Supporting Case-based Learning in Information Security with Web-based Technology

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ABSTRACT

Case-based learning has been widely used in many disciplines. As an effective pedagogical method, case-based learning is also being used to support teaching and learning in the domain of information security. In this paper, we present a detailed case study for teaching security management. A process model of integrating a case library and Web 2.0 technologies to facilitate case-based learning is also presented in this paper. Insights and recommendations for implementing the process model are offered as well.

1. INTRODUCTION

Information security is a serious worldwide concern of governments, industry, and academia (Wang et al, 2013). Due to the increased reliance of governmental, military, and financial functions on complex interconnected computer systems and networks, many universities are offering information security courses to both undergraduate and graduate students. ACM/IEEE has also published curriculum-related guidelines and recommendations (Computing Curricula, 2005) for accrediting five computing degree programs: computer engineering (CE), computer science (CS), information systems (IS), software, engineering (SE), and information technology (IT) and recommended all these five programs to include information security as a new focus area because of the emergence of security as a major area of concern.

However, teaching information security courses is technically challenging. An information security course in IS program typically covers many perspectives including technology, policy, management, behavior, economy and legal perspectives. Each perspective further discusses many different security-related topics. For example, the technology perspective discusses the use of a series of security analysis and testing services and tools such as source code analysis tools, SQL injection testing tools and web service penetration testing tools.

Due to the diversity of security topics, many novice instructors often have a hard time in teaching information security courses. The teaching of information security topics and principles is not easy without ready access to adequate examples. Examples have often been recognized as important when teaching conceptual or complex materials. Oftentimes, a life situation is complex and requires students to address complicated issues involving a variety of variables and parameters. To better comprehend security principles, techniques and approaches, students need exposure to sufficient examples.

In order to effectively help novice instructor teach information security courses and also help students learn information security more effectively, we recommend the case-based learning approach. Case-based learning has been found to help novice instructors develop expertise that experts evolve through the accumulation of experiences (Gwendoline & Wang, 2010). Through extensive analyses and discussions on different cases over various situations, novice instructors can learn different ways to interpret security issues, gain contextual knowledge, personal skills and situated experiences and eventually become more competent and capable teachers in teaching information security (Kim & Hannafin, 2009). On the other hand, case-based learning can engage students in a more authentic environment to relate theory to practice, help students to learn knowledge more actively and make learning more fun and interesting (Yuan et al., 2010a; Savelyeva, 2011; Elksnin, 2001; Shulman, 1992). Furthermore, technologies such as multimedia (Fitzgerald et al., 2006), Web 2.0 (He & Hartley, 2010) and case library (He, Xu, Means & Wang, 2009; Wang, 2002; Jonassen & Hernandez-Serrano, 2002; Duan & Xu, 2012; Fang et al, 2013; Feng & Xu, 1999; Shi et al., 2007; Sun et al., 2003;Xu, 1994; Xu, 1995a; Xu,1995b) can be used to facilitate case-based learning approach and make the learning process more efficient and effective.

In an effort to support information security education, this paper shares our experiences in using a case study to teach security management. A process model of integrating case library and Web 2.0 technologies to facilitate case-based learning is also proposed in this paper. The purpose of this paper is to promote the case-based learning approach for information security education and to propose an approach for developing and integrating a case library into teaching. The rest of the paper is organized as follows. Section 2 provides a brief literature review about the use of cases in instruction and technologies that can be used to support case-based learning. Section 3 presents a case study for teaching security management. Section 4 presents a process model that integrates several technologies to support case-based learning in security education. Section 5 provides recommendations and insights for implementing the proposed process model. Finally, conclusions and future research are discussed in section 6.

