

The effectiveness of applying an ontology framework to a higher education course on dealing with computer viruses

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ABSTRACT: Computer virus is an abstract term and students study the effectiveness of computer viruses in traditional teaching methods which are poor. This study used an innovative interactive learning system, Network Security Course with Ontology Framework (NSCOF), to enhance students' knowledge and problem-solving skills when dealing with computer viruses. A total of 86 junior students from a technical and vocational college in central Taiwan voluntarily participated in the study. The study adopted a quasi-experimental approach with a two-group design. The findings were as follows: 1) knowledge-learning achievement: the two groups performed similarly; and 2) problem-solving learning achievement: the treatment group significantly outperformed the control group. The results show that the students solved the problems caused by a computer virus more accurately and quickly after they had studied the teaching material. Integrating this proposed knowledge - that is, the ontology of a computer virus - into the current pedagogy could increase the effectiveness and efficiency of this field.

INTRODUCTION

The Taiwanese Ministry of Education's (MOE) plans and objectives include the following: enhancing students' cloud-based e-learning competency and their ability to address social concerns using digital technology, promoting information ethics and on-line safety, building environmentally sustainable campuses and increasing teachers' and students' environmental literacy, protection of the environment, and ability to prevent disasters and deal with contingencies [1].

The Institute of Engineering Education Taiwan (IEET) features an outline of computing accreditation criteria. Criterion 3: graduate attributes and assessment states that one of its purposes is to determine whether a degree-granting programme meets certain standards of quality, e.g. 3.1 ability to innovate and apply knowledge of computing and mathematics appropriate to the discipline; 3.2 ability to apply techniques, skills and modern tools necessary for computing practice; 3.3 ability to design a computer-based system, process, component or program [2]. Therefore, information and communications technology (ICT) and information security are very important issues.

ICT benefits our lives by reducing costs and by changing the way in which people communicate and share information. However, malware programs have been developed to monitor personal computers, manipulate computers' resources to prevent spamming and steal individuals' private data. These malicious activities are generally caused by computer viruses and are the biggest threat to computer users. Although commercial antivirus software is committed to preventing vulnerabilities within computer systems, no commercial antivirus software can guarantee complete protection against all computer viruses [3]. Therefore, information technology (IT) professionals should possess the expertise to identify types of computer viruses, and a computer's infection status to solve or recover injured computer systems.

How to teach an ill-structured, continuously changing subject (e.g. how to diagnose and remove a mutated virus) is a challenge for educators in the fields of technology and engineering in higher education. Computers can be infected in numerous ways by a range of computer viruses, and the antivirus solutions are not always consistent. Therefore, most students feel frustrated when trying to learn how to diagnose and remove the viruses according to the symptoms of the infected computer. Consequently, determining how to transform ill-structured problems into well-structured learning units is an important pedagogical issue.

Courses should provide the necessary links between elements or themes that enable students to produce a coherent understanding of the concepts [4]. Moreover, students should be immersed in specific scenarios in order to make a deeper impression and to acquire knowledge effectively. If the tutorial-like system considers how students perceive, process and apply knowledge, it would be able to customise the way in which it communicates knowledge to students to attain an optimal teaching strategy [5].

This study developed an innovative interactive learning system, NSCOF, which arranges computer virus knowledge based on an ontological framework. It not only improves students' knowledge, but also their problem-solving skills when dealing with computer viruses. This Network Security Course, supported by the new learning system, helps students to become proficient in the characteristics of computer viruses and their related infectious symptoms, teaching them to autonomously remove computer viruses. Finally, this course equips students with the practical ability to systematically solve problems, even when faced with unknown computer viruses.

APPLICATION OF ONTOLOGY IN COMPUTER SCIENCE TEACHING

Ontology represents knowledge as a set of concepts or terminologies that describe high-level, abstract knowledge [6], as well as some concepts with specifications, including the description of concepts, associations and attributes [7]. Ontology defines the basic terminology and relationship of topical vocabulary, and it uses the extension of rules for combining these terms and relationships [8]. Ontology is becoming quite important in the technology of computer and information science (e.g. semantic Web's core technology uses ontology techniques). In addition to searching semantics, it incorporates artificial intelligence (AI) into its network services [9].

