INDUCTIVE METHODS: DEVELOPING TEACHING/LEARNING STRATEGIES FOR A COMPUTER SECURITY COURSE

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Abstract

Constant risk to the confidentiality, integrity and the availability of information in our everyday lives and work has increased the need for responsible use of information and computing/networking systems. It is therefore vitally important that courses in information security encourage students to recognize relationships between concepts and comprehend the underlying structure of what is being learned. The current study examines the experiences gained in a senior-level undergraduate computer security course, with an emphasis on the students' reactions/perceptions/experiences as well as the educator's role in the teaching and learning process.

Introduction

Constant risk to the confidentiality, integrity and the availability of information in our everyday lives and work has increased the need for responsible use of information and computing/networking systems. Universities across the world try to integrate the topic of information security in various specializations such as IS-information systems, computer science, engineering, business, telecommunications, management, human resources, law, finance and health sciences. The Association for Computing Machinery (ACM) in its recent revised curriculum guidelines for a computer science program emphasizes the topic of security as one of the directions that needs to receive special attention (ACM, 2008).

Due to the importance of information security courses, encouraging students to recognize relationships between concepts and comprehend the underlying structure of what is being learned is of vital importance not only for their curriculum but for their future careers as well. It has been observed that the common reason for students to abandon sciences is the lack of connection between the course material and the real world (Kardash & Wallace 2001; Seymour & Hewitt, 1997). Academics and instructors should seek solutions to motivate and respond to the specific needs of students. A solution could be to

apply a student-centered method where the student is responsible for his/her own learning by building his/her own version of reality (Ktoridou, 2010). During the last few decades, education literature has presented a broad variety of student-centered teaching methods and has presented evidence that a proper implementation of a student-centered method could lead to a rise in motivation towards learning, a more positive attitude toward the subject and greater retention of knowledge and a deeper understanding (Bonwell & Eison, 1991; Johnson et al., 1991; McKeachie, 1986; Meyers & Jones, 1993). A student-centered approach includes inductive teaching and learning where students are primarily faced with challenges (questions, contextualized problems, complex problems, open-ended problems, authentic problem sets, authentic cases) and continue learning the course material in the context of addressing these challenges (Ktoridou, 2010).

Inspired by an earlier study (Ktoridou, 2010), the authors of this current work attempted to explore the practice of teaching an undergraduate computer security course incorporating the following three inductive methods: discovery-based learning, problem-based learning, and case-based learning. More specifically, this study examined the students' reactions/perceptions/experiences as well as the educator's role in the teaching and learning process. Based on this study, recommendations are given to academics and instructors who teach science courses and are interested in enhancing and enriching their teaching processes, increasing motivation, developing students' critical thinking and creative problem-solving skills, fostering a deeper understanding for the formation of positive attitudes and having confidence in their knowledge or skills towards the subject of information security (Prince & Felder, 2006).

Literature Review

Before describing the study and its findings, description of related terms and concepts is necessary and provided in this section.

Inductive Methods

Inductive teaching and learning is a general term that includes a range of instructional methods namely: inquiry-based learning, case-based instruction, problem-based learning, project-based learning, discovery learning, and just-in-time teaching. All these methods, besides being inductive, are student-centered; they initially present to students challenges (questions or problems) and the students continue studying the course material in the context of addressing these challenges. In class, students are actively involved in discussing questions and solving problems (active learning), while in and out of class the work is done in groups (collaborative learning). Prince and Fedder (2006) present a summary with the features of the common inductive teaching methods indicating obvious benefits. They also state that each method has its own research base, history, guidebooks, supporters, and critics, and it is not clear what the methods are and how they are interrelated. Lohman (2002) claims that similarities of case-based

and problem-based learning are obvious; however, in problem-based learning students are confronted with poorly structured problems driven by acquisition of new content knowledge while in case-based learning students analyze hypothetical situations that are well-structured, context rich, and involve finding solutions to problems and/or decision making. Other comparisons of case studies and problem-based learning have found no significant difference in regards to knowledge acquisition or performance (Katsikitis et al., 2002). Further definitions and applications of the methods discussed in this paper (discovery, problem-based and case-study learning methods) are summarized below.

Discovery learning. In this approach, students are given a problem or question to solve, a series of observations to explain, and finally they follow a self-directed work plan aiming to accomplish the assigned tasks, come up with a conclusion and "discover" the factual and conceptual knowledge through this work (Bruner, 1961).

Teachers assign problems or questions and assist students only on their effort without offering them any guidance or directions on their efforts. In higher education this method is avoided due to the lecturers' concern of sacrificing their intended content as students are to discover everything for themselves. However, in this paper the authors provide evidence that this does not occur when researchers apply the method with a small percentage of guidance during the learning process.

