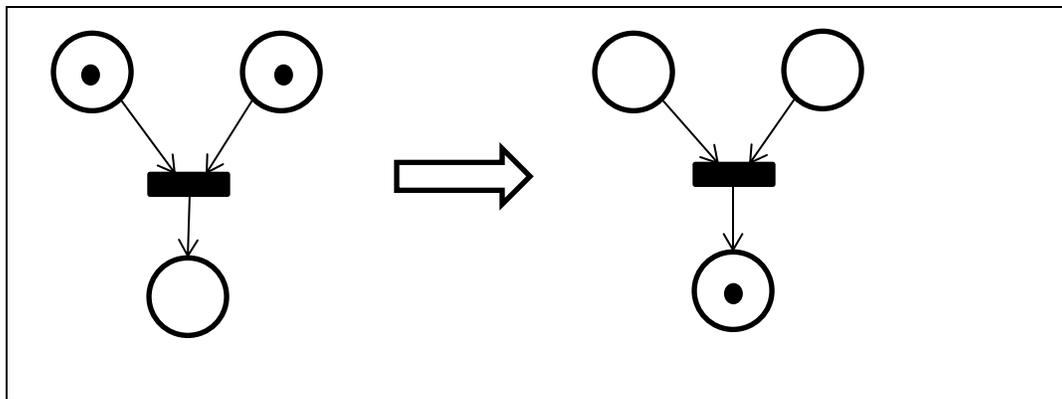


Figure 3: Firing of a Transition in a Petri Net

Beginning with the initial marking, transition firings lead to new markings, which in turn give rise to further transition firings. Transition firing sequences are used to define behavioral properties of Petri nets. These behavioral properties are used to analyze the system for which the Petri net model was created in the first place. The major advantage of Petri net models lies in their support for analysis of many problems associated with concurrent systems [5].

Petri nets are being used in a variety of application areas to model and analyze properties such as process synchronization, concurrent operations, asynchronous events, and resource sharing. These properties are some of the typical properties of discrete-event

systems such as computer-based systems, industrial automated systems, and communication systems [6].

Numerous researchers in their studies have discussed and recorded the several strengths of Petri nets that make them a widely-accepted modeling formalism. Some of these strengths can be outlined as follows:

- a. Given the fact that Petri nets have a strong mathematical background, they provide a precise semantics, which leaves no room for ambiguities [7].
- b. The graphical nature of Petri nets makes the process of visualizing a system along with its behavior easily possible [7].

Alongside the advantages we discussed above there is also the fact that Petri nets allow for extensions in several different ways to study specific system characteristics such as reliability and performance. Some of the better known examples of extended Petri nets are Timed Petri nets, Colored Petri nets, and Stochastic Petri nets [9].

In the next section we discuss some of the instruction methodologies that are currently employed to teach Petri nets.

### **2.1.2. Petri Nets Within Computer Science Curriculum**

The use of Petri net as a modeling tool finds application in a variety of courses that feature in both undergraduate and graduate level Computer Science curricula. Petri net modeling formalisms are used as an essential tool in courses that revolve around conceptual modeling of concurrent systems, model-driven software development, and design of workflow management systems [10]. The variety of courses that use Petri nets as conceptual modeling tool ranges from courses like Distributed Systems, Simulation Models, and Formal Methods of Software Engineering to courses like Systems

Engineering. The influence of Petri net as a modeling tool on computer science education has been reported by many researchers in the past [10, 11].

It is evident that knowledge of Petri net fundamentals is instrumental for Computer Science students to develop a deeper understanding of the subjects mentioned in the discussion above.

The fact that Petri net modeling knowledge is not delivered as a stand-alone course and is interwoven into a variety of advanced courses that make use of Petri net modeling concepts makes the overall learning curve steep for learners and educators alike.

Learners face the challenge of learning to create and analyze complex models without having the fundamental knowledge of Petri net modeling. On the other hand, educators face the challenge of designing the course work in such way that they do not end up spending too much time teaching the fundamentals.

In this paper we propose a Petri net fundamentals tutorial by doing an examination of the available technologies that can be integrated in the tutorial design, while incorporating learning and educational theories to establish the learning objectives of the tutorial.

## **2.2. Learning Theories**

The primary objective of instructional course design is to promote learning. Therefore for developing any instructional material, a thorough examination of the principles of learning is a must. The foundation of effective instructional or learning material is based upon a learning theory based course design approach. In this section we examine the predominantly practiced learning theories.

### **2.2.1. Learning Theories in Education**

A lot of research has been conducted on educational theory in the past. Multiple theories continue to evolve adding to the already extensive knowledge base that exists in the field of learning. Although there are numerous learning theories that have been proposed in the past and a lot of new ones keep evolving with new research being carried out in the field of learning and education, we discuss the three most widely-accepted learning theory models in this paper, which are Behaviorism, Cognitivism, and Constructivism [15].

#### **2.2.1.1. Behaviorism**

The main principle of behaviorism is that the environmental factors shape the behavior of a learner. This approach claims that individuals can be conditioned to events and this conditioning in turn leads to changes in behavior. The changes in behavior here are considered as the ‘evidence’ of learning [15].

This approach suggests that repetition of an event reinforces the behavior change and reinforcement is essential for learning.

The behaviorism approach has been shown to be appropriate learning model for relatively simple skills, but it is not an effective learning approach when more complex tasks are to be learned [13].

#### **2.2.1.2. Cognitivism**

Cognitive theories suggest a more brain-based learning. Cognitivism concerns with how human memory works to promote learning.

Cognitivism stresses on making knowledge meaningful and in assisting learners relate new information to existing knowledge in memory. They suggest that information

should be structured in such a way that learners are able to associate new information with existing knowledge in a meaningful way [17].

Cognitivism theories of learning have been used as a guide for Instructional design as they provide the framework for sequencing and organizing information to enable optimal processing [17].

### **2.2.1.3. Constructivism**

Constructivists define learning as understanding developed from experience. Constructivism views knowledge as an individual's interpretation, i.e. that knowledge cannot be dissociated from the individual and different learners may have different perspectives of the same information [17]. So, constructivism theory proposes that learners first reflect upon the information based on experience and only then incorporate it into their memory.

### **2.2.2. Bloom's Taxonomy**

Taxonomy is defined as a classification system which is ordered in a meaningful manner. There are many Educational Taxonomies that make use of the learning theories we discussed in the previous section. These taxonomies aid our understanding of learning by describing various stages in the learning process.

In this section we describe provide an overview of Bloom's Taxonomy, which is the most widely accepted educational taxonomy.

#### **2.2.2.1. Overview of Bloom's Taxonomy**

Bloom's Taxonomy was devised by Benjamin Bloom and his colleagues in the year 1956 [18]. Bloom's Taxonomy identifies Cognitive, Affective, and Psychomotor domains as the three domains of educational activities.

The Cognitive domain involves acquisition of knowledge and we discuss this domain at length later in this section. The Affective domain concern's the learner's attitude and includes feelings, emotions, attitudes, values, and motivations [18]. The psychomotor domain comprises of physical movement, coordination, motor-skills, and sensory-skills [18].

The Cognitive domain is the most widely used domains of the three domains and has been used on numerous occasions for developing instructional material.

The Cognitive domain is concerned with the acquisition and application of knowledge. The hierarchy of Cognitive domain is as follows:

- Knowledge: related to acquisition of facts.
- Comprehension: related to understanding of meaning of the knowledge attained.
- Application: related to applying the knowledge previously gained to a new situation.
- Analysis: related to the ability of a learner to draw conclusions based on facts presented.
- Synthesis: related to creating new ideas based on the material presented.
- Evaluation: related to assessing the knowledge presented.

The hierarchical concept in Bloom's taxonomy is based on the levels of difficulties, and each level addresses different learning outcomes. Evaluation, Synthesis and Analysis are referred to as higher order thinking skills, and Application, Comprehension and Knowledge are referred as lower order thinking skills [19]. It is largely accepted that a sequential structure is in place and higher order thinking skills cannot be effectively addressed unless the lower levels are covered. Figure 4 provides a

pictorial view of the six levels of Cognitive domain [25], with knowledge level being the lowest level and evaluation level being the highest.

