Abstract: Trust information is needed for both learners and teachers in virtual university system. In this paper, we presented an advanced Petri Net model to manage the workflow of a web-based multiple participants in virtual University. The presented approach not only can conspicuously help the developer to comprehend the interaction relationship between the client-server virtual environments but also to easily construct a shared and trusted virtual world. We proposed a e-learning system based on the scaffolding theory. Learning activities of students and teachers are supervised and understood by each others through an intelligent control system. Students and teachers have their individual activities and reports that were stored in database. Their behaviors including the student’s self regulations and the teacher's/virtual campus regulations are performed and built with trust development. Problems of providing the multi-user interaction on the Web and the solutions proposed by the Petri Net model are fully elaborated here. This paper can be used as a basic/fundamental research framework and tools to study and understand the characteristics of e-learning and to explore its optimal education application.

Key-Words: E-Learning, Virtual University, Scaffolding Theory, Trust Development, Activity Understanding

1 Introduction
In line with the growing popularity of distance education, we developed a series of distance learning software systems [1, 2, 3, 4] based on Internet and Web browsers. These systems were used in our university among different departments. The goal of the shared Web system is to support interaction among clients over the existent WWW environment. By the seamless integration of the network-based virtual reality system into the WWW architecture, the shared Web system provides a boundless way to retrieve information over the web environment while the users are interacting with each other[5]. We aim to develop a behavior supervision machine, based on Petri Net, to properly guide students while they are in the campus. The main goal of this paper is to model the workflow of an integrated web-based multi-user environment so that the researcher can easily design such a system on the Web. Hence, in the following subsections, the definition of the integration is introduced first and followed by the proposed Petri Net model to monitor the user’s activities.

In virtual university system, the size of each of these units of learning is referred to as its level of granularity [6, 7]. A complete virtual university system solution is illustrated in Figure 1[6]. The levels of learning products are arranged vertically in rows. The processes are arranged horizontally in columns. Everyone in virtual university system needs tools: the teacher/producer creating the content, the host hosting it, and the learner accessing it. In addition, tools are required for each level of learning product. At the top is the curriculum. The curriculum is a collection of learning product, for example, a academic program including related courses in a subject area. Courses are composed of several lessons; each organized to accomplish one of the major objectives of the course as a whole. At lower level are the individual web pages content, each designed to accomplish a single objective. At the bottom level are media components. These are the
individual images, block of text, animation sequences, and video passages that contribute to the web page.

Virtual university system comprises the integration of the classroom structure to the Web. Such systems combine learning management capabilities with collaboration features to provide online analogs for common classroom learning events, e.g. lectures, discussions, and grade books (course management system). Learning management system manages the whole development and administration of learning. Another option is the learning content management system, which manages the development of complex courses or the learning object for the needs if individual learners by assembling reusable units of education. Audio, video, animation, and other media may require specific authoring and editing tool. These media may also require media server to ensure that they play efficiently over the network. The content converter is also needs to make existing media content available online. Project involving collaboration among distant learners may rely on collaboration tools. Collaboration tools usually consist of a server component that transport messages among users.

While a student navigates through the virtual campus, a few items will be recorded:

- The international states visited in the Petri Net
- The type of communication tools used, including the frequency and duration
- The SCO (course units) visited, including the frequency and duration
- The values of state variables
- The declarative rule fired by the action, which includes
- Completeness of state transitions
- The Campus Alert types of agent triggers
- The Student Violation types of agent triggers
- The control buttons of virtual campus navigation pushed

In addition, chat room logs and question-answer logs were recorded. A statistic summary will be generated after each session of navigation of each student (for an optional review by the student). This information can be used to find out what are the popular locations (such as which class and which discussion room), which communication channels are popular, type of triggers fired by the system, and others.