2. A BRIEF LITERATURE REVIEW

2.1 Use of Cases in Instruction

Cases describing real-life situations or authentic activities have been used extensively in many disciplines to teach troubleshooting, to explain concepts, to solve problems, and to promote learners' critical thinking and analysis skills (Jonassen & Hernandez-Serrano, 2002; Kim et al., 2006). Oftentimes, a life situation is complex and requires students to address complicated issues involving a variety of variables and parameters. To better comprehend complex concepts or situations, students need exposure to sufficient real life examples or case studies. As a result, many case studies are practical in nature and focus mainly on situating students in an authentic context (Fitzgerald et al., 2006). For example, Antes et al. (2012) applied cases to solve ethical problems by asking participants to reflect on a case discussing relevant ethical experience in a business problem. Their study revealed that reflection on personal cases for making ethical decisions was associated with decisions of higher ethicality. Thistlethwaite et al. (2012) reviewed more than 100 articles that used case-based learning methods in health professional education. Their review reveals that students enjoy case-based learning approach and think that it enhances their learning; teachers also enjoy case-based learning partly because this approach engages and motivates students in learning. Çam & Geban (2011) compared the effectiveness of case-based learning instruction with traditionally designed chemistry instruction through an experimental study with high school students. The results of their study reveal that case-based learning method is a preferred instructional method which has improved students' epistemological beliefs and attitudes toward chemistry (Çam & Geban, 2011).

In the area of information security education, Yuan, Murthy, Xu, & Yu (2010) and Murthy (2010) used case studies to teach security topics such as physical security and security policy and received very positive feedback from students. Lincke (2012) designed a case study to enable students to practice security planning with a Doctor's office, including "risk analysis, business continuity, information security, network security, personnel security, incident response, and physical security". Her study revealed that the case study helped students to understand the perspective of the business owner. Savelyeva (2011) applied a case study-based approach to teach college students about security concepts. Her experiences showed that the case study-based approach provides a few key advantages such as providing an opportunity to conduct practical training with a minimum of equipment, ensuring a high level of student involvement. It is a comprehensive approach to teach information security from various perspectives (user, technical specialist, financial director, architect and top manager) (Savelyeva, 2011).

2.2 Case Library

Case libraries have received increasing attention in educational fields. In order for information-seekers and learners to learn through cases, cases must be stored properly for easy retrieval and use. Some pioneering educators have adopted the case library approach to store cases in order to facilitate their teaching. For example, Carroll & Rosson (2005) developed and used a case library of engineering case studies used for teaching human-computer interaction. Ma & Harmon (2006) developed an html-based prototype of an Online Teaching Case Library (OTCL) to store online teaching courses and the lessons that faculty members have learned from teaching those courses. Chen & Yeh (2006) implemented a searchable case library to enhance student

comprehension and problem-solving skills in an introductory C++ programming course. Wang, Moore, Wedman & Shyu (2003) developed a case library to help pre-service teachers learn the uses for different technologies in their classrooms. These examples demonstrate that case libraries are an effective means to support case-based learning and instruction. Building a case library has been proved to be an appropriate and viable option in providing students and faculty with case-based resources that support learning and teaching.   So far we have not yet found an open access Web-based case library that is designed specifically for the domain of information security education.

2.3 The Use of Web 2.0 in Education

Web 2.0 has essential characteristics such as user participation, collaboration and openness (Williams & Jacobs, 2004; Duffy & Bruns, 2006; Konieczny, 2007; Zyl, 2009; Levy, 2009; He & Hartley, 2010). Over the past eight years, the use of Web 2.0 methods in education has spread at a rapid pace. Instructors can now use Web 2.0 tools to create and publish course contents such as syllabus and lesson plans on the Internet without the need to learn HTML language. Students can use Web 2.0 tools to collaborate with their peers to work on group projects and other collaborative tasks. Some popular Web 2.0 tools used in education include RSS, tags, blogs and wikis.   Table 1 presents a brief description of these tools.