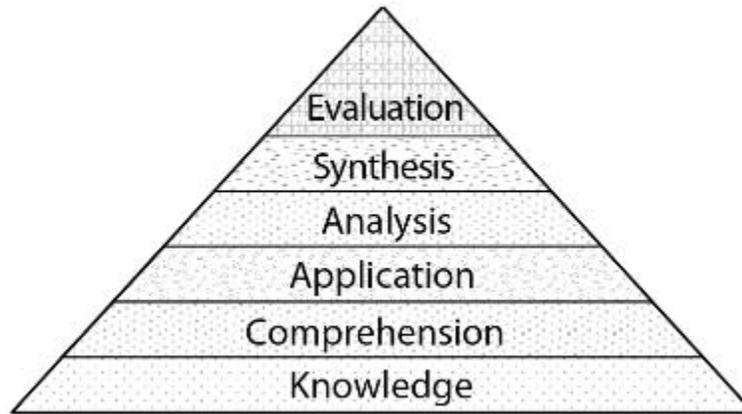


Figure 4: Bloom’s Taxonomy of Cognitive Domains [25]

Table 1 [20] gives a list of action verbs that are associated with each level in the Cognitive Domain of Bloom’s Taxonomy. Action verbs provide the educator with key words based on which educators can form the learning outcomes for each level.

Table 1: Cognitive Domain Levels and Action Verbs [20]

Name of the Level	Action Verbs
<b>Knowledge</b>	define; demonstrate; distinguish; enumerate; identify; label; list; match; name; read; recall; reproduce; restate; select; state; view.
<b>Comprehension</b>	classify; cite; convert; describe; distinguish, discuss; estimate; explain; generalize; give example; interpret; paraphrase; summarize; translate; understand
<b>Application</b>	Administer; apply; articulate; assess; chart; choose; collect; compute; construct; contribute; control; determine; develop; discover; establish; extend; implement; include; inform; instruct; organize; operationalize; participate; predict; prepare; preserve; produce; provide; record; relate; report; show; solve; take; teach; transfer; use; utilize.
<b>Analysis</b>	assess; break down; correlate; deduce; diagram; differentiate; distinguish; focus; illustrate; induce; infer; limit; outline; prioritize; recognize; separate; subdivide.
<b>Synthesis</b>	adapt; anticipate; categorize; collaborate; communicate; compare; compile; contrast; create; design; devise; formulate; generate; incorporate; initiate; integrate; model; modify; negotiate; plan; present; rearrange; recommend; reconstruct; reinforce; reorganize; revise; structure; substitute; validates.
<b>Evaluation</b>	appraise; conclude; confront; criticize; critique; decide; defend; interpret; judge; justify; re-frame; translate.

### 2.2.2.2. Revised Bloom's Taxonomy

A revision of the original framework of Bloom's Taxonomy was developed by Anderson, Krathwohl, et al., in the year 2001 [21]. The idea behind updating the original Taxonomy was to add more relevance to the present day teachers and learners as the original Taxonomy was created much earlier in 1956. The revision includes several seemingly minor yet important modifications to the original Taxonomy and occurred in the three categories: terminology, structure and emphasis [24].

#### 2.2.2.2.1. Terminology Changes

The changed terminology is perhaps the most obvious of the differences between the two versions of Bloom's Taxonomy. Basically, the six hierarchical categories were changed to verb forms in the revised taxonomy from noun forms in the original taxonomy [21]. Knowledge, which was the lowest level in the original taxonomy, was renamed to Remember. In the higher levels, Evaluation was moved from the top to second from the top and was retitled Evaluate, and Synthesis was moved from second on top to the top and renamed Create [24].

Figure 5 [25] provides a comparative view for a better understanding of the differences between the structures of the two versions.

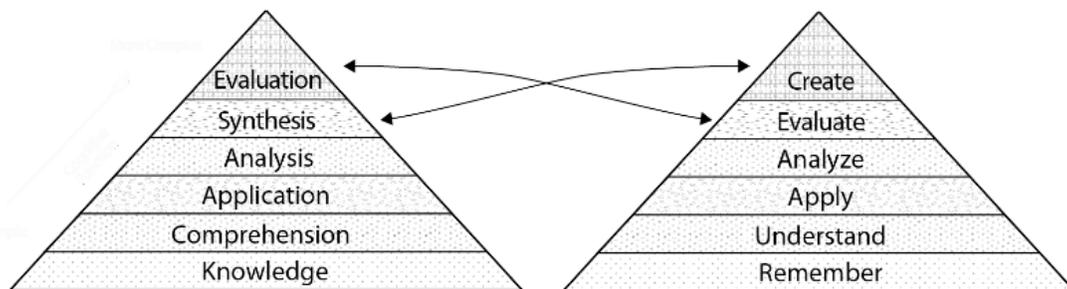


Figure 5: Comparison of the Original and Revised Bloom's Taxonomy [25]

The definitions for the new terms are provided in Table 2 [21].

Table 2: Revised Bloom’s Taxonomy – Definition of Terms [21]

Name of the Level	Definition and Key Words
<b>Remember</b>	Retrieving relevant knowledge from long-term memory. <ul style="list-style-type: none"> <li>• Recognizing</li> <li>• Recalling</li> </ul>
<b>Understand</b>	Determining the meaning of instructional messages, including oral, written, and graphic communication. <ul style="list-style-type: none"> <li>• Interpreting</li> <li>• Exemplifying</li> <li>• Classifying</li> <li>• Summarizing</li> <li>• Inferring</li> <li>• Comparing</li> <li>• Explaining</li> </ul>
<b>Apply</b>	Carrying out or using a procedure in a given situation. <ul style="list-style-type: none"> <li>• Executing</li> <li>• Implementing</li> </ul>
<b>Analyze</b>	Breaking material into its constituent parts and detecting how the parts relate to one another and to an overall structure or purpose <ul style="list-style-type: none"> <li>• Differentiating</li> <li>• Organizing</li> <li>• Attributing</li> </ul>
<b>Evaluate</b>	Making judgments based on criteria and standards. <ul style="list-style-type: none"> <li>• Checking</li> <li>• Critiquing</li> </ul>
<b>Create</b>	Putting elements together to form a novel, coherent whole or make an original product. <ul style="list-style-type: none"> <li>• Generating</li> <li>• Planning</li> <li>• Producing</li> </ul>

#### 2.2.2.2.2. Structural Changes

Bloom’s original taxonomy was single-dimensional structurally. As an example, in the original taxonomy the Knowledge level has activities such as define, list, label, recognize, repeat, and recall, but knowledge is of different types and mapping the activity

to a particular type of knowledge is a difficult task. In Revised Bloom’s taxonomy this problem was eradicated by making taxonomy two-dimensional.

A Knowledge Dimension has been added which helps in selecting the kind of knowledge that is to be learned. The second dimension is the Cognitive Process Dimension which identifies the process that’s to be used to learn [24]. This gives rise to a two dimensional format which is often termed The Taxonomy Table. An example of Taxonomy Table is shown in the Table 3.

Table 3: The Taxonomy Table [21]

<b>Knowledge Dimension</b>	<b>Cognitive Dimension</b>					
	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge						
Conceptual Knowledge						
Procedural Knowledge						
Metacognitive Knowledge						

The Knowledge Dimension on the left side of the Taxonomy table consists of four levels that are Factual, Conceptual, Procedural, and Metacognitive. The Cognitive Process Dimension which is shown across the top of the table consists of six levels that are Remember, Understand, Apply, Analyze, Evaluate, and Create [24]. The definitions

of these six levels of the Cognitive Process dimension have been provided earlier in this section in Table 2.

The four categories of the knowledge dimension are defined as follows:

- Factual knowledge: The basic elements that learners must know in order to be acquainted with a discipline or solve problems in it [21].
- Conceptual Knowledge: The interrelationships among the basic elements within a larger structure that enable them to function together [21].
- Procedural Knowledge: How to do something; methods of enquiry; and criteria for using skills, algorithms, techniques, and methods [21].
- Metacognitive Knowledge: Knowledge of cognition in general as well as awareness and knowledge of one's own cognition [21].

