

# **WebLan-Designer (v3) over the Past Six Years: Motivation, Benefits, Evaluation and Reflection**

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## **CONTEXT**

The educational tool considered in this paper (WebLan-Designer) has four network modules, including wired local area networks (LANs), wireless LANs, transmission control protocol/Internet protocol (TCP/IP), and data link-layer protocol. Each module provides a set of learning resources (tutorials, quizzes, modelling, scenarios, key terms and definitions, and review questions).

## **PURPOSE OR GOAL**

The purpose of this study is to report on the design, development and use of a web-based teaching suite (WebLan-Designer v3). This suite was developed with the aim of motivating students to learn TCP/IP networking and Data link-layer protocol design and analysis at introductory level, through interactive, hands-on and simulation-based learning activities.

## **APPROACH OR METHODOLOGY/METHODS**

This paper focuses on the design motivation underpinning the development of WebLan - Designer v3, and its educational value. As this educational tool aims to provide an engaging learning environment that supports knowledge building and skill development, its specific characteristics and potential benefits are addressed through the prism of student motivation and engagement.

## **ACTUAL OR ANTICIPATED OUTCOMES**

The paper WebLan-Designer v3 is the stage 3 development of WebLan-Designer in which two new modules, namely TCP/IP and Data link-layer protocol are implemented into the system. WebLan-Designer v3 is hosted at the Auckland University of Technology and can be accessed at <https://weblandesigner.aut.ac.nz/> (free of cost) at any time through the Internet; therefore, students can study network principles and design at their own pace.

## **CONCLUSIONS/RECOMMENDATIONS/SUMMARY**

WebLan-Designer v3 supports flexible learning environments and may especially useful in e-learning and remote learning scenarios. The suite has been used in the classroom and off campus with satisfying results indicating that the development and implementation of the new modules has been successful. The incorporation of wireless personal area networks (Bluetooth technology) is suggested as future development.

## **KEYWORDS**

Data link-layer protocols, TCP/IP, educational LAN design suite, WebLan-Designer.

## Introduction

Almost any computer science and engineering curriculum includes some basic courses in local area networks (LANs), transmission control protocol/Internet protocol (TCP/IP) and data link-layer protocol. Engaging and motivating students to learn these network fundamentals can be difficult using the traditional lecture format due in part to the limited options of providing students with the resources needed to build computer networks as a way of internalizing the abstract networking concepts taught in class (Huang, 2019); the issue was recently exacerbated by the global COVID-19 pandemic where universities had to find new ways of teaching subjects requiring hands-on experience (Gamage et al., 2020).

Computer networks, TCP/IP, and data link-layer protocol design are an essential part of the information technology (IT), computer and information sciences (CIS), and engineering undergraduate curricula at the School of Engineering, Computer and Mathematical Sciences (SECMS) at the Auckland University of Technology (AUT), New Zealand. However, students may find it hard to grasp the basic concepts of computer network protocols formats and envision packet flow when teaching is done exclusively in the classroom (Vijayalakshmi, Padmashree, & Meenaxi, 2016). Increasingly, educators are moving away from instructor-centred approaches towards student-centred, constructivist teaching and learning methods and strategies (Schindler, Burkholder, Morad, & Marsh, 2017).

In line with this paradigm shift, a team of researchers at AUT has developed a web-based educational suite called WebLan Designer that gives students an interactive and flexible learning experience in wired and wireless LANs (Sarkar & Petrova, 2005). The suite is available across the university and is used in introductory undergraduate courses which cover LAN media, topologies, protocols, wireless technologies, TCP/IP networking, link layer protocol design, and various aspects of network design and analysis. The current version, WebLan Designer v3, can serve both as a student-centred, self-paced learning tool, and as a classroom teaching support tool.