Web 2.0 tools	Description	Benefits
RSS	RSS is an XML-based format for content distribution. RSS feeds can be accessed via an RSS icon link on any webpage.	RSS allows users to subscribe to a web page to get rapid data updates and notifications as the page content changes (Duffy & Bruns, 2006; He & Hartley, 2010).
Blog	A blog is a web page in diary format that allows users to tell their own stories and to elicit comments from others on their entries. A blog can be easily created by using blog sites such as Blogger.com and Wordpress.com.	Blogs can increase the level of participation, can help to develop a greater sense of community, and can facilitate learning for students within the higher education sector (Williams & Jacobs, 2004;).
Wiki	A wiki is a web site that allows collaboration from a group of users who can add, remove, edit, and change the content of any web page. A wiki can easily be created by using software such as wikispaces.com.	Since a wiki is a community-created resource, it can be used as a tool for collaborative learning and knowledge construction (Konieczny, 2007; He, 2011).
Tags	Tags are keywords that are associated with information pieces such as video clips or images.	Tags make an item easier to find; they can be used as a form of social bookmarking to facilitate the tracking of specific content (Godwin-Jones, 2006; Zyl, 2009).

Table 1: Popular Web 2.0 tools

Research shows that Web 2.0 tools have a positive impact on the use of Web-based case libraries (He, Xu, Means & Wang, 2009; He & Hartley, 2010). Therefore, there is a need to integrate a case library with interactive Web 2.0 tools to provide more functionalities or features to users. We expect that Web 2.0 tools can encourage and enable users including instructors and students to share their own opinions and learning experience about the security case studies stored in the case library. Web 2.0 provides an easy way to solicit feedback from Internet users to improve the quality of case studies in the case library.

3. A CASE STUDY ON SECURITY MANAGEMENT

In this section we give an example case study that has been used in teaching security management. The case study is described and our teaching experiences are discussed.

3.1 Incident response planning case study

Contingency strategy is an important topic in security management and is often taught in information security courses. It is a topic included in the National Training Standard For Information Systems (NSTISSI No.4011) (NSTISS, 1994). Contingency strategy includes incident response planning, disaster recovery planning and business continuity planning. Teaching this topic will benefit from using real life case studies.

We present an incident response planning case study (Murthy *et al.,*2009; Yuan *et al.*, 2010a) that was developed based on NIST special publication 800-61 "Computer Security Incident Handling Guide" (NIST, 2009). NIST special publication 800-61 presents the following four phases of incident response lifecycle:

(1) Preparation and planning. During this phase, an incident response team composed of members from various functional roles in the organization is formed.

(2) Detection and analysis. During this phase, potential incident information is monitored and gathered. Incidents are identified and classified into different severity categories.

(3) Containment, eradication, and recovery. This phase includes activities to minimize and isolate the damage incurred, eliminate the components of the incident, and restore the operation of the compromised system to normal business mode.

(4) Post incident activity. This phase includes a lessons-learned meeting to review the incident, identify the weakness of the incident response plan, update the incident response plan and document the incident in detail.

The case study has the following format (NCAT, 2013):

1) Case learning objectives. Case learning objectives describe the measurable learning outcome of the case study. Table 2 shows the case learning objectives of the incident response case study.

Case Learning Objectives:
• Identify an incident.
• Classify an incident according to its severity.
• Identify the roles and responsibilities in an incident response team.
• Identify the steps an organization should take to contain and recover from an incident.
• Recommend measures to prevent similar incidents from occurring in the future.
• Recommend actions to improve the detection of similar events.

Table 2: Incident Response Planning Case Learning Objectives

2) Case description. Case description describes the context of the case study, and provides one or more realistic scenarios. In the incident response planning case study, the students are given a realistic incident response plan "XYZ University Computer Incident Response Plan" and two realistic scenarios which are adapted from the incident handling scenarios in NIST Special publication 800-61 Appendix B (NIST, 2013). One example is show in Table 3.

Case Scenario
On Thursday morning, John, an XYZ university employee, noticed a warning message on his computer saying that the system has been attacked by a worm Win32.VB. Even though the antivirus software was present in the system, the software failed to detect the new worm because it was not updated to the latest version. When John tried to open his e-mail, he experienced a slow internet connection. He noticed there were some unusual file names in the disk. John immediately informed his friend Bob, who was also an XYZ employee, of the problem. Bob checked his computer in his office and experienced the same problem as John. John and Bob checked several computers in the laboratories, and found that Win32.VB worm had infected many other computers in the laboratory. They contacted the system administrator of the XYZ University. The system administrator checked the computers in the laboratory and reported the incident to the incident response team. The system administrator also checked the computers in other laboratories. As a result of the worm attack the activities in the XYZ University laboratory were suspended for a day, which caused a great inconvenience.