Each level of both the dimensions of the Taxonomy table is further subdivided. All the four Knowledge Dimension levels are subdivided into two to three subcategories. Table 4 shows the subcategories included in the Knowledge dimension [26].

Table 4: Subcategories of the Knowledge Dimension Categories [26]

	Knowledge Dimension Categories			
	Factual	Conceptual	Procedural	Metacognitive
<b>Subcategories</b>	Knowledge of terminology.  Knowledge of specific details and elements.	Knowledge of classifications and categories.  Knowledge of principles and generalizations.  Knowledge of theories, models, and structures.	Knowledge of subject-specific skills and algorithms.  Knowledge of subject-specific techniques and methods.  Knowledge of criteria for determining when to use appropriate procedures.	Strategic knowledge  Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge.  Self-knowledge

The Cognitive Process Dimension levels are also subdivided into sectors ranging from two to seven subcategories which we shown in Table 2 earlier in the section concerning terminology changes in the Revised Taxonomy. For example, Remember is subdivided into the two categories, Recognizing and Recalling [24].

This kind of a table structure is a helpful tool for teachers in writing objectives and lining up standards with curricular as this grid approach makes it easy for the teacher to select the cognitive process based on the knowledge type the learner is dealing with.

The two dimensions when carefully considered together allow the teacher to categorize learning and assessment. For example, a specific learning item like a ‘Quiz’ might aid a learner in recall of factual knowledge. This item can be placed in the cell corresponding to Factual knowledge on the Knowledge Dimension and Remember level on the Cognitive process dimension. This example is shown in Table 5 below.

Table 5: Placing Learning Items in Taxonomy Table.

<b>Knowledge Dimension</b>	<b>Cognitive Dimension</b>					
	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge	Quiz					
Conceptual Knowledge						
Procedural Knowledge						
Metacognitive Knowledge						

#### **2.2.2.2.3. Changes in Emphasis in the Revised Bloom's Taxonomy**

Bloom himself noted that the original taxonomy was being "unexpectedly" used for various purposes which were never considered when the original taxonomy was being developed. But the original taxonomy was not addressing the needs of areas like instructional design and research. The revised version of the taxonomy addresses these areas as well. Emphasis is placed upon the use of the revised taxonomy as a tool for curriculum development, instructional design and preparing assessment plans [24].

#### **2.2.2.2.4. Lower Order Thinking and Higher Order Thinking Skills**

Remember, Understand, and Apply are the three lower levels in Bloom's taxonomy and they are often called Lower Order Thinking skills as they represent the categories where learners develop concrete knowledge of fundamentals of the subject being taught. On the other hand, Analyze, Evaluate, and Create constitute the Higher Order Thinking skills as they represent categories where learner moves towards an abstract knowledge of the subject having already learnt the fundamentals.

In this paper, we target only the lower order thinking skills as the goal of the paper is to develop tutorial materials for teaching the fundamental concepts of Petri net modeling.

#### **2.2.3. Learning Styles**

The process of learning can be made more effective by making a close examination of learning styles and carefully choosing an approach that not only meets the pedagogical requirement of the topic that is to be taught, but also tries to find a balance between the various learning styles.

In this section we discuss the various learning style that were proposed in Felder-Silverman learning style model (FSLSM) by Felder and Silverman in 1988 [28], a learning style model designed for traditional learning which finds frequent use in technology-aided course content creation. The Felder-Silverman learning style model provides four dichotomous dimensions of learning styles: Active-reflective, Sensing-Intuitive, Visual-Verbal, and Sequential-Global. Individual learners can be characterized by a specific preference from each of these dimensions.

#### **2.2.3.1. Active and Reflective Learners**

The first dimension distinguishes between active and reflective styles of processing information. Active learners learn best by doing something active with the learning material, like applying the material. Active learners like to discuss the material and tend to do well when working in groups. Reflective learners prefer to think about the material and reflect on it quietly first. Reflective learners prefer to work alone or in very small groups.

#### **2.2.3.2. Sensing and Intuitive Learners**

Sensing learners tend to be patient and methodical and do not like surprises. Sensing learners prefer established methods, concrete facts and dislike abstract concepts without strong links to the real world. Intuitive learners tend to be abstract and imaginative. Intuitive learners like innovation and dislike repetition.

#### **2.2.3.3. Visual and Verbal Learners**

Visual learners remember best what they see. Visual learners tend to retain best when the instructional material contains visually appealing content like pictures,

diagrams, flow charts, demonstrations, and animations. Verbal learners respond well to words in the form of written and spoken explanations.

Highly regarded researchers in the field of engineering education research Richard Felder and Barbara Soloman mention in their paper, “Learning Styles and Strategies” [30] that everyone learns more when information is presented both visually and verbally. Felder and Soloman also make the following observation in the paper [30].

In most college classes very little visual information is presented: students mainly listen to lectures and read material written on chalkboards and in textbooks and handouts. Unfortunately, most people are Visual Learners, which means that most students do not get nearly as much as they would if more visual presentation were used in class.

#### **2.2.3.4. Sequential and Global Learners**

Sequential learners gain better understanding of the material when it is ordered in logically progressing or linear learning steps. Global learners tend to learn in large jumps and might often fail in grasping the subject until the big picture is made clear.

#### **2.2.3.5. Hypermedia Instruction and Learning Styles**

A lot of research has been carried out in the past on the topic of increasing the effectiveness and student learning and satisfaction using innovative approaches to learning. A specific approach that has gathered huge attention from the educational-research community is the use of hypermedia based instructional content. Many empirical studies have been done to prove that hypermedia-assisted instruction methods accommodate different learning styles better than conventional instruction methods.

In their paper titled “The Effect of Hypermedia Instruction on Achievement and Attitudes of Students with Different Learning Styles”, Zywno and Waalen [31] provide data that reveals that hypermedia-assisted instruction enhances academic performance for students of all learning style preferences. Their study was essentially a comparison study of two types of learning settings: hypermedia-assisted and conventional instruction. The study had a quasi-experimental design, with the experimental group (n=54) receiving the hypermedia-assisted instructions and the control group (n=48) receiving conventional lectures [31]. In the experimental group Hypermedia contents were used as supplements to the conventional lectures. The primary focus was on finding out if hypermedia based instruction was capable of accommodating different learning styles better than conventional instruction. At the end of the study it was found that an average student in the experimental group improved as much as the 74th percentile student in the control group [31].

In another study titled, “The Effect of Individual Learning Styles on Student Outcomes in Technology-enabled Education”, Zywno and Waalen [29] conducted a survey to find if students with different learning styles preferred technology-enhanced instructions. The results of the survey reported an overwhelming approval of all aspects of hypermedia usefulness. Table 6 adapted from [29] shows the percentage of students who chose hypermedia instruction over conventional instruction, broken down by learning style groups.

Table 6: Preference of Hypermedia Instruction Over Conventional Instruction [29]

<b>Learning style</b>	<b>Percentage of Students who prefer hypermedia based instruction</b>
Active	100
Reflective	93
Sensing	100
Intuitive	90
Visual	100
Verbal	50
Global	100
Sequential	96

In the next chapter we examine some of the technologies that can be used to support the design and delivery of educational content. We specifically focus on hypermedia technologies that can be exploited for the purpose of creating educational content and align with the context of current work.

### **3. TECHNOLOGY FOR ENHANCED EDUCATION DELIVERY**

In this chapter we examine some of the hypermedia technologies that can support educational content design and delivery. We start the discussion with Internet and how technologies associated with Internet like hypertext, scripting, and style sheets can come together with multimedia technologies like graphics, animations and multimedia textual formats to create a technology-enhanced learning environment.

#### **3.1. Internet**

The Internet and the World Wide Web has become an important component in the modern-day educational framework. Educational resources use the internet not only as a supplement to traditional teaching technologies, but in some cases as the primary means of educational content delivery. Internet's power lies in the fact that it can be used as a carrier for delivering a wide variety of interactive content to the learner. In this section we discuss the most widely used Internet content creation technologies: HTML

##### **3.1.1. Hyper Text Mark Up Language (HTML)**

HTML is the de facto presentation standard for the Internet. HTML is a tool that provides the means for navigating between documents that are spread across a network. HTML makes use of mark-up in a simple text document to provide the mechanism for content formatting and linking the documents.