In support of the above learning types, we integrate a set of tools into a web-based system. We carefully look at user requirements from the perspective of educational professionals. We realize that, it is possible to design an integrated learning environment to support the application of the scaffolding theory [7, 8]. Scaffolding, proposed by L. S. Vygotsky, was viewed as social constructivism. The theory suggests that students take the leading role in the learning process. Instructors provide necessary materials and support. And, students construct their own understanding and take the major responsibility. Between the real level of development and the potential level of development, there exists a zone of proximal development. This zone can be regarded as an area where scaffolds are needed to promote learning. Scaffolds to be provided include vertical and horizontal levels as a temporary support in the zone of proximal development. Scaffolding is essential for cognitive development. It also plays an important role in the process of social negotiation. There are three properties of the scaffold:

1. The scaffold is a temporary support for the learner to ensure the success of a learning activity.
2. The scaffold is extensible (i.e., to be used in other knowledge domains) and can be offered through interactions between the learner and the learning environment.
3. The scaffold should be removed in time after the learner is able to accomplish the learning task independently.

The scaffolding theory indicates three key concepts. Firstly, in the zone of proximal development, the relationship between the scaffolds providers and the receivers are reciprocal. That means that the instructor and learners should negotiate a mutual beneficial interactive process. Secondly, the responsibility is transferred from the instructor to the learner during the learning process. Depending on the learning performance, the instructor gradually gives more control of the learning activities to the learner for the attainment of the ultimate goal of self-regulation. Finally, interaction is essential to facilitate learners to organize their own knowledge. Hence the use of language or discourse is crucial to promote reflection and higher-order thinking.

As shown in Figure 2, the Scaffolding-by-Design Model [8, 9, 10, 11] describes a process of mainly social interactions, as state in vygotsky’s work. Further it builds on aspects of cognitive apprenticeship, which is chosen as a pedagogy to support student learning. As a model for learner support, one of the aims of this model is that the learner learns to self-regulate learning. Some suggestion for learning to self-regulate were found that are applied in this model. One of the means to learn to self-regulate can be the application of Scaffolding. The two main components that define Scaffolding, support of the learner and fading, are
emphasized in the Scaffolding-by-Design Model. In this paper, we based on this model then propose an activities supervision and behavior understanding model for Virtual University System. Our approaches can let the learner, instructor period to check reports and manually adapts their course/curriculum by re-configure the weight, progress and tests.

In this paper, we outline the philosophical perspective and social constructivism that frame our understanding of e-learning. The section 2 outlines the activity supervision and behavior understanding models. The implementation consideration of the virtual university system is discussed in section 3. Finally, we will make a brief conclusion in section 4.

2 Building Trust Development with Advanced Petri Net Model

Before we begin to introduce the Petri Net model for the multi-user collaboration on the Web, the basic concept of the Petri Net is given as follows. The Petri Net was originally proposed by C. A. Petri [12] which attempts to develop a formal methodology to describe and analyze a system behavior. The Petri Net model [13, 14, 15, 16, 17] is a graphical and mathematical modeling tool which is especially useful to capture the synchronization characteristic among modules of a system. With the help of the neted representation by the Petri Net, the researcher can easily discover the potential problem of a running system and adjust its design to maintain the validity of this system. Petri Net and workflow both support graphics representation, nesting structure, verification, and simulation. Petri Net can also be evaluated and analyzed by a simulation tool. A Petri Net model can be formally denoted as a 5-tuple, PN = (P, T, F, Mo) where:

- **P** = \{P₁, P₂, ..., Pₘ\} is a finite set of places.
- **T** = \{T₁, T₂, ..., Tₙ\} is a finite set of transitions. Most importantly, P and T must satisfy the properties of P \[\not\equiv\] T = ☐ and P \[\not\equiv\] T \[\not\equiv\] ☐. That is, at least one of these two sets P and T must be nonempty.
- F \[\subseteq\] (P \[\not\equiv\] T) \[\not\equiv\] (T \[\not\equiv\] P) is a set of arcs (flow relation) that network places and transitions. That is, (P \[\not\equiv\] T) represents the set of arcs that flow from places to transitions whereas (T \[\not\equiv\] P) is the set of arcs flowing in opposite directions.
- **Mo**: P \[\not\equiv\] \{Mo₀, M₁, M₂, ..., Mₘ\} is the set of initial marking of each place. For the definition of the Petri Net model, Mᵢ represents the token number on place Pᵢ at time i and a token can be a resource of a system or control of a program.