Table 3: Incident Response Planning Case Scenario

3) Case discussion questions. Based on case description, the students should answer the case discussion questions, which may be open ended and may involve group discussion, role playing, problem solving, research, etc. The case discussion question is mapped to the six levels of cognitive skills and capabilities defined by Bloom's Taxonomy (Forehand, 2013). The goal was to use Bloom's Taxonomy to guide our design of the case discussion questions so that they map to all the six cognitive levels of Bloom's taxonomy while stressing higher level skills. Table 4 shows the case discussion questions for the incident response planning case study, and their mapping to Bloom's taxonomy.

Case Discussion Questions	Bloom's Taxonomy Level
Would the organization consider this activity as an incident? Justify your answer	3 (Application)
What's the severity level of the above mentioned incident	3 (Application)
Who or what groups will be involved in the situation?	3 (Application)
Suggest measures to contain and recover from the incident.	5 (Synthesis)
Suggest measures to prevent similar incidents from occurring in the future.	4 (Analysis)
Suggest actions to improve the detection of similar events.	5 (Synthesis)

Table 4: Incident Response Planning Case Discussion Questions

3.2 Evaluation results of the incident response case study in teaching

This case study was used in an undergraduate level "Security Management of Information Systems" course at North Carolina A&T State University in the Spring 2009 semester. We used three steps to teach this case study. First, after introducing to the students the basic concepts of incident response planning in the lecture, the case description and discussion questions were given to the students, and the students were asked to provide solutions to each question individually. Second, after the students turned in their individual work, they were paired up to discuss the questions and generate a new group solution. Third, the student groups presented their solutions to the whole class. Each student receives an individual score based on his individual work, and a group score based on group work and group presentation. The average of these two will be the grade of this case study for this student. Student opinions survey on this case study shows that they enjoyed learning incident response planning using this case study. The students liked the case study approach because it allowed them to apply the concepts to real world situations, and conduct research. The students felt they were confident that they would be able to apply the knowledge in their future jobs.

This case study was also used in the "Foundations of Information Systems Security" course at Fort Hays State University in the Fall 2009 semester. It was given to the students as an individual project after the students learned the basic concepts of incident response planning in the lecture. The students were given two weeks to complete the project.

Before the students started with the project, they were asked to fill out a pre-survey, which asks them to rate their level of knowledge or skills on the six learning objectives of

this case study using the scales 1 to 5 (1 means very low, 5 means very high). After the students completed the project, they were asked to complete a post-survey which includes three parts. The first part asks the students to rate their level of knowledge or skills on the same learning objectives of this case study. The second part asked them to rate their degree of agreement (from strongly agree to strongly disagree) on the six statements shown in Table 5. The third part asks what the students liked best about the project, what they liked least about the project, and what could be improved in the project.

Paired t-tests results on the students' ranking of their knowledge and skills on the learning objectives on the pre-survey and post-survey are shown in Table 5. Table 5 shows that post-survey results are significantly higher than pre-survey results. This implies that students believed that they improved their knowledge/skill on all the six learning objectives of the case study after the project. Table 6 shows the results of how much the students agree with statements (a) to (f). On average 78% of the students agree or strongly agree with these statements. The students liked that they worked with some interesting and real life scenarios, and information was provided to complete the case study. They liked to refer to real material used in the field such as NIST document, and felt that working on such as project was beneficial for their job in the future. Some students also liked the fact that there was room given to students so that students could try to come up with what they would do about the situations rather than giving a response from something that was already determined. The students were challenged to get creative with their research.