The research question we consider in this paper is: What impact WebLan-Designer v3 has in motivating students to learn TCP/IP and Data link-layer protocols? To address the question, the paper presents the key features of WebLan-Designer v3 and reports on the educational use of the suite by sharing the authors' experiences over the past six years, including the learning objectives underpinning the system design, a description of its functional components, and an evaluation of and reflection on its benefits. The main contribution and strength of this paper is the design and evaluation of such a web-based tool to be effective in motivating students to learn TCP/IP and Data link-layer protocols at introductory level. The most innovative aspect of this paper is the development and evaluation of educational suite that effectively complements the delivery of course content both in the classroom, and remotely. The rest of the paper is organized as follows. First, we present a review of existing network simulation and modelling tools relevant to our study followed by a description of the features of WebLan-Designer v3 and a discussion of its benefits. Next, we reflect on and evaluate the effectiveness of the tool in teaching and learning context. Finally, a brief conclusion ends the paper.

## Related Work

Learner motivation, or a learner's desire to learn is a personal psychological feature that activates a goal-oriented behaviour (starting to learn). Learners work towards achieving the goal by being persistent in their effort to learn, and by intensifying their intellectual engagement with the subject of learning; therefore, stimulating and maintaining learner motivation is important as motivation is one of the key antecedents to academic achievement (Aluja-Banet, Sancho, & Vukic, 2019; Ross, Chase, Robbie, Oates, & Absalom, 2018).

Research results have indicated that students learn computer network protocol design and feel more engaged with their courses if they are given hands-on experience that illustrates the theoretical concepts (Gotsis, Goudos, & Sahalos, 2005; Sarkar, 2006). However, computer

networks are complex systems in which the interactions between the numerous components cannot be easily observed; using simulation and visualization as part of the learning environment may lead to a better understanding of network communication protocols and the way they work (Marquardson & Gomillion, 2018).

A number of web-based learning systems that aim to support learning and teaching through interactive simulation and virtual experimentation have been proposed in the literature, as discussed in (Aller et al., 2005; Djordjevic, Nikolic, & Milenkovic, 2005; Garcia & Alesanco, 2004). In particular, software tools and suites have been designed specifically for the purpose of teaching and learning various aspects of computer network design, ranging from simple simulators to advanced specialized software systems. The authors tested several of these packages, from the perspective of fusing them in introductory computer networking courses. It was observed that both open source and commercial software packages often simulated a network environment in far more detail than necessary for a simple introduction to the subject, and resulting in a steep learning curve (e.g., Fall & Varadhan, 2020; Riverbed Modeler, 2020). A brief review of existing software tools reported in the computer networking literature is presented below.

- **Ns-2** (Fall & Varadhan, 2020): The ns-2 network simulator is a very powerful simulation software package suitable for performance analysis of computer networks. However, it is of limited use as a teaching and learning tool mostly because its text-based interface is not user-friendly.
- **Riverbed Modeler** (Riverbed Modeler, 2020): Riverbed (previously OPNET) is another commercial package commonly used by researchers and practitioners for the modelling and simulation of complex communication networks. A free version of Riverbed Modeler is available (from time to time) for educational purposes. However, the software maintenance cost is quite significant.
- **Cisco Packet Tracer** (Cisco Packet Tracer, 2020): A network simulation/emulation program that can be used by students to experiment with network behavior scenarios, especially with wide area networking, and the Internet.
- **EMPOWER** (Zheng & Ni, 2003): A network animator that can be used as an aid to illustrate the concept of wired/wireless networking. However, EMPOWER requires students to have some basic knowledge of computer networks.
- **Cnet** (McDonald, 2020): A network simulator that enables experimentation with various protocols at the data link, routing, and transport layers. However, Cnet requires students to have good knowledge of the Linux/Unix operating system.
- **WebTrafMon** (Hong, Kwon, & Kim, 1999): A web-based tool for network traffic monitoring and review. However, this tool requires an extensive setup for use in classroom settings.