According to the definition of the Petri Net, The generic components of a Petri Net include a finite set of places and a finite set of transitions. A Petri Net is a finite bipartite graph that places are netted with transitions, which in turn are connected to output places. The distribution of tokens over places is called a marking of the net. A transition may enable or fire when each of its input places contains at least one token. The firing of a transition results in removing tokens from their input places and adding to output places via transition. A marking represents the state of a system, which is removed from its place when a transition fired and a new marking is then generated to the output places of this transition.

We define learning behavior based on the characteristics of the Petri net. As a graphical tool of Petri net, the followings are basic properties of a Petri net and the description of learning objects:

**Definition 2.1**: A learning behavior Petri net is a 8-tuple, PN = (P, T, A, K, Sw, Dt, F, ID) where:

- **P** = \{P₁, P₂, ..., Pₘ\} is a finite set of places,
- **T** = \{T₁, T₂, ..., Tₙ\} is a finite set and a sequence of transitions,
- Tₙ \[\rightarrow\] Tₙ₊₁ \[\rightarrow\] Tₙ₊₂ \[\rightarrow\] ... is a sequence of transitions,
- **A** \[\subseteq\] (P \[\times\] T) \[\cup\] (T \[\times\] P) is a set of arcs,
- **K** = \{α, β, ..., ζ\} ∈ String is a set of Keyword,
- **Sw** = \{0, 1, 2, ...\} is a set of significance weight within learning objects,
- **Dt** : P \[\rightarrow\] \{0, 1, 2, ...\} is the duration of time tags,
- **Fs** : P \[\rightarrow\] \{0, 1, 2, ...\} is the frequency of the learning objects to be stayed,
- **ID** : P \[\rightarrow\] \{0, 1, 2, ...\} is the identifier of a learning object,
- **P** \[\cap\] T = ☐ and P \[\cup\] T \[\neq\] ☐.

The generic components of Petri net include a finite set of places and a finite set of transitions. Petri net is a finite bipartite graph. Its places are linked with transitions in turn are connected to the output places. For a given place, there are input and output transitions defined.

In [18], they proposed swift trust for virtual learning communities. Their analysis showed online faculty role changed in cognitive, affective, and managerial activities. In distributing environment, content awareness is also need to trust. The [19, 20]

![Figure 2: The Scaffolding-by-Design Model](image-url)
studied a formal approach and revised a theory of trust, that contained techniques for modeling trust changes and theory changes, a method for computing the new trust state from the old one and its change, and a method to get the theory change corresponding to a given trust change. They addressed the trust is very essential to source and high quality interactions on the semantic web. FuzzyTrust, EigenTrust [21] algorithm computes a global trust/reputation value in peer-to-peer network.

The trust weigh of each path is calculated using following definition.

**Definition 2.1.1:**

\[ T(t_i \rightarrow t_j)w = \sum_{i=1}^{m} Tiw \cdot Si \]  
(1)

Where \( Si \) is the local trust confidence score of user’s rated from transition \( T_i \) by \( T_{i+1} \), range= \([0, 1]\).

The average trust rate is calculated as:

\[ \text{avg. } T(t_i \rightarrow t_j)w = \frac{\sum_{i=1}^{m} Tiw \cdot Si}{N} \]  
(2)

Where \( N \) denotes the number of edges in path between \( T_i \) to \( T_j \).

By retrieval we mean the virtual university system can satisfy the storage and retrieval requirements of a very large number of atomic learning objects (by learning tasks) where a learning progress can have a storage requirement of several hundred gigabytes. Therefore, this is very difficult to query in virtual university system by using content-based image/video retrieval techniques. In our approach, we defined the attributes “keyword” to achieve user demand. Keyword attributed can be extracted from the virtual university place \( Pi \) with \( Sw \).