	Obj. 1	Obj. 2	Obj. 3	Obj. 4	Obj. 5	Obj. 6
pre-survey mean	2.94	2.69	2.56	2.69	2.63	2.63
post-survey mean	3.94	3.81	3.94	3.88	4.06	3.81
Improvement from pre-survey	1.00	1.12	1.38	1.19	1.43	1.18
two-tail p-value	0.0004	0.0003	7.84E-05	0.0002	2.59E-05	0.0004

Table 5: T-test results of students' ranking of their knowledge/skills on incident response planning (number of students: 16)

Statement	Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
(a) This project is practical and will help you to apply what you learned to a job you may have in the future.	28%	60%	6%	0%	6%
(b) You enjoyed working on the project.	17%	71%	6%	6%	0%
(c) This project increased your understanding of incident response planning.	44%	39%	11%	0%	6%
(d) This project stimulated your interest in learning information security.	17%	49%	28%	6%	0%
(e) This project combined classroom and real-life experiences.	17%	50	17	11	5
(f) This project helped with your motivation in learning security management and information security.	17%	60	17	6	0

Table 6: The results of how much the students agree with statements (a) to (f) (number of students: 16)

4. A PROPOSED PROCESS MODEL

In an effort to promote the use of case-based learning methods in information security education, we propose a process model that uses a Web-based case library and Web 2.0 tools to facilitate the use and sharing of information security cases. This proposed process model can be used to provide guidance for the development of an information security case library which can be used as a teaching resource for educators who are interested in teaching security principles and skills to students in their courses. We feel that such a case library will be an effective way to help students learn the variety of security principles and techniques that they will use to solve the kind of security problems which they will encounter in their professional careers. Figure 1 presents our proposed process model for building such a Web-based case library system.

The proposed process model suggests collecting or capturing information security knowledge and experience (scenarios, stories, etc) using two approaches: either from security experts and experienced security teachers through the interview/storytelling approach or from an extensive literature review by examining existing reports, articles, documents and other resources. Interviewing and storytelling have been widely used to elicit explicit and tacit knowledge (Reamy, 2002; Whyte & Classen, 2012; Niu et al, 2013). Once the shared experience and knowledge is collected and captured as separate cases, they will be stored in a case library for indexing, retrieval, sharing and reuse.
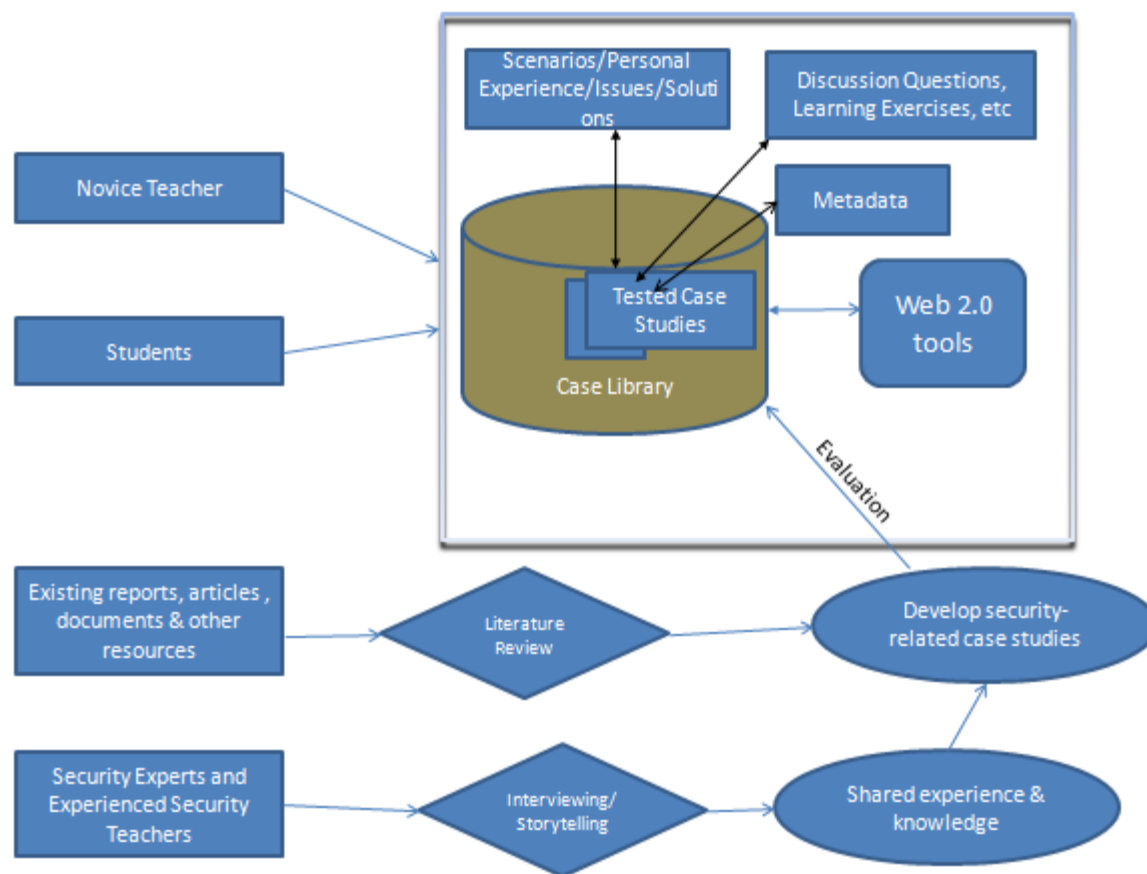
Figure 1. A process model for building an information security case library