Smith and Weiss in year 1988 defined Hypertext is defined as "an approach to information management in which data is stored in a network of nodes connected by links. Nodes can contain text, graphics, audio, video as well as source code or other forms of data." [33] Hypertext with multimedia content is called hypermedia.

Jeff Conklin in his work, “Hypertext: An Introduction and Survey” [34], provides the following perspective on the power that hypertext provides for the development of content that resides over network.

The essence of hypertext is precisely that it is a hybrid that cuts across traditional boundaries. Hypertext is a database method, providing a novel way of directly accessing data. This method is quite different from the traditional use of queries. At the same time, hypertext is a representation scheme, a kind of semantic network which mixes informal textual material with more formal and mechanized operations and processes. Finally, hypertext is an interface modality that features “control buttons” (link icons) which can be arbitrarily embedded within the content material by the user. These are not separate applications of hypertext: They are metaphors for a functionality that is an essential union of all three.

### **3.1.2. Cascading Style Sheets (CSS)**

HTML, as we have already discussed, allows designers to control how a document is viewed in a browser. During the initial few years of World Wide Web, authors who created and put pages on the Web had very little control over what those pages looked like [37]. They could only control the structural features of their pages like making a piece of the text heading and writing a part of the text in paragraph format. On the presentation side, there were only few things that could be done like make text bold or italic and but that's where their control over presentation ended [37]. Cascading style sheets introduced in 1996 provided a solution [37].

Cascading Style Sheets is a tool for achieving a consistency of presentation across browsers. The main purpose of cascading style sheets is to allow Web designers to manipulate a document's appearance without disturbing its HTML structure [35]. CSS therefore allows the separation of presentation from content [35].

### **3.1.3. Scripting in HTML**

In the beginning, client interaction was limited to either navigating to amongst nodes or sending information to a server from an HTML page. Any other types of interactions were not possible. Scripting presented a solution to this problem in the fact that scripts allow web authors to add interactivity to their web documents.

Scripting is used to define the behavior of a web page. A client-side script is essentially a program that executes on the machine of the client when the web document loads [36]. These programs may accompany an HTML document or can be directly embedded in the document.

## **3.2. Multimedia Information Technologies**

Dave Marshall in his work, "Introduction to Multimedia" [38], defines Multimedia as follows:

Multimedia is the field concerned with the computer-controlled integration of text, graphics, drawings, still and moving images (Video), animation, audio, and any other media where every type of information can be represented, stored, transmitted and processed digitally.

Multimedia is being utilized as tool for interactive learning in education very frequently these days. In multimedia there are five formats that authors use to design and

deliver their message: written format, graphics format, audio format, video format, and animation.

### **3.2.1. Written Format (Textual Content)**

The basic delivery mode for information is text. We have already discussed that text can be formatted and structured using HTML and presented on browsers. Another multimedia format used frequently for delivery of text is the Portable Document Format (PDF). Document can be designed using standard text editing tools and converted to PDF using conversion tool.

The most popular proprietary textual content delivery system is Microsoft Word which is distributed by Microsoft as a part of Microsoft Office suite of software.

### **3.2.2. Graphic Format**

Graphic multimedia formats make use of pictures to effectively deliver the author's message across to the users. Multimedia graphic formats like Bitmap graphics, Graphics Interchange Format (GIF), and JPEG formats are used frequently for educational as well as general purposes to effectively reach the audience.

### **3.2.3. Audio Format**

Several types of audio content like sound effects, music, and narration can be created using multimedia applications in order to enhance the effectiveness of material being presented.

### **3.2.4. Video Format**

Visual media can provide the added advantage of making the material more visual and in turn more effective. Increasing the effectiveness of learning material is especially vital in the case in educational content delivery.

The most frequently used static video formats are Audio Video Interleaved (AVI), Quick Time Movies (MOV), and Motion Picture Expert Groups (MPEG). Streamed video formats, which can be buffered by the host, viewed and, discarded finally have also gained popularity in the recent times.

### **3.2.5. Animation**

Multimedia animation applications like Adobe Flash Professional and Autodesk Maya are used to improve information delivery and enhance the impact of presented material. The animations created using applications like Adobe Flash are interactive and give the user the freedom to stop the animation, pause it and continue later, etc. Explanation can be added to give descriptions of what is being simulated with the animation.

### **3.3. Delivering Education Using Technology**

Up until now we have discussed how HTML and its associated technologies and Multimedia technologies can enhance the content creation and delivery. There are several approaches that can be used to combine the powers of HTML and multimedia technologies to deliver educational content.

One of the popular approaches is to use HTML for text and also as a carrier for various multimedia formats like graphics, animations, and so on. In this approach HTML documents can be created using either plain text editors or using a tool like Dreamweaver and various multimedia information formats can be embedded to create a hypermedia-based learning environment. Such a learning environment when built on the principles of educational theories can provide educators with a solid platform to efficiently present new and complex concepts to students.

#### **4. DESIGN PHILOSOPHY OF THE PETRI NET TUTORIAL**

This paper focusses on both learning and teaching aspects. Teaching aspect consists of the design and creation of course material and mapping the created material to revised Bloom's taxonomy. Learning aspects include development and inclusion of multimedia material to enhance learning.

In this chapter we discuss the design and development of a Petri net fundamentals tutorial expected to help learners achieve the lower order thinking skills (Remember, Understand, and Apply) of Bloom's taxonomy. An effort was made to accommodate the various learning styles into the tutorial. The design discussion in this chapter also includes discussion on how the Petri net learning material provided caters to learners with different learning styles.

##### **4.1. Integrating the Remember Level in the Tutorial**

The Remember level is the lowest level in the Cognitive Process dimension in Revised Bloom's Taxonomy. The learning outcome of this level is that the learner should be able to provide evidence that they are able to retrieve what they have learnt from long-term memory. Learning items like quizzes, flash cards, and memory games are widely used by teachers to assist learners achieve the cognitive process requirements of this level.

The Knowledge dimension objective of this level in the context of current work is that the learner must first be imparted with the knowledge of terms associated with Petri nets, i.e. the factual knowledge associated with Petri nets. The basic elements of Petri nets need to be defined for the learner to be able to make the transfer of information to long-term memory. Table 7 shows the Taxonomy Table for the Remember level.

Table 7: Taxonomy Table for Remember Level

Knowledge Dimension	Cognitive Dimension		
	Remember	Understand	Apply
Factual Knowledge	<ul style="list-style-type: none"> <li>• Definitions</li> <li>• Recall Quizzes</li> </ul>		
Conceptual Knowledge			
Procedural Knowledge			
Metacognitive Knowledge			

#### 4.1.1. Learning Material Provided for Remember Level

The material provided at the Remember level should be a good starting point for the learner to be able to easily remember the terminology associated with Petri nets. The learning outcome of this level is that the learner has the knowledge of terminology and can retrieve it from long-term memory.

##### 4.1.1.1. Definitions of Basic Elements of a Petri Net

To achieve the first objective we start the tutorial by providing the definitions of key terms associated with Petri nets. The goal is to introduce the learner to the basic elements of Petri nets.

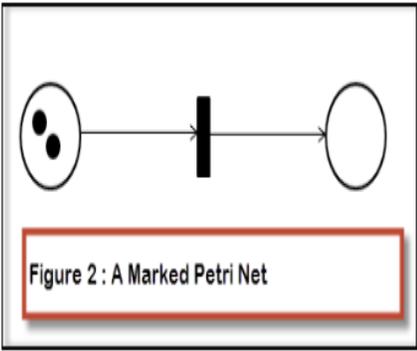
This type of approach wherein the learning of basic terms precedes the learning of complex concepts is highly suited for Sequential learners because Sequential learners

tend to respond well to learning material that progresses in linear steps of increasing complexity.

Definitions provided in the tutorial are both in written format to suit the Verbal learners and in the form of pictures to suit the Visual learners. Figure 6 provides a screen capture taken from the tutorial website that shows the definition of Tokens and Markings

### 1.2. Tokens & Markings

- *Tokens* control the dynamic behavior of a Petri Net.
- Tokens exist in the places of a Petri net, and are represented by small black dots in the circles (places). Any number of tokens may exist in a place at a time.
- *Markings* essentially specify the distribution of tokens in the Petri Net. A Petri Net with a Marking is called a Marked Petri Net. An example of a marked Petri Net is shown in Figure 2.