According to the earliest definition of ontology within the field of computer science, it is an abstract format. Ontology is the knowledge of a set of terminology, which includes the relationship between vocabulary and semantics, and the rules of inference and logic. Moreover, ontology constructs the system of a concept between knowledge and action in the real world [10]. Therefore, this study defines ontology as follows: ontology establishes the relationship between concept, terminology and vocabulary [9]. Further, it helps to organise structural knowledge to illustrate hierarchical concepts through abstract ontology. Using ontology theory, this study will low-structure computer virus categories, and through relations and characteristics, create rules of inference, logic and structured hierarchical concepts. Figure 1 shows the relevance between various computer viruses - some computer viruses may have their own specific characteristic attributes, while other computer viruses share common characteristics.

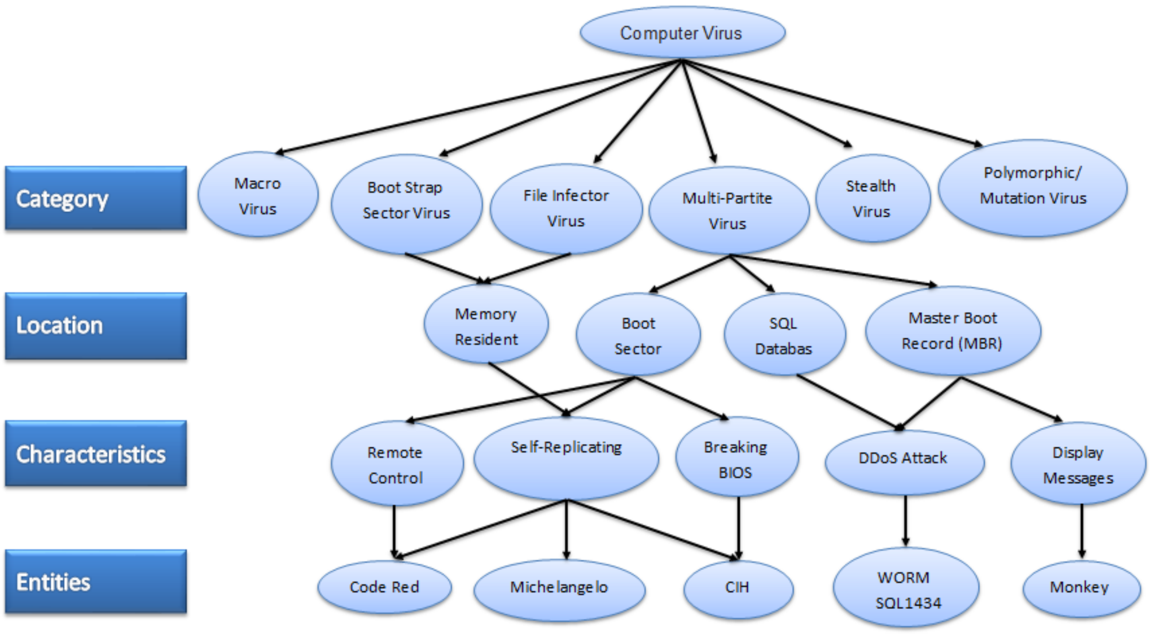

Figure 1: Ontology framework for computer viruses' schematic diagram.

EXPERIMENTAL METHOD

It is a challenge for educators to teach students an ill-constructed subject, such as detecting computer viruses - there are many ways to infect a computer, and the solutions are inconsistent. Students feel frustrated when attempting to diagnose and fix a computer virus. Therefore, it is important to transform the ill-structured learning unit into a well-structured one to maximise the benefit to students. It is believed that ontology could develop well-structured concepts to provide students with a better understanding of the field and to promote effective learning. Accordingly, this study developed an innovative interactive learning system, NSCOF, to enhance students' knowledge and problem-solving skills when dealing with computer viruses. A quasi-experimental approach with a two-group design was adopted to validate the proposed course.

