

# Assessing Students' Conceptual Knowledge of Computer Networks in Open Wonderland

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**Abstract**— Computer Networks, an undergraduate computer science course, is taught through a variety of new technological tools but more attention on assessment strategies using those technological tools is desirable. Research studies have shown that assessment methods also influence students' learning. Current assessment techniques, even those which include technology, focus more on summative assessment rather than formative. Formative assessment is necessary for teaching and assessment of complex skills like troubleshooting or network design. Therefore, there exists a need for assessments to capture students' problem solving process and chosen approaches during the assessment. By tracking a student's behaviors in an immersive assessment environment, the path that the student takes towards the solution can be studied. Virtual Worlds are naturally immersive environments and can be effectively used to record interactions that students made in the worlds. We have developed NetWorld in Open Wonderland, an open source software for creating 3D virtual worlds. NetWorld is a 3D virtual world built for detailed assessment of computer network concepts for computer science undergraduate students. This detailed assessment happens at 3 levels – conceptual understanding, diagnostic abilities and the ability to design a network. This paper describes the design principles and implementation of NetWorld and a plan to evaluate its usability.

**Keywords**—Virtual World; E-Assessment; Open Wonderland; Computer Networks; Simulations; Trouble Shooting; Conceptual Knowledge

## I. INTRODUCTION

Computer Networks is an integral part of Computer Engineering. The ACM syllabus [1] for Networks and Communication highlights that the course should be a mixture of principles and practice. Even though teaching and learning of computer networks course happens with tools like packet tracer, very less tools are used in comprehensive assessment of the students. By comprehensive we mean, assessment which considers all activities of the students during their assessment and not just some artifact that they might produce in the end. A comprehensive assessment should also evaluate on different cognitive levels like understanding, evaluate and create levels in Bloom's taxonomy [2]. Paper & pen based assessments cannot be used to evaluate these skills because they miss out on finer details [3]. The assessment should have formative components in it to capture the finer details. We have developed a virtual world based environment called 'NetWorld' which can be used to assess students in a

comprehensive manner. Detailed tracing of students' activities can be done in a virtual world which might help in identifying students' difficulties and misconceptions. This detailed tracing is enabled by a knowledge structure. We have built a knowledge structure, which has information about concepts that the students have to learn and a log of the student interaction in the virtual world.

This paper is structured as follows: In section II, we review the current research about teaching and assessing concepts in Computer Networks and the affordances of a virtual world. In section III, we describe the design and architecture of 'NetWorld'. In section IV, we describe a student interaction scenario in NetWorld. In section V, we present a plan of doing usability study to improve the tool. In section VI, we discuss the probable implications of this tool in teaching and learning and possible extensions of this research.

## II. RELATED WORK

Computer Networks is a fundamental course in the undergraduate engineering curricula for students with computer science as majors [4] which deals with inter-connection of computer systems and devices such as routers. The communications happening between computer systems follow certain established rules that are known as protocols. The course entails learning of these protocols, their applications and management. Internet is the largest application of the computer networks and is often taken as an example to teach theoretical concepts. The course also usually comprises of laboratory exercises that aim at providing hands-on experiences in the subject. The abstract nature of the course contents such as protocols has been found to be difficult for students to conceptualize [5, 6].

A variety of emulators, simulators, packet analyzers and web-based interface have been adopted in both classroom teaching and laboratory exercises for teaching these abstract concepts [7]. These tools help the students visualize the flow of packets traveling in the network and understand the protocols easier. The simulators and emulators can bring in the scenarios that happen at real-time and engage students to work on real-life problems. These tools aim to bring in-depth learning amongst students.

Many of the tools developed like WebLan-Designer [8], WebTrafMon [9], INetwork [10] provide browser-based interaction interface for students. These interactive tools allow students to learn concepts and perform network modeling, monitoring and analysis. The tools mentioned above have built-in assessments which are mainly multiple

choice questions. Such assessments evaluate the students on the final answer and not their problem-solving process. Assessment works best when it provides diagnostic feedback, enables progress evaluation and motivates performance. This feedback when presented to the instructor and student results in a more constructive learning environment. Therefore, it is important that the problem solving process be tracked because it will help to understand the difficulties of the students better [11]. Tracking the students' process will also help in giving in-time feedbacks.

A virtual world can provide affordances to track the students' problem solving process and give them real-time feedback. Virtual Worlds are highly interactive and also provide immersivity. In 2012 Gartner a technology research and consulting firm estimated that 80% of active Internet users will have a "Second Life/avatar" in some form of 3-D virtual world environment [12]. Virtual Worlds are highly interactive and also provide immersivity with the experiential settings. Second Life, a popular 3D virtual world has been seen to be adopted by many educational applications though most of them in collaborative language learning settings [13].