The diagram shows a Petri net with two places (circles) and one transition (vertical bar). The left place contains two tokens (black dots). The transition is in the center, and the right place is empty. Arrows point from the left place to the transition and from the transition to the right place.

Figure 2 : A Marked Petri Net

Figure 6: Screen Capture that Shows How Key Terms are Defined

#### 4.1.1.2. Quizzes

Two types of quizzes are supplied to assess whether the learners have successfully achieved the objectives of the Remember level of Bloom's taxonomy.

Several Recall Quizzes have been included in the tutorial for learners to assess whether or not they have assimilated the knowledge. These Recall quizzes are basically multiple choice type quizzes and readily provide a feedback to the student stating whether the choice made was correct or incorrect. These Recall quizzes appear in the places in tutorial where new terms are introduced to the learner.

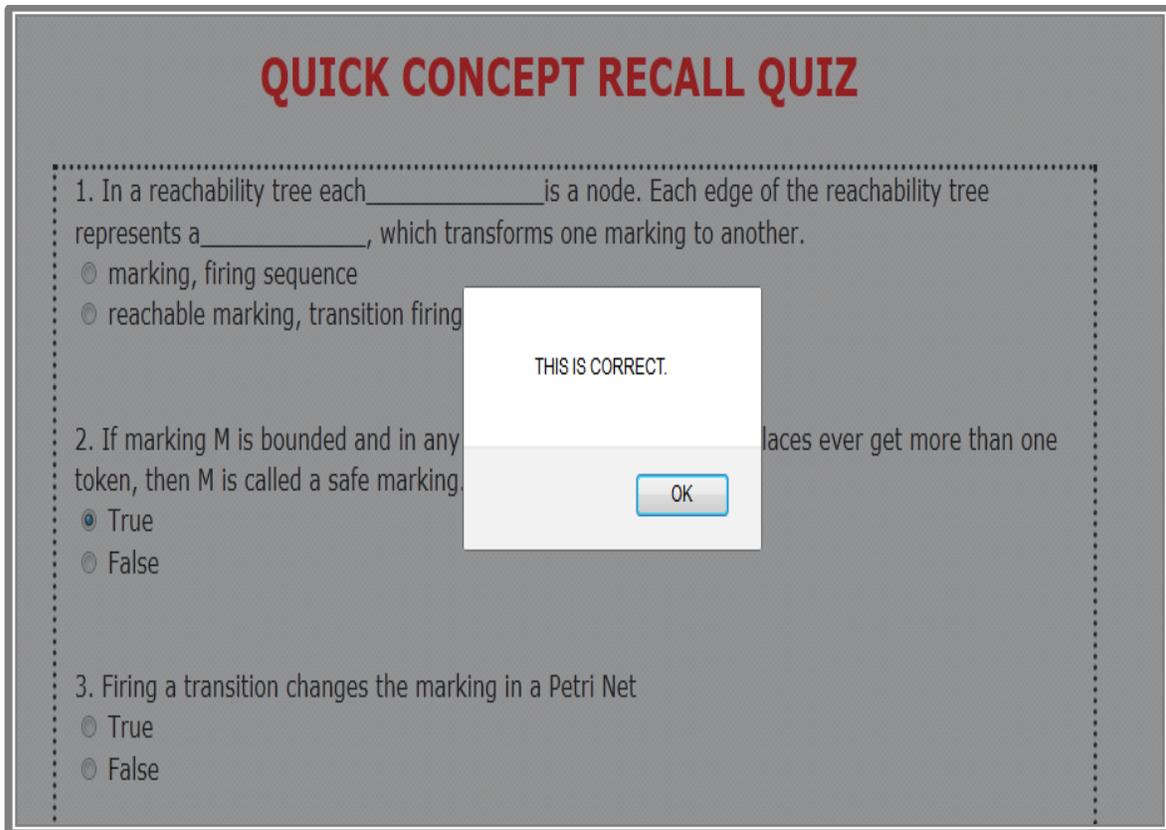


Figure 7: Screen Capture of a Recall Quiz in Action

A scored Knowledge Recap Quiz is provided at the end of the tutorial. The idea behind this quiz is to provide an assessment tool for both learners and teachers to assess how well the learners are able to retrieve the information that they were given in the tutorial.

#### 4.2. Integrating the Understand Level in the Tutorial

The idea behind having Remember level below the Understand level in the hierarchy is to provide a logical progression of increasing complexity while learning a discipline. Once the student has gone through the Remember level, it is assumed that the student has the factual knowledge about Petri nets and is able to retrieve that knowledge from long-term memory.

The Understand level involves the explanation of how the basic elements of Petri nets function together and how Petri net models are formed. The key concepts and theories of Petri nets are explained at this level. Thus, on the Knowledge dimension of the Taxonomy table the Conceptual Knowledge category is chosen. Table 8 shows the Taxonomy table for the Understand level.

Table 8: Taxonomy Table for the Understand Level

Knowledge Dimension	Cognitive Dimension		
	Remember	Understand	Apply
Factual Knowledge			
Conceptual Knowledge		<ul style="list-style-type: none"> <li>Explanation of Key Concepts and Theories</li> </ul>	
Procedural Knowledge			
Metacognitive Knowledge			

#### 4.2.1. Learning Material Provided for Understand Level

The material provided for the Understand level should help the learners in understanding how the basic elements of Petri nets function together to form verifiable models. Care should be taken while designing the material as the order of presentation and simplicity of explanation are very important here and are essential for making learning easier.

Use of multimedia formats like graphics and animations can make learning a more stimulating and interactive process for the learners.

The learning material provided for Understand level includes written and pictorial explanation of concepts, and animations to get a deeper understanding of Petri net principles. The inclusion of pictures and animation is expected to be beneficial for Visual learners.

An effort was made to show how Petri nets can be used for modeling real world scenarios. This aligns with the natural tendencies of Sensing Learners who respond well when the learning material shows that the theories and concepts are strongly connected to the real world.

The use of hypermedia based learning environment aligns with the learning style of Global learners in the fact that a hypermedia based learning medium supports the non-linear mode of learning. We have discussed in an earlier chapter that Global learners tend to absorb information in large jumps and with the hypermedia-based learning material that is being presented in this paper, the learners are allowed to explore and discover the learning material in accordance with their individual needs.

#### **4.2.1.1. Explanation of Principles**

The learning objective here is to impart the conceptual knowledge about how the basic elements of Petri nets are inter related to each other to form larger structures (or models). The major governing principles of Petri net modeling have been explained with the help of written material and visual material. An effort has been made to keep the language of the written material as close to conversational-style language as possible.

This puts the learner at ease and is more effective as a relaxed learner is a better learner.

Figure 8 shows a screen capture of a Petri net principle description from the tutorial.