Problem-based learning. This approach to teaching offers students opportunities to learn via contextualized problem sets and situations. Group work and independent investigation enables students to achieve higher levels of comprehension, and develop more learning, knowledge-forming skills and social skills. Based on Duch's work (2008), lessons can be designed using different scenarios such as: (a) entire class discussion, (b) groups of students reporting their progress on earlier learning issues and listing their present learning issues and future plans of work, and (c) short lectures on group work, aiming to keep the class up to date on general issues and clarify common difficulties, as well as to suggest additional learning issues.

Prince (2004) examined several meta-analyses of problem-based learning and concluded that the strongest positive effects of the method relates to the student's and lecturer's responses to the method and to a small but robust improvement in students' skill development. Similarly, Nelson (2003) in his work provides evidence of successful implementation of problem-based learning in graduate courses in instructional design, software development, and project management. Furthermore, a meta-analysis of the effectiveness of problem-based learning done by a group of scientists clearly indicates the positive effects of problem-based learning on knowledge acquisition and development of problem-solving skills (Dochy et al., 2003).

This paper, following the work of Ktoridou (2010), discusses the implementation of problem-based methods using complex, open-ended, authentic problems whose solutions require knowledge and skills specified in the learning objectives of the computer security course.

Case-based learning. In this approach, cases teach students about realistic decision-making situations involving one or more challenges: diagnosing technical problems and formulating solution strategies; making business management decisions taking into account technical, economic, and possibly social and psychological considerations; and confronting ethical dilemmas (Lundeberg, Levin, & Harrington, 1999). The cases should be real life — e.g., situations based on professional practice coming from magazines, newspapers or the interviews of those involved in the case.

The use of real-world case studies, in the course of computer security, was inspired by Lundeberg, Levin and Harrington's work (1999), which states that students, by analyzing complex real-world cases, should:

- acquire theoretical and practical understanding of the subject,
- become aware of the kinds of situations they will possibly face as professionals in the future,
- develop critical reasoning skills,
- explore their existing preconceptions, beliefs, and patterns of thinking, and
- make necessary modifications in prejudices, beliefs, and patterns to accommodate the realities of the cases.

Computer Security

There is still an ongoing debate in the academic community regarding a universally accepted precise definition of computer security. Informally, computer security deals with the protection of data (including raw data, user data, software, firmware, etc.) residing on end-systems from accidental or malicious modification, disruption, unauthorized access, and disclosure. Due to the diversity in definitions and approaches, an educators designing a course on computer security puts emphasis on topics that capture their interpretation of the security concept.

Nevertheless, a course on computer security typically has at least the following learning objectives:

- to appreciate the need for data and information protection;

- to provide the student with a thorough knowledge of basic, computer security aspects such as user authentication, access control, and formal methods for multi-level security; and

- to expose students to techniques to manage the security of computers and users by means of contemporary host-based intrusion detection/prevention tools, physical security measures, auditing, and logging.

The authors' work that is presented in this paper focuses on exploiting the effect of diverse educational activities on the learning process of topics related to computer security.

Research Methodology

The collection of qualitative data was done through focus groups and classroom observations during an undergraduate course on computer security at the University of Nicosia. Forty-four senior-level students were enrolled in the course and they served as the sample for the current study. They worked in groups and individually to solve complex problems and real-life cases related to the subject and were required to report their results. Classroom observations took place and focus groups were organized with the students in order to address the goal of the educational activity.

The research objectives of the study were addressed through a case study design. Merriam (1998) in his work states that research that focuses on discovery, insight and understanding from the perspectives of those being studied makes significant contributions to the knowledge base and practice of education. Attention was focused on (a) teaching/learning processes rather than learning outcomes, (b) general course context rather than some specific variables, and (c) the process of discovery rather than in confirmation. The research method was designed to answer the question "How do students in an inductive learning environment perform, collaborate, exchange ideas and acquire the subject?"

The Computer Security course is currently being offered in the Spring 2011 semester, in weekly three-hour sessions, to a class of 44 computer science students. The curriculum was designed based on a student-centered approach including an inductive teaching and learning method. Based on the objectives of the course students worked individually and in groups on question answering, situation exploration, realistic decision-making situations, contextualized problem sets and situations.

Data Analysis

The authors used group work skills, communication, problem-solving skills, and content learning as four different types of evidence to analyze the results of the study. The lecturers moderated the students' work in class and documented their assessment results.

Discovery Learning

In this educational activity students were given the topic of information security in an enterprise setting, a completely new topic, and were asked to search for this topic. As a slight diversion from the original principles of discovery learning, the students were given the sources and their task was to prepare a five-slide presentation and assume the role of the lecturer.