Constructing a Computer Virus Database with an Ontology Structure

By using model access application programming interface (API), external applications of ontology, such as reasoning, merging and authoring tools, can be used to access the ontology object model and provide a clear representation of knowledge about ontology [11]. Virus databases should contain virus-related references (e.g. the original place in which an initial date on which the computer virus was found, its author, its symptoms, an infection history, damage, likely causes and how to remove it) [3]. The current study sought the opinions of information teachers about the importance of different computer virus topics in ICT textbooks, and six dimensions were created as a result [12]: definitions, categories, characteristics, spread channel, damage and prevention of a computer virus. Among these six factors, prevention of a computer virus was considered to be the most important; hence, this article constructed a database to store the characteristics of a computer virus, which included the following five categories: infections, symptoms, location, how it infects and how to remove it. The virus database collected 483 computer viruses and integrated these into the ontology knowledge structure.

Experimental Approach

A quasi-experimental approach with a two-group design was adopted in the one-semester course *Information Technology Network Security*. It aimed to give students the capacity to conceptualise computer viruses and the practical skills of antivirus protection. A total of 86 junior students from the Department of Information Technology of a technical and vocational college in central Taiwan were divided into two groups: the treatment group (who learned material organised via the ontology structure), and the control group (who learned material via the traditional teaching methods). This study evaluated and validated the proposed course by assessing the knowledge and practical problem-solving skills that the students gained. The research model is shown in Figure 2.

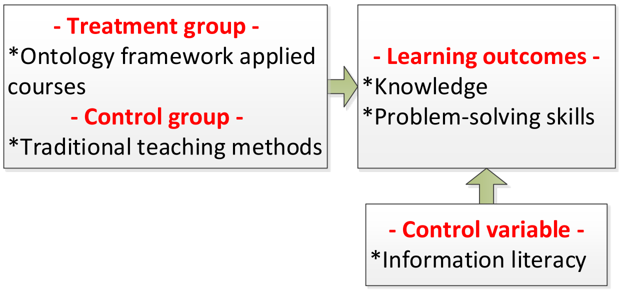

Figure 2: Research model.

Studying the topic of computer viruses in the traditional course, the lecturer only focused on teaching the knowledge of computer viruses. When students encountered actual computer viruses, they only had one solution to combat them: installing commercial antivirus software. Figure 3 depicts the traditional steps for removing a computer virus. If the students majoring in information-related fields do not know how to remove a new computer virus or the computer virus still persists after scanning by commercial antivirus software, their only option is to search for related information on the Internet and leave a message on the commercial antivirus software company's Web site. Students cannot extend or develop valid problem-solving skills based on traditional virus theory.

Accordingly, this study proposed an innovative interactive learning system for students to acquire knowledge of computer viruses that was based on an ontology framework. Figure 4 contains the flow chart of the proposed learning system, NSCOF, to enhance students' practical problem-solving skills. In this course, students learned to figure out the possible solutions for computer viruses by classifying their characteristics and building up the schema of the viruses.

Innovative Interactive Learning System with an Ontology Framework

Figure 5 depicts the functions of the interactive learning system, NSCOF. Here, students can input the characteristics of the computer's operation or the disease (characteristics) of the computer to acquire related information. This system displays information about the computer virus and calculates the similarity between this and various viral properties that match the search criteria. Students can identify the relationship between different computer viruses to infer the most effective solution via the concept of similarity. This concept was enacted by inputting a query and calculating the properties of a computer virus (considering the match percentage of the overall results). Students could refine this characteristic relationship via search criteria, learning of any similar computer viruses through the information provided by the system. By applying an ontology implementation system to introduce the theory and practice of computer viruses, students understood the concept of a computer virus and enhanced their practical computer virus prevention, infection characteristics and problem-solving skills.