In abstraction operation, we defined the attributes “significance weight” to achieve user demand. Significance weight attributed can be remarked by the learning objectives or teacher’s specified of the learning objects in her teaching materials. Abstractions are expressed in terms of high-level declarative constructs that allow both learner and teacher to match somehow “assessing qualify” what they want to abstract from the virtual university system. The abstraction operation definition is defined as follow.

**Definition 2.3:** The abstracting operation, \( \alpha \cdot Sw \) (\( PN\{P_1, P_2, ..., P_n\} \)) compares all the virtual university place \( Pi \) with \( Sw \).

Let the set of Significance weight \( Sw_1 \in P_1, Sw_2 \in P_2, ..., Sw_n \in P_n \) where \( Pi \in PN \).

\[ \alpha \cdot Sw (PN\{Sw_1, Sw_2, ..., Sw_n\}) = PN\{Sw_1, Sw_2, ..., Sw_n\} \rightarrow \alpha \cdot Sw (PN\{P_1, P_2, ..., P_n\}) = PN\{P_1, P_2, ..., P_m\} \]

where the \( Sw \) of \( P_i \) in \( PN\{P_1, P_2, ..., P_m\} \) is equal to or greater than \( Sw \).

In assessing participation operation, there are two additional time factors in our model: duration time and frequency time. Firstly, we defined the attributes “duration” to achieve user demand. The purpose of the duration factor is one the critical characteristic in learning environment. It records how long with the place (learning object) to be stayed and the total time by the learner took.

**Definition 2.4.a:** The duration assessing participation operation, \( \gamma_c \) (\( PN\{P_i, P_j, ..., P_n\} \) sums all the virtual university place \( Pi \) with specific learner had been visited \((Lx)\).

Let the set of duration time \( Dt_1 \in \gamma(P \in Lx), Dt_2 \in \gamma(P \in Lx), ..., Dt_n \in \gamma(P \in Lx) \), where \( P_i \in PN \).

Process:

1. FOR i=1 to i<=n DO
2. IF (Pi \( \in Lx \)) THEN Dt=Dt+Di END IF
3. Return Dt
4. End FOR
5. End Process

**Secondarily,** we defined the attributes “frequency” to achieve “number-of-posting” as indicator for assessing participation operation. The purpose of the frequency is the other critical characteristic in learning environment. It records how many times
with the place (learning object) to be stayed. The
remained processes are same as the duration
assessing participation operation.

**Definition 3.4.b**: The frequency assessing
participation operation
Let the set of frequency $F_{s_1} \in (\forall (P_1 \exists Lx))$, $F_{s_2} \in (\forall (P_2 \exists Lx))$, $\ldots$, $F_{s_n} \in (\forall (P_n \exists Lx))$, where $P_i \in PN$.

Process:

\[
\text{FOR } i=1 \text{ to } i=n \text{ DO } \\
\text{IF } (P_i \exists Lx) \text{ THEN } \\
\quad F_s = F_s + F_{s_i} \\
\text{END IF} \\
\text{Return } F_s \\
\text{End FOR} \\
\text{End Process}
\]

\[\gamma_c (PN\{ F_{s_1}, F_{s_2}, \ldots, F_{s_n}\}) = PN\{ F'_{s_1}, F'_{s_2}, \ldots, F'_{s_m}\} \rightarrow \gamma_c (PN\{ P_1, P_2, \ldots, P_m\} \exists Lx \rightarrow \Sigma (F'_{s_1}, F'_{s_2}, \ldots, F'_{s_m}) \text{, where the } P'_{i} \text{ in } PN\{ P_1, P_2, \ldots, P_m\} \exists Lx .
\]

3. To frame the Virtual University

We used The Petri Net model to establish the
common activities in Virtual University [19]. It
includes the following five stages:

**The Registration stage**: this stage is the first step to
apply for admission to a school. For the web-based
virtual university, the user should be able to log into
the virtual university system and then follow the
registration subsystem guidance.