Group work skills. Students were separated into eight groups of approximately five students in each group. They worked together to gather resources, investigate the topic, and develop the five-slide presentation. Based on the presentation results it was evident that students worked as a team with a mutual respect and responsibility towards presenting their results. Each group member was responsible for his\her slide initially and then answered questions on the overall work.

Communication. Communication among students was based mainly on responsibility issues. Students felt responsible towards their learning and their team mates. An ongoing communication among team mates led students in delivering a good job and by the deadline.

Problem-solving skills. The well-organized teamwork led students in finding common solutions to any problems they faced since they were all responsible for their learning.

Content learning. Content learning for all students was significantly satisfactory since they were entirely responsible for their learning and, more importantly, the transmission of their knowledge to their lecturer and classmates.

Problem-based Learning

Problem-based learning relies on presenting contextualized, open-ended authentic problem sets on a topic that the students individually or as group will further investigate and derive a solution. In order to appreciate the need for computer security, the students were asked to construct an attack tree that will allow an attacker to view the wall of a Facebook group. The lecturer briefly explained the concept of an attack tree, and the students formed groups to discuss and come up with a solution.

Group-work skills. The success of this activity depended on working as a group. Indeed, all teams use all members to provide an answer. Because there was no

single correct answer, the students felt more comfortable to present and voice their ideas within their team.

Problem-solving skills. It was apparent that the teams approached the solution based on the knowledge of the team members. Some teams presented a very technical solution (network-oriented attacks) whereas other teams relied on a more social approach (social engineering techniques).

Communication. During discussions for the development of the group report, students seemed satisfied to share their ideas, perceptions and investigation results with their team mates. This basically was derived from differences in their prior knowledge, the way they approach a given problem and how they come up with solutions.

Content learning. The solutions were presented in the class and it was evident that the students not only comprehended the topic but they also showed great interest in the other teams' approach. A follow-up article on attack trees (Schneier, 1999) was made available to the students after the end of the lecture.

Case-based Learning

It is challenging for students to relate theory with real-world situations, unless they are exposed to a real-world case. Exploring, analyzing and discussing realistic cases, students can better acquire theoretical and practical understanding of the subject and develop critical reasoning skills. Furthermore, students may possibly face similar situations as professionals in their future careers (Ktoridou & Dionysiou, 2011).

The objective of this educational activity was to get familiar with the ISO 17799 through case-based learning. ISO 17799 is a set of recommendations and best practices for information security management that security-aware enterprises should follow. The lecturer assigned a paper reading (Google Inc., 2010) on the ways Google creates a security-based platform for offering its Google Apps products, which is based on the ISO 17799. The reading assignment was accompanied by the case study assignment that required students to do preparatory work prior to the lecture. This individual work was followed by group discussions during class time, and then the preparation of a group report that was collected by the lecturer. The groups were formed in an ad-hoc manner during class, without any involvement from the lecturer. The observations for this activity are summarized below:

Group-work skills. Out of the eight teams, only a couple worked as a group to provide answers to the questions. The majority of the teams simply divided the questions among the team members and then combined their answers into a report. There were also teams that only a couple of members did the work, mainly due to the fact that the remaining team members came to the class unprepared.

Problem-solving skills. The students were very specific in their answers, mainly because the paper was quite detailed and precise in presenting the ways Google deploys the ISO 17799 in their everyday activities.

Communication. Communication among students was not satisfactory during their teamwork. The reason was mainly because only two groups operated as a "team." The lack of communication led to misunderstandings and failure of the group work.

Content learning. The majority of the students got familiar with only specific aspects of the actual deployment of the ISO 17799, depending on the question they were responsible for. However, each team gained knowledge in concepts related to Google Apps, such as cloud computing, distributed data centers, and data redundancy vs. data backups, as at least one member from each team made inquiries during class about these topics. The lecturer provided answers to the team member but the entire team had to pay attention as well.

Conclusions

The three teaching methods presented in this paper (discovery learning, problem-based learning, and case-based teaching) were presented to students inductively. Students acquired the content, knowledge, methods, and skills that an undergraduate computer security course should offer with different levels of guidance provided by the lecturer during the implementation of each method.

The authors' conclusion was that the problem-based learning was by far the best learning method for the particular course and students. It did not require pre-class preparation and the students worked as a team to produce results. On the other hand, the case-based learning was effective only if the students prepared prior to the class. Otherwise, unprepared students become a burden on their team. A suggestion to the lecturer that wishes to get engaged in this learning method is to require the students to submit electronically their pre-class work. In this way, each student has to at least get familiar with the case study. The discovery-based learning was implemented with a slight diversion from its original principles by supplying the students with particular sources of information. In this way, the students were guided towards sources by constraining their discovery methods.

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