The concept similarity calculation formula is as follows:

$$W = \frac{Tot\_Solt}{Tot\_Class} \text{x}100\% \tag{1}$$

W denotes the value of concept similarity calculated by the system.

Tot_Class denotes the number of computer virus compliance with the search criteria.
Tot_Solt denotes the number of occurrences of the same attribute compliance with the search criteria.

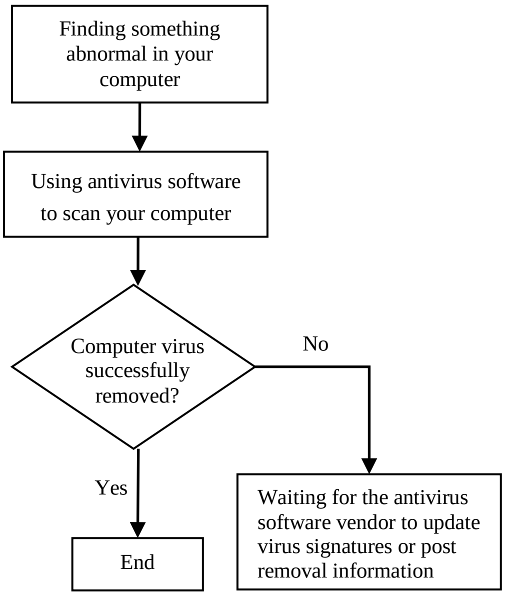

Figure 3 Flow chart of the traditional antivirus procedure.

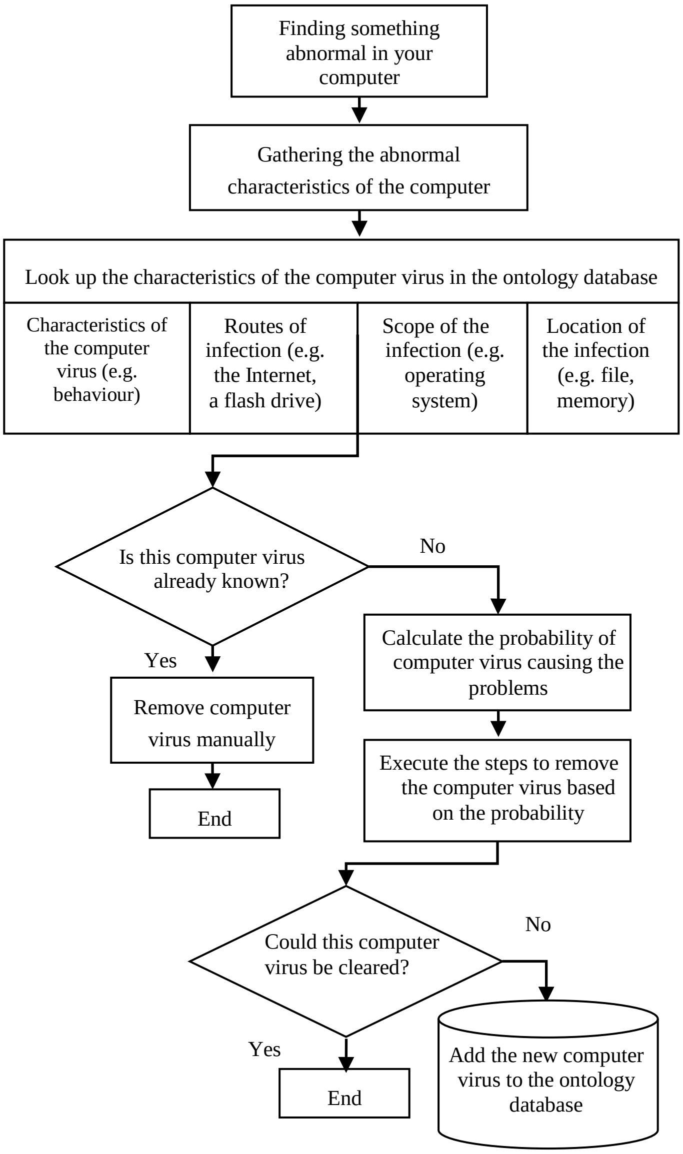

Figure 4 Flow chart of the NSCOF, for enhancing students' practical problem solving skills on antivirus.