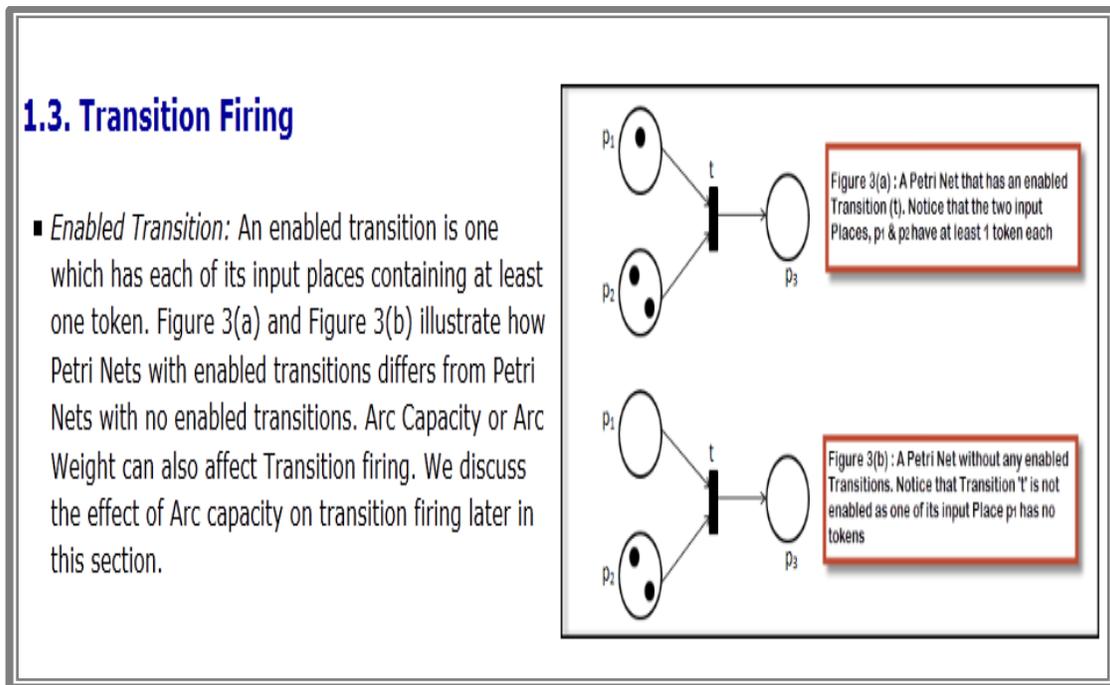


Figure 8: Screen Capture Showing Explanation of a Petri Net Concept

Along with the pictorial explanation of concepts, an animated view of some of the concepts has also been provided. The idea behind using animations in the tutorial is that it gives a more thorough demonstration of process or procedure to help the learner generate an adequate mental model [39]. In static pictures sometimes abstract signaling cues like arrows or highlighted items need to be interpreted by the learner and then integrated with the pictorial information [39]. Animations provide a solution to this problem.

Figure 9 shows an example of screen capture from the tutorial where an animation has been used to present the principle of Transition Firing, which is a process and use of animation can help the learner create a better mental view of the process.

■ *Firing*: When an enabled transition is fired a token is removed from each of its input place and a token is added to the output place. Press the green 'Play' button in the Animation Figure 1 below to see what happens when Transition 't' fires.

Notice how 1 token is removed each from place p1 & place p2, but only 1 token is added to the place p3. This is where the concept of Arc Capacity or Arc Weight comes into picture. We address this concept later in this section.

LEARN HOW TO CREATE THIS PETRI NET ON A PETRI NET DESIGN TOOL ([SNOOPY](#)) IN CHAPTER 8

■  Remember: Transition firing causes system to change its state and it also leads to new marking.

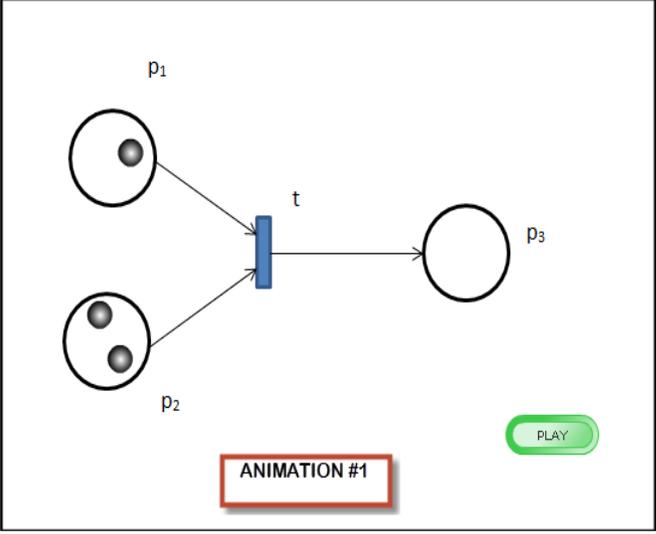


Figure 9: Screen Capture of a Petri Net Principle Description with Animation

#### 4.2.1.2. Interactive Animations for Complex Concepts

Interactive presentation style animations are provided in the tutorial to explain the complex concepts of Petri nets like Marking Concepts, and extended Petri net concepts like Colored Petri nets.

The idea behind the use of interactive animations is that when learners control the pace of animation they are allowed to view the concept as many times as they desire and spend as much time as they want, comprehending specific details of the concepts. This kind of interactivity is expected to improve the retention of concepts. An example is shown in Figure 10.

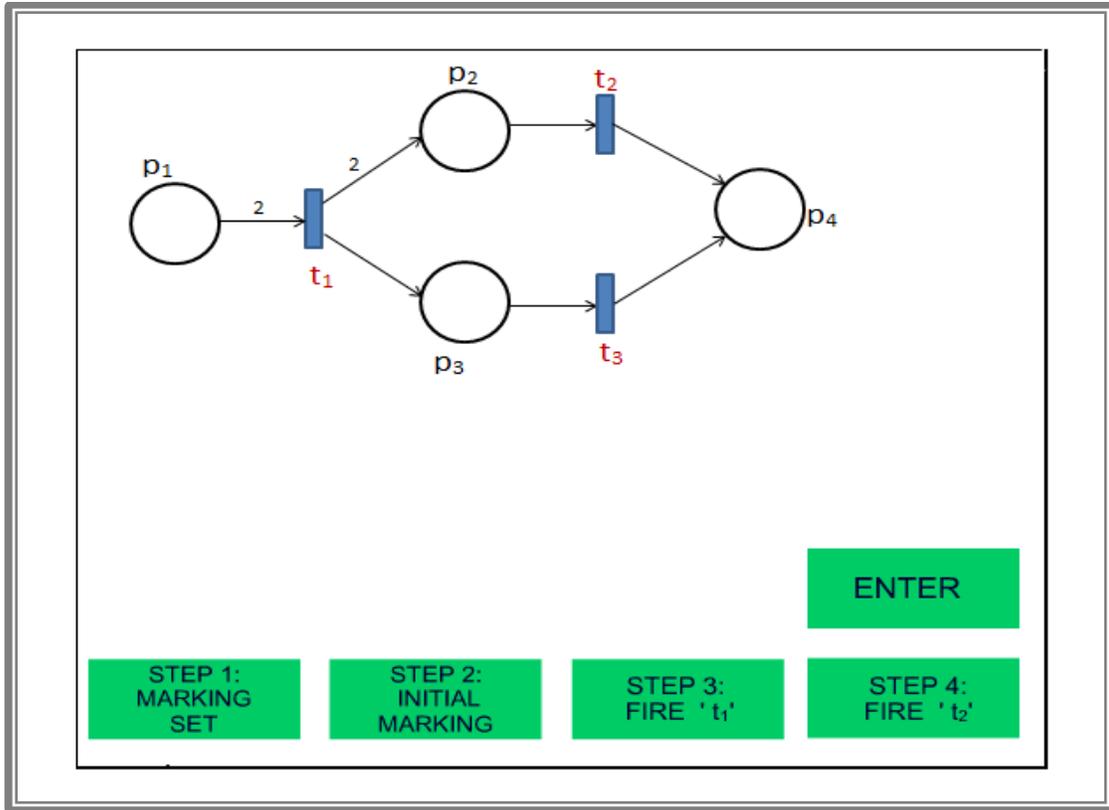


Figure 10: Interactive Presentation-Style Explanation of Concepts

In the example shown in Figure 10 the user is given complete freedom of choosing whether the learner wants to see the complete animation all at once or step by step. The learner can press the 'ENTER' button to see the complete animation or see the step by step process (of Marking Changes in the case of Figure 10) by pressing the 'STEP' buttons.

### 4.3. Integrating the Apply Level in the Tutorial

Understand level forms the basis for the Apply level. The learner is expected to apply the knowledge of concepts gained in Understand level in a given situation. In the context of Petri nets, the learner is expected to create Petri net models using the conceptual knowledge they have gained from the explanations of concepts provided.

The learning outcome of the Apply level is that the students should be able to provide evidence that they are able to implement the Petri net principles to specific situations. This can be achieved by providing the students with the knowledge of a Petri net tool, which acts as platform for students to execute Petri net modeling tasks assigned by the teacher. Table 9 shows the Taxonomy table for the Apply level.