Open Wonderland [14] is an open source toolkit that allows users to create 3D virtual worlds. The toolkit has been used for language learning [15], business communication [16], and pedagogical agents in STEM tutoring [17]. There is an instance of using Open Wonderland for semantic assessment [18], but the assessment is mostly rule-based and for K-12 Physics content. The affordances of virtual world have not yet been completely tapped for the usage in assessment. We believe that virtual world will allow us to assess the students at a deeper level because the environment is identical to real environment and it provides us affordances to capture every action performed by the student [19]. In this paper we present a virtual world for assessing complex topics such as computer networks.

### III. THE DESIGN OF NETWORLD

Open Wonderland is an open source toolkit for creating 3D virtual worlds [14]. Open Wonderland's architecture provide features for developers to add and create their own modules (entities in virtual world like a building, a network component etc) and assemble virtual worlds. Open Wonderland provides a variety of tools for content creators like whiteboard, audio and video player, document viewer, etc. Avatars can interact with other avatars and perform tasks collaboratively. These features make Open Wonderland an ideal environment to implement our intervention.

#### A. Design Considerations

The developed system named NetWorld is implemented in Open Wonderland. Open Wonderland provides 3D environment for students interacting with the virtual world. However, there are certain features that Open Wonderland does not have. Hence certain considerations are made while designing the system.

1) Knowledge Structure – NetWorld assesses students' understandings of Computer Networks knowledge, specifically the concepts involving routers and its

associated protocols. These concepts have to be appropriately represented in the system, in order to evaluate students' acquisition of these concepts. NetWorld also provides a set of challenges that the students have to undertake. Performance in these challenges determines which concepts have been well learnt. The relationships between challenges and its corresponding concepts have to be stored and represented so that the above-mentioned tasks can be carried by NetWorld. All this information is stored as a knowledge structure in NetWorld. Representing information as a knowledge structure enables for the system to be easily extended for new concepts and challenges. We have divided this knowledge structure into 3 parts:

- a) Concepts: This is stored in an xml file called `concept.xml`. This file has relevant concepts in computer networks. For each topic, prior knowledge required for the topic, learning objectives for the topic etc are stored. The information like prior knowledge and learning objective will help in the automatic selection of next topic by the system thus enabling adaptive topic selection.
  - b) Challenges: Challenges are like scenarios with a problem. These are stored in a xml file `challenge.xml`. Each challenge has associated related concepts, maximum score for that challenge, the level of the challenge (conceptual, diagnostic or design) and prerequisite challenges. The information about related concepts, prerequisite challenges and the level of challenge will again enable the system to adapt at a challenge level. The mapping between challenges and concepts can also help in providing detailed assessment reports to the student and instructor.
  - c) Participants: For each participant, the system stores the score achieved for each challenge, time taken, concepts covered by solving challenges, actions performed while solving a challenge etc. This data can be used in generating real-time feedback and detailed report.
- 2) Student Interactions – The interactions which happen between the students and NetWorld can provide important insights about their learning. NetWorld can provide real-time feedback and infer learning behaviors of the students accordingly. Provisions have to be made to capture essential keyboard and mouse interactions.
  - 3) Access Layer – NetWorld needs to have an access layer that supports the identification of relevant mouse and keyboard interactions that the students made and the update of corresponding knowledge structures.

#### B. Architecture

The design considerations mentioned above have been incorporated into the design of NetWorld as Fig. 1 shows. NetWorld comprises the following components:

- 1) Virtual World Module – This module (at bottom right of Fig.1) includes all visible 3D objects in the virtual world and its properties and interactions. For example - "Router"

is a 3D model and has properties such as its size and location in the virtual world. The basic 3D visual building blocks inside Open Wonderland are called Cells. The 3D model and properties of the Cell are modeled as Java objects. Since significant time and effort is required to create 3D structures in Open Wonderland, we have used 3D artifacts which were produced from 2D images. It also involves certain actions that will be triggered by NetWorld when corresponding interactions happen; for instance, when a student clicks the router, NetWorld transports the student immediately to the inside of the router so that he or she can see internal parts of the router like its input ports, switching fabric, routing processor and output ports.