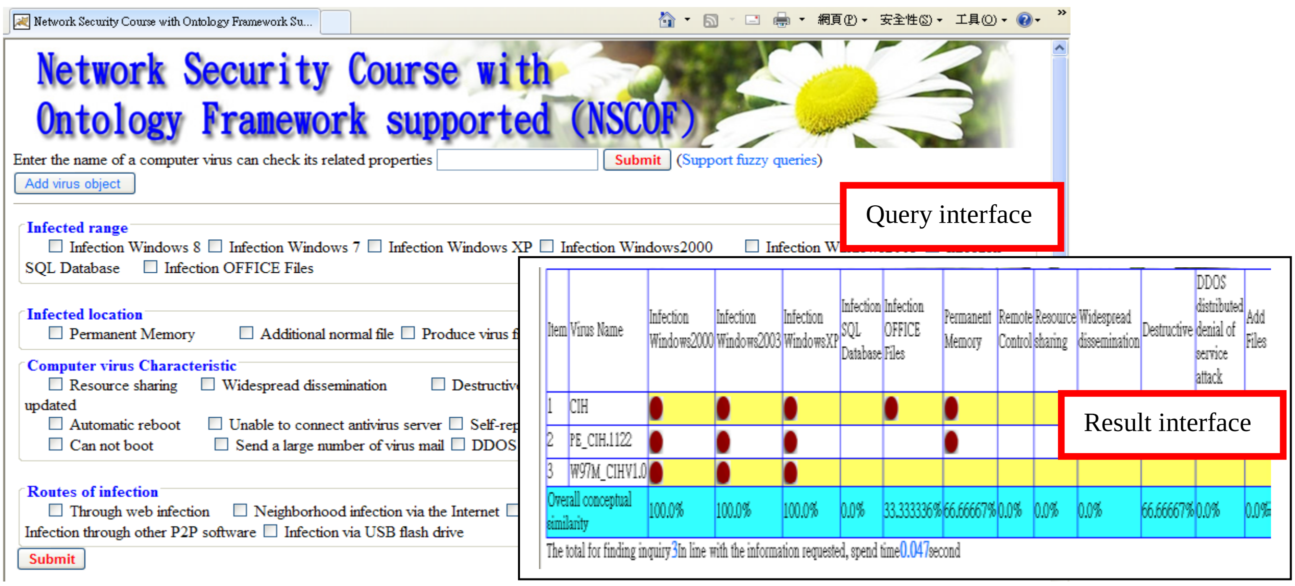

Figure 5: Results list of learning interaction showing the relationship between known computer viruses and the searched viruses' characteristics.

ANALYSIS AND RESULTS

The 86 participants were divided into two groups: a treatment group (48 students) and a control group (38 students). This study adopted the students' scores from the course *Introduction to Computers* as the students' level of knowledge coming into the study (pre-test). After the three-week course (three hours per week), the students were asked to take an examination to determine their knowledge and problem-solving skills (post-test).

Homogeneity Tests on Prior Information Literacy

To evaluate the differences in the prior information literacy between these two groups, the study adopted the two groups' scores on the subject *Introduction to Computers*. Table 1 shows that there were no significant differences in the prior knowledge in these two groups (t = 1.126, p = 0.263 > 0.05). This means that the students in these two groups had similar levels of prior knowledge.

Table 1: *T*-test of the pre-test on information literacy for the treatment group and the control group.