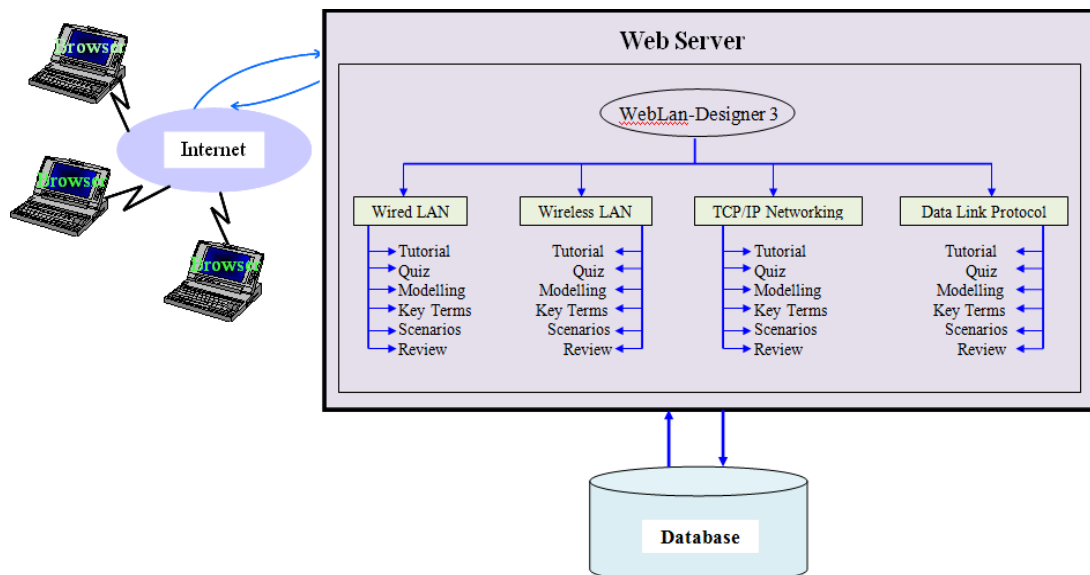
## Design and Implementation of WebLan-Designer

The educational suite WebLan-Designer v3 considered in this paper is substantially different from the tools and suites reviewed, in terms of its learning goals and functional capabilities. In particular, the system aims to support student in learning TCP/IP networking and data link-layer protocol and network design by providing a challenging yet friendly environment where learners can build and self-evaluate their knowledge through a comprehensive set of learning resources. It is flexible system which allows students to work at their own pace. The following learning objectives guided the design:

- **Knowledge development:** The system should enable students to develop and build their knowledge of network protocol design and analysis.
- **Self-evaluation:** The system should provide students with means of testing their knowledge of computer networking.

- **Problem-solving:** The system should provide students with means to develop and verify network design solutions.
- **Knowledge retention:** The system should provide students with means of reinforcing what was learned order to achieve deeper leaning and advance knowledge building.

The architecture of WebLan-Designer v3 is shown in Figure 1. The system consists of four main modules: Wired LAN, Wireless LAN, TCP/IP Networking, and Data link-layer protocol. These modules provide scope for the study of the fundamental concepts of computer network design and protocols and for achieving the learning objectives above. Furthermore, each module is structured as a set of motivational learning components (tutorial, quizzes, modelling, scenarios, key terms, and review). For example, the components involving computer simulations (e.g., the modelling exercises and the scenarios) aim to support motivation persistence by providing an interactive learning experience while the quizzes and the review questions aim to support motivation intensity by assisting students to construct their own knowledge and by providing informative feedback on their achievement. The learning components are described in more details next.