On the other hand, case studies can also be developed through examining existing literature including various reports and secondary documents. Furthermore, large amount of information on cased-based learning of information security is currently stored and shared in a digital format available online. Therefore, Web-based search tools can be used to enrich the content of our Web-based case library (He, 2013; He & Xu, 2011; He, Wang, Means & Xu, 2009; Xu, 1996). In particular, the education information discovered and located through web-based search tools, such as Google, is typically developed by professionals from academia and industry. Those cases developed from academia incorporated education consideration during the development, which make them easy to be adopted and adapted to the education environment with certain customization, such as Carolyn Brodie's work on usable security and privacy (Brodie, 2005). As to case studies developed by professionals from industry, such as Roger Benton's work on how to security the enterprise (Benton, 2005) and Abdulwahed Mo. Khalfan's work on how to secure outsourcing projects (Khalfan, 2004), provides valuable insights on operations in enterprise environment. These resources certainly can enhance student learning in information security and prepare necessary knowledge and capability to transit students into working environment. Our process model will be able to integrate these resources to

develop case studies that can be easily adopted in the classroom environment. However, the copyright issue should be carefully considered and addressed in using literature and these online resources to develop case studies.

Furthermore, a case can be improved or enriched by adding additional materials such as reflection questions, discussion questions and learning exercises to enhance the case-based learning and instruction. Metadata can be used to enable the efficient search and browsing of cases in the case library (Richards, McGreal & Friesen, 2002; Yahya & Yusoff, 2008; Xu & Li, 2000; Xu, Liang & Gao, 2001; Xu, Wang, Luo & Shi, 2006). Both teachers and students can search the case library to find cases that meet their needs and special contexts in information security education. Through studying and testing cases stored in the case library, novice teachers can easily acquire specific knowledge and skills for teaching information security principles and techniques and students can get access to a variety of cases and examples to better comprehend security concepts in different contexts. Thus, the proposed process model can be used to promote and support knowledge capturing and transfers from various sources and further enhance information security education.

In addition, our process model will also help analyze the current development of case-based learning in information security for the following fields: Fundamental Aspects, Cryptography, Security Ethics, Security Policy and

Governance, Digital Forensics, Access Control, Security Architecture and System Administration, Network Security, Risk Management, Attacks / Defenses, Operational Issues, Secure Software Design and Engineering. The above fields are extracted from both Information Assurance (IA) guidelines developed by Steve Cooper et al. (Cooper et al., 2010) and Strawman's CS curriculum 2013 (Sahami et al., 2012). The purpose of such analysis is to classify and match existing resources with known curriculum guideline, so that instructors can utilize case studies in their security education easily. Such analysis will also help us to figure out if any of the above fields lack cases for information security learning. This will lead to further development of case studies in the identified fields or help us identify root causes for the lack of cases in the identified fields.