Group	Amount	Mean	SD	*t*	*p*
Treatment group	48	70.574	10.0858	1.126	0.263
Control group	38	67.757	13.1186		

Difference between Ontology Framework-Applied Courses and Traditional Teaching Methods in Relation to the Knowledge and Problem-Solving Skills

To evaluate the effect of ontology framework on the groups, both groups took a three-week course on information network security and, then, completed an examination to measure the differences in their computer virus knowledge. MANOVA (multivariate analysis of variance) was used to examine the difference between ontology framework-applied courses and traditional teaching methods in relation to the knowledge and problem-solving skills. The results indicated there was no significant difference between these two groups on students' knowledge (p = 0.340). However, there was significant difference between these two groups in regard to students' problem-solving skills (p = 0.000). The experimental results showed that students in the treatment group improved their problem-solving skills through the ontology framework. Regarding control variable, information literacy was not found significant in regard to the students' knowledge (p = 0.108). However, information literacy was found significant in regard to the students' problem-solving skills (p = 0.014).

Table 2: Results of the MANOVA analysis.

Source	SS	DF	F-value	Significance
Knowledge				
Information literacy (control variable)	5.114	1	2.640	0.108
Class (treatment group vs. control group)	1.785	1	0.922	0.340
Problem-solving skills				
Information literacy (control variable)	0.460	1	6.370	0.014**
Class (treatment group vs. control group)	5.998	1	82.991	0.000***

Note: **p < 0.05; ***p < 0.001

DISCUSSION AND CONCLUSION

Although this proposed teaching material did not significantly impact on the acquisition of knowledge of computer viruses, the implementation score (which evaluated students' problem-solving skills) of the treatment group was much better than that of the control group. The findings imply that the conceptual scaffolding provided by NSCOF has a similar effect as the traditional instruction approach on enhancing students' knowledge development. However, the strategic scaffolding provided by NSCOF greatly enforced the students' problem-solving skills. In other words, the proposed NSCOF narrowed the gap between knowledge and action. According to in-depth interviews with the students in the treatment group, they agreed that NSCOF provided the following useful functions:

1. Constructing computer virus knowledge via the ontology framework helped them to organise their knowledge structure systematically.
2. Searching for information about computer viruses via the ontology database revealed the relationship between different computer viruses. This was done using a similarity analysis of the overall concept and, then, inferring the most effective way to combat the virus.
3. Querying the information about the computer virus using this system, which can display the relationship between different types of computer viruses, helped students to identify the implicit association rules and cluster methods of the common attributes.
4. The ontology database helped students to clarify their prior knowledge and thoughts on removing computer viruses or to develop a new solution to a virus by looking up the concept of attributes.

5. When students looked up the related concepts of computer viruses via this system by searching for specific attributes of the virus, they felt they could better organise the distributed computer virus concepts into a systematic knowledge structure, improving their memorisation and learning performance.

Thus, the treatment-group students obtained the following learning advantages from the course: 1) constructing computer virus knowledge via the ontology framework facilitated a systematic knowledge structure; 2) searching for information about the computer virus in the ontology database revealed the relationship, as well as enhanced the connection between different characteristics of computer viruses via a similarity analysis of the overall concept; further, it induced effective antivirus tactics; and 3) the ontology system helped the students to clarify their knowledge of removing computer viruses and equipped them with the ability to develop a new heuristic solution to viruses by evaluating the viruses' attributes.

In order to develop the learning system, educators should spend a great deal of time on constructing a knowledge ontology framework of computer viruses. However, evaluating educational performance depends not only on efficiency, but also on effectiveness. Educators should spend extra time preparing the teaching material, as it will provide the students with an overall picture of computer viruses, increasing their problem-solving abilities. Instead of trial-and-error, this study proposed a systematic and hierarchical problem-solving method.

Students in information-related departments enrolled in a course on computer viruses could further understand the characteristics of computer viruses and related infectious characteristics through the proposed ontology interactive learning system. Students could learn how to apply tools to get rid of computer viruses instead of depending on commercial antivirus software. The current designed course material can give students problem-solving competency when they face new computer viruses.

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