Table 9: Taxonomy Table for the Apply Level

Knowledge Dimension	Cognitive Dimension		
	Remember	Understand	Apply
Factual Knowledge			
Conceptual Knowledge			<ul style="list-style-type: none"> <li>• Petri net Tool</li> <li>• Assigned Modeling Tasks</li> </ul>
Procedural Knowledge			
Metacognitive Knowledge			

#### 4.3.1. Learning Material Provided for Apply Level

In order to achieve the learning outcomes of the Apply level, a Petri net design tool is introduced to the learners and a set of design tasks are provided for the learners to implement using the tool.

The Apply level of the revised Bloom's taxonomy provides an opportunity to integrate the learning style of Active learners into the learning material. The Active learners tend to respond well when they do something active with the information, like apply the material to solve problems or in the context of our tutorial, create Petri net models.

#### **4.3.1.1. Snoopy: A Petri Net Design and Animation Tool**

We introduce Snoopy, a Petri net design and animation tool, to the learner for helping the learner in achieving the Cognitive Process established for Apply level in the revised Bloom's Taxonomy.

##### **4.3.1.1.1. Overview of Snoopy**

Snoopy is a software tool developed to create and animate hierarchical graphs, among others Petri nets. The tool has been developed and constantly extended at the University of Technology in Cottbus, Dep. of Computer Science, "Data Structures and Software Dependability" [40]. The development of Snoopy began in 1997 as a student's project and the tool is constantly under development and maintenance. The programming language used to develop the tool is C++, with use of the Standard Template Library [41]. The tool runs on Windows, Mac OS X, and Linux operating systems and is available free of charge [40].

The tool comes along with several inbuilt or pre-fabricated graph classes, especially various classes of Petri nets [41]. Some examples of pre-fabricated Petri net classes that have been realized in Snoopy are Petri Nets, Extended Petri nets, Timed Petri nets, and Colored Petri nets.

The graph class Petri Net allows creation of Petri nets based on the principles of Place/Transition Petri nets, which are the primary focus of our tutorial. One of the advantages that Snoopy provides lies in its token game animation feature that provides a firsthand insight into the dynamic behavior of Petri net models. The other reason behind choosing Snoopy as a part of our tutorial is that the tool has an elegant and easy-to-use user interface that shortens the learning curve for new users.

#### **4.3.1.1.2. Tool Demonstration Provided in the Tutorial**

A comprehensive tool demonstration is provided in the tutorial for users to get a head start before they begin implementing their knowledge of Petri nets to create Petri net models on the tool. The follow-along demonstration provides step by step creation of a sample Petri net model.

The demonstration contains written material to explain the step and also a picture of that step being carried out on Snoopy. Speech (or dialog) balloons have been used in the pictures to give the learner a sense of being a part of the demonstration. Figure 11 provides a screen capture that shows one of the steps in the tool demonstration.

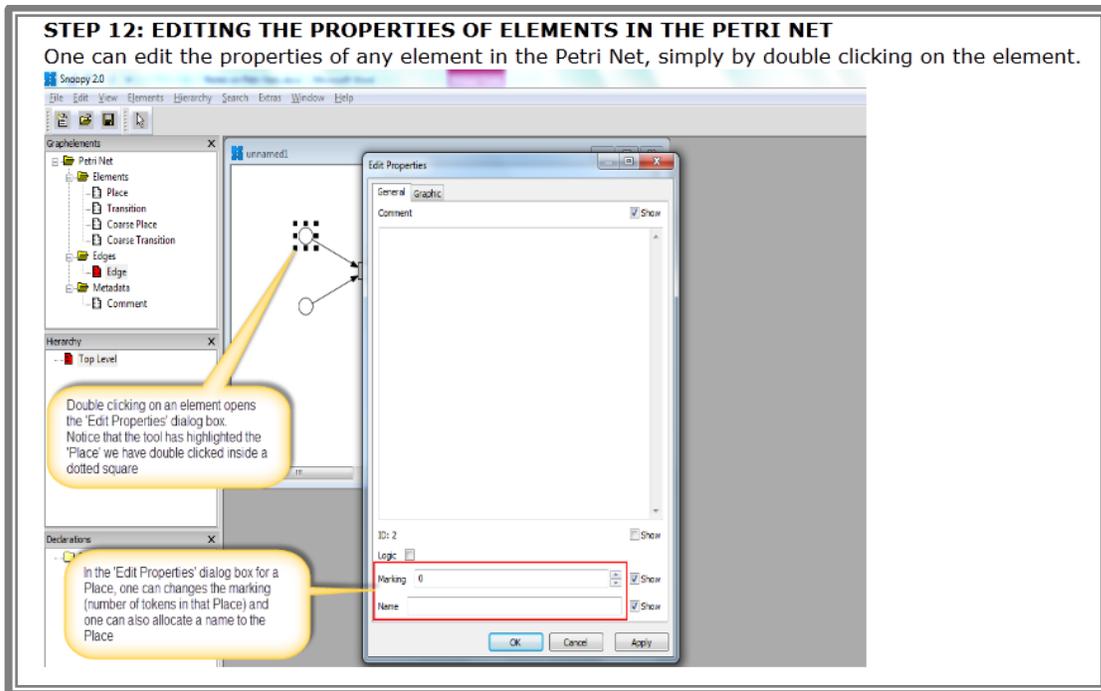


Figure 11: Screen Capture that Shows One of the Steps in the Tool Demonstration

#### 4.3.1.2. Assignments

The learning outcome of the Apply level is that the learners should be able to provide evidence that they are able to use the conceptual knowledge to carry out or implement tasks related to the discipline. To achieve this, a set of exercises have been provided that can help assess the learners' understanding of the concepts.

The exercises can be given as 'Hand-in' assignments by educators if they use the tutorial as a part of their curriculum.

The exercises are designed in such a manner that an assessment can be made whether the learners can implement their knowledge of Petri nets when faced with a particular situation pertinent to the information that they have been provided in the tutorial. Figure 12 shows a screen capture showing one of the exercises given to the learners.

**"HAND-IN" ASSIGNMENT BUILDING BLOCK 1**

**EXERCISE 1**  
 For this exercise, see the Petri Net shown in figure titled 'Exercise 1'.

**PART A**  
 For the Petri Net shown,  
 (i) Compute the Initial-marking ( $M_0$ )  
 (ii) Notice that the sequence of first two transitions-firings is in the following order:  
 $t_1 \rightarrow t_2$   
 Compute the resultant markings after these two transition firings.

**PART B**  
 Now, create the net shown in the figure on [Snoopy](#) and run the animation to evaluate the following behavioral properties for this net:  
 - Boundedness  
 - Liveness  
 Please provide comments to validate your answer.  
 Please provide a screen shot of your computer (*Ctrl+Printscreen*) to illustrate the Petri Net that you have created on Snoopy.

**Exercise 1**

Figure 12: Screen Capture Showing an Exercise given to the Learners

#### 4.4. Summary

Table 10 provides a Taxonomy table that summarizes the learning material that we have provided at each level of the Cognitive dimension of the Revised Bloom's Taxonomy. Table 10 also provides a summary of the various Learning styles that have been incorporated in the Petri Net tutorial. The learning material provided in the tutorial covers the Factual Knowledge and Conceptual Knowledge categories of the Knowledge dimension of the Revised Bloom's Taxonomy. Hence, we have not shown the Procedural Knowledge category and the Metacognitive Knowledge category in the summary table.

Table 10: Summary of Learning Material Provided and Learning Styles Covered

Knowledge Dimension	Cognitive Dimension		
	Remember	Understand	Apply
Factual Knowledge	<p><b>Learning Material Provided</b></p> <ul style="list-style-type: none"> <li>• Definitions</li> <li>• Recall Quizzes</li> </ul> <p>The Learning material provided incorporates Verbal, Visual, and Sequential learning styles</p>		
Conceptual Knowledge		<p><b>Learning Material Provided:</b></p> <ul style="list-style-type: none"> <li>• Explanation of Key Concepts and Theories</li> </ul> <p>The Learning material provided incorporates Sensing, Global, Verbal, and Visual learning styles</p>	<p><b>Learning Material Provided</b></p> <ul style="list-style-type: none"> <li>• Petri net Tool</li> <li>• Assigned Modeling Tasks</li> </ul> <p>The Learning material provided incorporates the Active learning style</p>

## **5. CONCLUSION, LIMITATIONS, AND RECOMMENDATIONS**

### **5.1. Conclusion**

A close examination of educational theories shows that use of a sound educational theory provides the framework for design of a structured curriculum. A proven educational theory provides specific objectives that educators can use to create learning outcomes during the curriculum.