**Figure 1: WebLan-Designer v3 Architecture**

- **Tutorials:** WebLan-Designer v3 provides a walk-through tutorial for students to complete a set of learning tasks related to network protocol design. The TCP/IP networking tutorial focuses on encapsulation and the hop metric, and IP addressing and subnetting. The tutorial on the data link-layer protocol assists in developing knowledge and understanding of the concept of data link protocols, and of frame structure. Each tutorial includes self-assessment, both at the start and at the end of the tutorial. The tutorials aim to motivate students to embark on a learning journey, by providing a detail rich but easy to comprehend presentation of the key topics.
- **Scenarios and modelling:** These two components provide learners to observe the built-in network design and modelling scenarios. For example, with the TCP/IP network modelling option, students are prompted to download a network simulator program which allows students to create and experiment with their own network topologies, and to learn about network behaviors (e.g., the way packets are forwarded between devices). Students can play the built-in animation and observe how data and frames travel across the network; short explanations of the models are provided alongside the animation. When the student pauses the animation or hovers over a device, media access control (MAC) addresses and a switch table will show beside the device.

Motivation persistency is supported by interactive interface that encourages students to learn by exploring a variety of topologies and thus strengthen their understanding of how the interplay of the network communication protocols shape and govern network traffic.

- **Quizzes and review questions:** Students can test their knowledge of TCP/IP and data link-layer protocol design at any time using the interactive quizzes. A quiz consists of a set of 25 multiple-choice questions (four possible answers); Each question covers a key concept of network protocol design. At the end of a quiz session, the system displays various scores (e.g., correctly answered questions in %) and provides feedback on incorrect answers. Similarly, the review questions (available for each learning module) provide an opportunity for students to reinforce their learning by answering questions such as (i) Which multicast IP address does EIGRP protocol use?; and (ii) What are the common techniques for error detection?, and checking their responses against the review question answers. Thus, the quizzes and the review questions serve to intensify learner motivation as the learner critically assess their own level of knowledge and understanding and plan their next learning activity. In addition, the quiz scores may be useful for educators too, as instructors can use them to gauge students' prior knowledge on network protocol design and fine tune course delivery accordingly.
- **Key terms:** The key terms and definitions of various topics related to network protocol design, TCP/IP, and data Link-layer are presented as part of the relevant module, in alphabetical order. Examples of key terms of TCP/IP include frame, hop, hop count, enhanced interior gateway. routing protocol, open shortest path first, routing information protocol. The key terms related to Data link-layer protocols include frame, frame relay, cyclic redundancy check, point-to-point protocol, 802.11 wireless frame structure. Key terms aim to support motivation by providing an easily accessible, structured presentation of the main concepts and terms.

In addition, the 'useful links' to selected external materials (e.g., simulation tools, textbooks, white papers and articles relevant to computer network design) provided within each module expand the scope of the resources available to the learner and stimulate further engagement with the subject of learning. Students can intensify their learning by drawing on the wider body of global knowledge.

To support the required functionality, the system was implemented using PHP/HTML, with an MySQL database running at the backend. Its performance and robustness have been tested throughout the implementation of the subsequent versions (TCP/IP and Data Link modules were developed for the current version). WebLan-Designer v3 is hosted by AUT (<https://weblandesigner.aut.ac.nz>) and is accessible globally through the Internet, without any restrictions (no registration is required). Its Web-based graphical user interface (GUI) is user-friendly and facilitates an interactive learning experience.

## WebLan-Designer in Practice: Reflection and Evaluation

As an educational tool, WebLan Designer can be useful to both teachers and students, in a variety of teaching and learning contexts. For example, a teacher may choose to use the system in the face-to-face or virtual classroom as a demonstration tool, livening-up their lecture presentation while students can use the system either in the classroom or off-campus.

Recently, the authors had the opportunity to use WebLan-Designer v3 during COVID-19 remote teaching in Semester 1 (March - June), 2020. To make the lessons more interesting and to encourage student participation, WebLan-Designer v3 was made the integral part of several lectures and tutorial sessions, including assessing students' prior knowledge before introducing advanced networking topics. Students also used WebLan-Designer v3 from home, to complete the network design exercises and the tutorials at their own pace. Overall, our

experiences with WebLan-Designer v3 were very positive. The high level of questions and comments in the chat facilities indicated an increased level of student engagement.