Some additional features can be used to enhance the case library through Web 2.0 tools. Below are some examples of the additional features:

- Commenting and feedback function. Users can use blogs or wikis to comment on each case study, and to reflect and exchange ideas and comments with other users. Users can also provide materials such as reflection questions and learning exercises to enhance existing cases in the case library through blogs or wikis.
- Social tagging. Users can enter tags to categorize and retrieve content stored in the case library. User-created tags are also a kind of metadata. This tagging feature should make specific cases easier to find.
- RSS feeds. The RSS feeds feature can allow users to keep up-to-date with the case library when new cases are uploaded to the case library. RSS feeds can also notify users when new comments or information are added to an existing case in the case library.

5. RECOMMENDATIONS FOR IMPLEMENTING THE PROPOSED PROCESS MODEL

Some recommendations to implement the proposed process model are listed below:

- Using existing taxonomies or ontologies of information security to categorize the case studies. Previous researches in the information security domain have developed various taxonomies and ontologies such as vulnerability, threat origin, security scale, control type, and asset to formalize information security knowledge (Herzog, Shahmehri & Duma, 2007; Fenz & Ekelhart, 2009; NIST, 2009). These developed taxonomies and ontologies can be reused to guide the development of case structures and case features.
- Supporting case representations using multiple formats. The case study we describe in section 3 is a textual case. However, case representations should not be limited to only one format. Other ways to enhance the learning of case content such as graph, concept maps, animations (Yuan et al., 2010b), and multimedia (audio, video, etc) should be considered or incorporated to enrich the case representation too.
- Case reflection and/or discussion questions are valuable resources to stimulate student thinking and learning. We recommend the development of case reflection questions and discussion questions using an existing

taxonomy such as Bloom's taxonomy (1956), a revised Bloom's taxonomy (Anderson & Krathwohl , 2001), or Fink's taxonomy (2003). Our case study in section 3 is a good example that reflects the role and value of the Bloom's Taxonomy in developing discussion questions for an information security case.

- Creating quality assurance benchmarks to assess the case quality. While case quality is difficult to define, there is no doubt that case quality is critical to learning and teaching. Quality assurance benchmarks should be established to assess each case in a systemic way in order to assure user acceptance of the case library. Ongoing feedback from users on the cases stored in the case library should be incorporated to refine the cases.
- Providing multiple methods to support the case retrieval. Users have different levels of information seeking experience and thus have varying preferences over different information seeking methods such as keyword searching, metadata searching and browsing(Wang, Moore, Wedman & Shyu, 2003; Moore, Erdelez, & He, 2006; Li et al, 2013). We recommend developers to provide different options on the interface for users to look for cases that match their needs or requirements.

There are some challenges associated with the operation of the proposed case library. Below are two challenges for future developers to consider.

- How to efficiently populate the case library with a sufficient number of cases? A valuable case library needs a number of quality cases to attract users. Developers need to find cost effective ways to rapidly populate the case library.
- How to maintain this case library for the long run? The cases stored in the case library may need to be updated to capture emerging trend. New cases also need to be added to the case library on a regular basis to keep the content of the case library up to date.

6. CONCLUSIONS AND FUTURE RESEARCH

As the concerns and interests on information security continue to grow, more and more colleges are offering information security courses to students. However, instructors in information security courses are confronted with many challenges in teaching various information security principles, concepts and techniques. One way to improve information security education is to use case-based learning methods. This paper presents a case study to show the value of case-based learning in improving the teaching of information security. Furthermore, this paper proposes a process model of developing an information security case library through Web-based technologies. This paper makes contributions to the literature by not only providing first-hand evidences to support the effectiveness of cases in teaching security management concepts but also presenting a process model of systematically applying case library technology to support case-based learning approach in the domain of information security education. As for the future research direction, we plan to develop more case studies, collect more cases from a variety of sources, and seek grants to apply the process model to build a shareable and searchable case library for information security education.

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