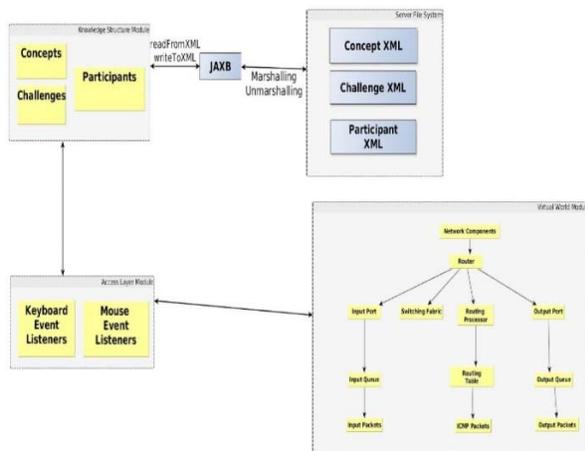


Figure 1. Architecture Diagram of NetWorld

- 2) Access Layer Module – The Open Wonderland Input API provides a common API and framework so that components can receive events for keyboard and mouse input. The access layer has various listeners for keyboard and mouse events that are triggered by students in the virtual world. For a particular keyboard or mouse event, appropriate changes to be done to the knowledge structures are defined in the access layer.
- 3) Knowledge Structure Module – The knowledge structures that store Computer Networks related knowledge and challenges as well as students’ profiles are created and managed as XML files at server side. When a student signs into NetWorld, these XML files are read and converted to Java objects via the use of JAXB Java library<sup>1</sup>. Based on the student’s interactions in the virtual world, NetWorld modifies corresponding objects accordingly. The modified objects are then transformed back to XML files and written back to the system. These XML files can provide details of the problem solving process of the student.

<sup>1</sup> <http://docs.oracle.com/javase/8/docs/technotes/guides/xml/jaxb/>

#### IV. VIRTUAL WORLD - NETWORLD

In this section, we describe the pedagogical aspects of NetWorld and how students can use NetWorld via a walkthrough of a challenge in the system. When a student logs in for the first time, he or she sees a computer network with several computers and a router in the virtual world. This scenario is shown in Fig. 2, where a student, lakshmiganesht moves around and explores the world on her own pace. She tries to send message packets from one of the computers to another at a console by clicking the computer. However, the system notifies her that packets sent from the computer have never reached the destination. This scenario sets up the challenge for the student. The objective of this challenge is to fix the router and hence allow packets to reach the destination.



Figure 2. A challenge student sees after signing into NetWorld

In order to solve this challenge, the student needs to have prior knowledge about routers and its internal configuration. She has to investigate the problem, by exploring the router as well as its internal parts to come up with a solution for the situation she is encountering in the virtual world. NetWorld allows the student to move in and out of the router. The student makes changes in the internal parts of the router, and observes the corresponding changes in the network. Fig 3 shows the internal parts of a router. Hence, there are different levels of visualization in the virtual world - the real-world level, where the student sees the router, and the inside device level, where the student sees the inside of the router. The student has to move back and forth from the inside device level of the router to the real-world. The affordance of the virtual world allows the student to understand how changes in the one level are reflected in another level in a computer network. The concepts required to solve this challenge is stored in the Concept XML. Hence a challenge can be solved by applying a series of concepts. This relationship between the challenge and the concept is stored in the Challenge XML. The challenges in NetWorld are embedded in real-life like scenarios. This makes it a relevant and interesting problem for the student to solve.

All interactions that the student makes with the system are captured and appropriate changes are made to the Participant knowledge structure via the access layer module. For example, when lakshmiganesht successfully completes the challenge, the Participant knowledge structure is updated

with assessment results of the concept “Router Internals” as Fig. 4 shows.



Figure 3. Inside of the router the student clicked

In addition to basic interactions, useful information like mouse clicks and time spent in each level in the virtual world can also be captured. This interaction data can be analyzed to track the student's problem solving process.

```

1 <?xml version="1.0" encoding="UTF-8" standalone="yes"?>
2 <participants>
3   <participant id="lakshmi ganesht">
4     <completedConcept>
5       <concept id="Router_Internals">
6         <learningObjectives>
7           <learningObjective id="1">
8             <level>1</level>
9           </learningObjective>
10          </learningObjectives>
11        </concept>
12        <score>10</score>
13        <time>20.5</time>
14      </completedConcept>
15    </participant>
16 </participants>

```

Figure 4. The updated Participant knowledge structure

## V. USABILITY STUDY PLAN

Prior to testing the effectiveness of NetWorld as an assessment tool for Computer Networks course, we intend to test its usability. For the usability study a group of 10-15 students will be selected to use NetWorld. These students will attempt challenges inside NetWorld at their own pace. The students will be provided with questionnaires that are used to capture their perceived ease of use and the difficulties encountered while using NetWorld. This preliminary evaluation can provide appropriate feedback that helps us enhance NetWorld and improve its usability.

## VI. CONCLUSION

In this paper, we have presented the design and 3D virtual world based implementation of an assessment tool for Computer Networks. This tool brings in immersivity and real-life scenarios to the student during assessment which supplements the assessment process. The instructor is able to track the students' problem solving approach by reviewing the recordings of their interactions within the tool.

We have developed the tool for assessment in the topic - "Router and its internal components". The concepts, challenges and learning objectives of the topic are modelled in the knowledge structure. This knowledge structure is an independent module, which makes it available for other researchers/educators for creating challenges in other topics.

In the future we wish to extend this tool for other topics in Computer Networks, create additional challenges and collect teachers' perception of using NetWorld for assessment in their classrooms.

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