In 2019, WebLan-Designer v3 was introduced to students at the China Jiliang University as part of a collaborative teaching programme. The class discussion was quite encouraging; staff also expressed in using WebLan-Designer v3.

## Evaluation by students

In the last several years, WebLan-Designer v3 suite has been evaluated both formally by students and informally in discussions within the teaching team. More specifically, as part of the formal evaluation process, the system was introduced in Advanced Network Technologies (a third-year undergraduate course) in Semester 2 (July-October), 2020. At the end of the course, students were asked to complete (anonymously and voluntarily) a short questionnaire comprising questions about WebLan-Designer's usefulness, ease of use, and effectiveness: (i) How convenient did you find the user interface of WebLan-Designer v3 to use? (ii) How useful did you find the interactive learning experience to be? (iii) How useful did you find the learning resources to be? (iv) How easy did you find WebLan-Designer v3 to use and follow? (v) How easy did you find it to navigate through WebLan-Designer v3 web pages? (vi) How effective (overall) was WebLan-Designer v3 in helping you to improve your understanding of network design concepts? A five-point Likert scale was used in the questionnaire (from 1 (poor) to 5 (excellent)). Students were also given an option to provide textual comments (reflective statements).

Twenty students (about 50% of the class) completed the questionnaire and their responses were recorded. The survey results show that student found WebLan-Designer v3 a useful and a user-friendly tool with the average per questionnaire ranging from 4 to 5, and overall 4.5 on the average.

The reflective statements showed high level of satisfaction, especially with the modules on the TCP/IP and Data-link layers. For example, a student commented that:

*"I like especially TCP/IP and Data link protocol modelling aspects. Review questions and answers, and the network scenarios are very useful. Interactive learning through tutorials and quizzes ... A very useful resource good for learning and teaching."*

The student comment above shows that the student was persistent in their work as they engaged in problem-solving and intensified their learning through the revision material; as already mentioned, persistence and intensification are the two behavioural indicators of learner motivation.

## Informal Feedback

Over the years, many students and colleagues from overseas sent their feedback via email and have suggested further improvement of WebLan-Designer. Some reflective statements regarding the system performance are listed below. We have already incorporated the feedback into the latest version of WebLan-Designer.

*Excellent work by you, and AUT University. (Source: Head, community education provider establishment.)*

*Hello, I am an IT student here at XX State University, using your site for an assignment for one of my classes. First, I must commend your site, in its ease of use and explanations of terminology and key concepts. However, the portion that is proving to be confusing is the "modelling" application. Again, I commend your site, as it is more user-friendly than most dedicated software programs that I've seen. Thank you.*

*Could you send me the link to the tool? It sounds very interesting not only as a teaching tool for students but also as a learning tool for practicing engineers. Thank you. (Source: Education technologist.)*

*Thanks for the link and e-mail. Web-based questions and answers are useful for students. I have experienced that students like to use these for self-review. (Source: Head, education provider establishment.)*

## Concluding Remarks

The WebLan-Designer v3 educational suite has been developed as a Web-based tool for learning the basics of network protocols and network design, to be used either in the classroom to enhance traditional lectures, or in remote education scenarios. The incorporation of TCP/IP networking allows students to explore this area in more depth by designing and experimenting with their own network topologies; the interactive interface is motivating and enjoyable, thus helping develop and enhance knowledge. In the data link-layer protocol module, students can learn and explore animation-based models, link layer protocols, frames and switches. The outcomes of the formal evaluation provide support for the effectiveness of WebLan-Designer v3 as a Web-based teaching that may motivate students to learn TCP/IP networking and Data link-layer protocol design and analysis at introductory level.

Although WebLan-Designer v3 was developed to meet the specific needs of the School of Engineering, Computer and Mathematical Sciences at AUT, the suite can be used in other disciplines, such as business information systems and electrical engineering. Currently, the suite comprises four modules; it can easily be upgraded to accommodate more practical scenarios and to address feedback obtained from students and academics, including comments posted on the website.

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