**The Curriculum stage**: this stage is the selecting
courses step for learner. The curriculum subsystem
should provide and record the user chooses. The
Virtual University System may provide the courses that
contain on-line courses and off-line courses.

**The Authoring stage**: this stage is the course design
step for the teacher. The authoring subsystem should
provide the course creating and editing function
module.

**The Examination stage**: this stage is the one of the
important evaluation/examination function for the
learner or education training. The examination
subsystem should provide the various examination
styles, such as questionnaire, question-and-answer
drill or the collaboration examination.

**The Assessment stage**: this stage is important index
for learner’s learning achievements. The assessment
subsystem keeps track two learner’s learning records:
curriculum and examination records. Curriculum
records contain the learning activities and workflows.
Learning activities could represent the histories and
behaviors that could be understood some certain
extent of the learning acquisition.

The Petri Net model of these five stages are then
elaborated as follows.

3.1 Registration Stage

In this stage, the client site accesses the HTML or 3D
VRML files from the server site. As shown in Figure
3, user uses the web browser to access the main page
of the Virtual University System, Transition $T_{n_1}$, to
load the login page. When the login page is replied
from the server, user should input the personal
identification information into the desired fields
respectively (Transition $T_{n_2}$).

After finished the applying for admission
confirmation procedures (Transition $T_{n_3}$), learner
could check the registration demands (e.g. Academic
Background, payment voucher) that were filled the
bill or not. After admission demands confirmation
step (Transition $T_{n_4}$) were done by the applicant, they
could modify the personal information (Transition
$T_{n_5}$) or change the login password. After the above
registration procedures, server will auto apply the
re-login page (Transition $T_{n_6}$), and then the user can
be granted the legal authorization (Transition
$T_{n_7}$).

![Figure 3: The Petri model for registration stage](image)

3.2 The Curriculum stage (for Student)

The curriculum subsystem should provide and record
the user chooses (the curriculum and courses levels).
This subsystem is important to keep the core function
of Learning Management System (LMS) and the
Learning Content Management System (LCMS). The
Virtual University System may provide the courses
that contain on-line courses, off-line courses, as well
as collaborative events and online meeting.

First of all, the learner login with granted
authorization (Transition $T_{c_1}$) is illustrated in Figure
4. The curriculum subsystem presents a menu and
catalog of courses (Transition $T_{c2}$ for selecting the curriculum, Transition $T_{c3}$ for selecting the courses). Learners can see a list of courses in which they are enrolled. Some suggested courses are based on a learner’s profiles; some analysis a learner’s progress at the level of individual objectives or the instructor manually adapts content to individual learners (Transition $T_{c4}$ for selecting the demanded tools and checking the curriculum certifications is sufficient or not). After finished and passed the above procedures, the learner’s curriculum activities records and degrees certification could be confirmed (Transition $T_{c5}$).

Figure 4: The Petri Net model for curriculum stage

$T_{c1}$: Login with Granted Authorization  
$T_{c2}$: Select Curriculum Subsystem  
$T_{c3}$: Starting a Select with Curriculum Subsystem  
$T_{c4}$: Tools Select Subsystem (Communication Tools)  
$T_{c5}$: Curriculum Activities Record or Degree Confirmation  

$P_{c1}$: Curriculum Subsystem  
$P_{c2}$: Retrieval Curriculum  
$P_{c3}$: Online Curriculum  
$P_{c4}$: Offline Curriculum  
$P_{c5}$: Syllabus Information  
$P_{c6}$: Curriculum Activities Record Subsystem  
$P_{c7}$: Insufficient the Curriculum criteria Record

3.3 Authoring Stage

For developers of Virtual University System, authoring tools make it possible to create and manage large numbers of independent pages and their assets. The authoring subsystem should provide the instructor to work on the site as a whole, rather than just a collection of independent pages. In Figure 5, with granted authorization (Transition $T_{au1}$), instructor could creating/updating a course page by specifying characteristics (Transition $T_{au2}$) such as where to put it on the server and what content database connection it will use. Authors are not limit to editing/creating individual pages. They can organize the entire site and link individual pages in a virtual map (Transition $T_{au3}$). Authors can make changes throughout a site without having to open and change individual pages or learning objects (Transition $T_{au4}$). In order to analysis the learner’s learning achievements (for individual learner’s progress), instructors can configure/adapt the weight for individual learning objects (Transition $T_{au5}$).