Individuals differ in their learning styles and tend to respond better to certain information formats. Hypermedia offers a mechanism for serving learning material that caters to various learning styles.

A close examination of various technologies that can be used to create and deliver educational content shows that HTML provides a medium for presenting text as well as for carrying other multimedia formats, making HTML the ideal platform for developing a hypermedia-based learning environment. The fact that objects can be embedded in HTML simplifies the content creation process.

Educational material that helps students to learn the fundamentals of Petri net modeling were developed by applying the principles of Revised Bloom's taxonomy. It was shown that the Knowledge and Cognitive Process dimensions of revised Bloom's taxonomy provide an easy-to-adapt framework and can be used as a guide to create the educational material for Petri net modeling fundamentals.

A genuine effort was made to integrate the various learning styles into the tutorial in order to engage all type of learners.

## **5.2. Limitations**

The tutorial presented in the paper has not been tested with the learners. An assessment needs to be made by conducting an empirical study to support the benefits of developing educational material for Petri nets using revised Bloom's Taxonomy.

For educators, updating the multimedia content like animations used in the tutorial to tailor a learning environment of their choice would require a lot of effort and cost.

The educational content has been presented as a web-based tutorial that contains animation content developed using Adobe Flash. The tutorial would not be supported by certain devices that do not have the necessary software required to play animations made using Adobe Flash.

## **5.3. Recommendations**

This paper can be further extended by adding material on advanced Petri net classes like Timed Petri nets and Continuous Petri nets.

Along with the learners, this tutorial was also developed for educators to use as an aid in their modeling classroom. Addition of explanatory videos by educators to the content can help in making this tutorial a complete self-study tutorial for learners [42].

## REFERENCES

- [1] Mei, Chao. Zhang, Xiaoyang. Zhao, Wenfei. Periyasamy, Kasi. Headington, Mark. A Tool for Teaching Petri Nets, (2011).
- [2] Othman, Mohd Fairuz Iskandar. Bahaman, Nazrulazhar. Muslim, Zulkiflee. Abdollah, Faizal. New Curriculum Approach in Teaching Network Security Subjects for ICT Courses in Malaysia, (2008).
- [3] Thornton, David Willson. Using Distributed Technology for Teaching Distributed Systems, (1999).
- [4] Bonet, Pere. Llado, Catalina Matas. Puigjaner, Ramon. Knottenbelt, William. PIPE v2.5: a Petri Net Tool for Performance Modeling, (2007).
- [5] Murata, Tadao. Petri Nets: Properties, Analysis, and Applications, (1989).
- [6] Zurawski, Richard. Zhou, MengChu. Petri Nets and Industrial Applications: A Tutorial, (1994).
- [7] Desel, Jorg. Kindler, Ekkart. Petri nets and Components – Extending the DAWN Approach, (2001).
- [8] Desel, Jorg. Juhas, Gabriel. What Is a Petri Net? Informal Answers for the Informed Reader, (2001).
- [9] He, Xudong. Murata, Tadao. High-Level Petri Nets—Extensions, Analysis, and Applications, (2005).
- [10] Mikolajczak, Boleslaw. Petri Nets Across Graduate Computer Science Curriculum, (2008).
- [11] Christensen, Soren. Mortensen, Kjeld Hoyer. Teaching Colored Petri Nets - A Gentle Introduction to Formal Methods in a Distributed Systems Course, (1997).

- [12] O'Neill, Geraldine. Murphy, Feargal. Guide to taxonomies of learning, (2010).
- [13] Brewer, James. Burke, Michael. Fenty, Linda. Patton, Dan. Post, Jerry. Simpson, Henry. Learning Methodology Reference Document, (1999).
- [14] Hung, David. Theories of Learning and Computer-Mediated Instructional Technologies, (2001).
- [15] Dillon, Brian J. Courseware on the Fly, (1998).
- [16] [www.infed.org/biblio/learning-cognitive](http://www.infed.org/biblio/learning-cognitive), retrieved on December 26th, 2012.
- [17] Ertmer, Peggy A. Newby, Timothy J. Behaviorism, Cognitivism, Constructivism: Comparing Critical Features from an Instructional Design Perspective, (2008).
- [18] <http://www.macalester.edu/academics/geology/wirth/learning.pdf>, retrieved on December 26th, 2012.
- [19] Mohtashami, Mojgan. Scher, Julian M. Application of Bloom's Cognitive Domain Taxonomy to Database Design, (2000).
- [20] Bloom, Benjamin S. Taxonomy of Educational Objectives, (1956).
- [21] Krathwohl, David R. A Revision of Bloom's Taxonomy: An Overview, (2002).
- [22] <http://www.naperville203.org/departments/curriculum/AcademicallyTalented.asp>, retrieved on December 26th, 2012.
- [23] Amer, Aly. Reflections on Bloom's Revised Taxonomy, (2006).
- [24] <http://www.roe11.k12.il.us/GES%20Stuff/Day%204/Process/Blooms/Mary%20Forehand%20discussion-Bloom%27s%20Taxonomy.pdf>, retrieved on December 26th, 2012.
- [25] [http://www.personal.psu.edu/bxb11/Objectives/GoalsAndObjectives\\_print.html](http://www.personal.psu.edu/bxb11/Objectives/GoalsAndObjectives_print.html), retrieved on December 26th, 2012.

- [26] <http://www.celt.iastate.edu/pdfs-docs/teaching/RevisedBloomsHandout.pdf> ,  
retrieved on December 27th, 2012.
- [27] Felder, Richard M. Learning and Teaching Styles in Foreign and Second Language Education, (1995).
- [28] Graf, Sabine. Viola, Silvia Rita. Leo, Tommaso. Kinshuk. In-Depth Analysis of the Felder-Silverman Learning Style Dimensions, (2007).
- [29] Zywno, Malgorzata S. Waalen, Judith K. The Effect of Individual Learning Styles on Student Outcomes in Technology-enabled Education, (2002).
- [30] <http://vis.lbl.gov/~romano/Ed198-SEM/LearningStyles.pdf>, retrieved on December 27th, 2012.
- [31] Zywno, Malgorzata S. Waalen, Judith K. The Effect of Hypermedia Instruction on Achievement and Attitudes of Students with Different Learning Styles, (2001).
- [32] <http://www.w3.org/TR/2010/WD-html5-20100624/>, retrieved on December 29th, 2012.
- [33] Balasubramanian, V. State of the Art Review on Hypermedia Issues and Applications, (1994).
- [34] <http://www.ics.uci.edu/~andre/informatics223s2007/conklin.pdf>, retrieved on December 29th, 2012.
- [35] <http://www.edb.utexas.edu/minliu/multimedia/CSS.pdf>, retrieved on December 29th, 2012.
- [36] <http://www.w3.org/TR/html4/interact/scripts.html>, retrieved on December 29th, 2012.

- [37] <http://people.opera.com/howcome/2005/ala/sample.pdf> , retrieved on December 29th, 2012.
- [38] <http://www.qiau.ac.ir/Services/elearning/dehghan/1.pdf>, retrieved on December 30th, 2012.
- [39] Hoffer, Tim N. Leutner, Detlev. Instructional animation versus static pictures: A meta-analysis, (2007).
- [40] <http://www-dssz.informatik.tu-cottbus.de/DSSZ/Software/Snoopy#manual>, retrieved on January 1st, 2013.
- [41] Heiner, Monika. Richter, Ronny. Schwarick, Martin. Snoopy - A Tool to Design and Animate/Simulate Graph-Based Formalisms, (2008).
- [42] Tan, Heidi Yeen-Ju. Kwok, Joyce Wai-Jing. Neo, Mai. Neo, Tse-Kian. Enhancing Student Learning Using Multimedia and Web Technologies: Students' Perceptions of an Authentic Learning Experience in a Malaysian Classroom, (2010).