Figure 5: The Petri Net model for authoring stage

$T_{au1}$: Login with Granted Authorization  
$T_{au2}$: Selecting a Course  
$T_{au3}$: Course Organization Design  
$T_{au4}$: Content Object Editing  
$T_{au5}$: Weigh-bearing Point Configuration  

$P_{au1}$: Authoring Course Subsystem  
$P_{au2}$: Creating a Course  
$P_{au3}$: Updating a Course  
$P_{au4}$: Course for Lecture  
$P_{au5}$: Course for Examination  
$P_{au6}$: Course Preview

3.4 Examination Stage

The examination subsystem measures the effectiveness of learning. Learner may rely on tests to gauge their learning progress in a course. Instructor can use test scores to assign subsequent learning activities or to measure the effectiveness of the distance learning. In Virtual University, tests often usually find their way onto pages created with authoring tools.

As shown in Figure 6, if the learner login with granted authorization (Transition $T_{e1}$), they can choose desire course to exam. Anyway, the instructor may set some qualification for some tests. So the learners may be qualified/compares with some curriculum records (e.g. rate of attendance). After finishing that contingent qualification (Transition $T_{e2}$), learners can take the tests for course or curriculum level assessments (Transition $T_{e4}$ for disqualification, Transition $T_{e3}$ for qualification). Tests and quizzes are usually tracked as separate activities that may not as part of a specific lesson. The results reported to the learner and if specified by the test’s author, sent back to the server (Transition $T_{e5}$). The instructor can check results stored on the server to see how learners are progressing in the course/curriculum.
3.5 Assessment Stage

In this stage, we propose the assessment subsystem for measuring the learner’s progress. The assessment subsystem keeps track of the learner’s learning records: curriculum and examination records. Curriculum records contain the learning activities and workflows. Learning activities could represent the histories and behaviors that could be understood some certain extent of the learning acquisition. We could evaluate and produce the reports: learners, curriculums, courses, tests, activities, and online meetings.

As shown in Figure 7, with granted authorization (Transition \( T_{aa1} \)), instructors and course’s authors can periods check reports/results of the course or examination (Transition \( T_{aa2} \)). If the instructor set some qualification for some tests (Transition \( T_{aa3} \)) and if the learner was disqualified then he will not be allowed to take some test (Transition \( T_{aa4} \)). If the instructor didn’t set any qualification for some tests or the learners was qualified (Transition \( T_{aa5} \)) then they will get the examination results (Transition \( T_{aa6} \) for pass, Transition \( T_{aa7} \) for fail); however, the completed reports of the learner will be produced (Transition \( T_{aa8} \)).

4 Conclusion and Future Work

In this paper, we contributes a trust development framework and approach to the understanding of the virtual university and explains why it is proliferating throughout a rapidly evolving learning society. This is the important comprehensive and coherent framework to guide our understanding of e-learning in education and society. It is to the purpose of mapping the territory of e-learning, then providing directional choices for higher education and specific guidelines to reach worthwhile destinations. This paper can be used as a basic/fundamental research framework and tool to study and understand the characteristics of e-learning and to explore its optimal education application. The proposed system demonstrates the preliminary results of an on-going distance learning research project among several universities. We have implemented the generic user interface as well as a state machine engine which runs the specification language. Interactions via communication tools, such as video conferencing and chat room discussion are possible due to the support from the underlying system provided by Microsoft. Preliminary system shows the feasibility of using scaffolding theory in distance education, which is considered the most important contribution of this paper.

References:


