Enabling Constructivist Learning in a Graduate Information Security Course

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Abstract – Constructivism is a learning theory that emphasizes learner-centered knowledge acquisition and assimilation. In this paper, I report my experience of implementing a constructivist learning environment in a Master's course in information security. Following constructivist tenets, the implementation was composed of (a) a personal knowledge construction component culminating in a security presentation and (b) a social construction component in which students constructed knowledge with their peers. In addition to narratives of these components, potential drawbacks are discussed.

Index terms – Constructivism, learning theory, information security education

I. Introduction

In this paper, I report my experience of implementing a constructivist learning environment in a Master's elective course in information security at a large public university in southwestern United States.

II. Constructivism

As a pedagogical paradigm, constructivism has its roots in the theories of Dewey [1], Piaget [2], [3], and Vygotsky [4]. It has enjoyed rapid development since the 1970s and is becoming an influential learning theory [5]. According to constructivism, individuals assimilate new knowledge by producing cognitive structures based on their own exploration. The theory emphasizes the learner's critical thinking ability, which he/she applies to analyze situations, look for evidence, and make connections between the subject matter and his/her prior knowledge and experiences [6], [7], [8].

Constructivism stresses leaner-centered learning [5], [9]. In the traditional, objectivist paradigm, the instructor controls the instructional process and is considered the authoritative source of knowledge [5], [7]. The knowledge is delivered to the students through lectures and students absorb the knowledge passively [5]. By contrast, in constructivist learning, the instructor is no longer the sole authority on knowledge but, instead, acts as a facilitator of learning [5]. The learner plays an active part in his/her learning process. His/her role transforms from the recipient of knowledge to the "constructor" of knowledge [10], by seeking out new information and incorporating it with personal experiences.

Constructivism has been found to achieved a number of desirable learning outcomes, including improved critical thinking and problem solving abilities [5], enhanced creativity [11], deeper understanding of [12] and positive attitude toward [11] the subject matter, and better communication and presentation skills [5].

I had taught the Master's course in information security for three semesters in the traditional paradigm before I decided to implement a constructivist learning environment in Spring 2011. This decision was based on, in addition to the merits of constructivism, high maturity and diverse background of the students, which are desirable conditions for constructivist learning.

III. Implementation

Discourse and interactions are fundamental to learning [13]. Accordingly, a constructivist learning model is composed by two parts: individual constructivism, in which the learner constructs knowledge, and social constructivism, in which a group of individuals acquire knowledge through interactions within the group [8]. These two parts complement each other and should be integrated into a constructivist learning environment [14].

Therefore, for each student, my implementation of constructivism in this course was composed of two components: (a) a personal construction component that culminated in a security presentation as articulation of the knowledge constructed by the student, and (b) a social construction component during which students interacted with both the presenter and other peers to assimilate knowledge.

A. Personal Construction of Knowledge

Constructivist learners take more responsibilities in their learning process, including determining their learning needs, setting goals, monitoring progress, and deciding on how to reach the desired learning outcomes [15]. Furthermore, a learner should be provided the opportunity to articulate his/her newly-acquired knowledge [13]. "Articulation is a cognitive act in which the student presents, defends, develops and refine ideas" [6, p. 33].

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To articulate his/her knowledge, the student must organize his/her thoughts into suitable level of abstraction and knowledge structures [6], hence engaging in active learning.

Out of the 14 weeks in the semester (after excluding three weeks in which exams and guest speaker presentations were scheduled), only four weeks were carried out as the traditional, "objectivist" lectures. In each of the remaining 10 weeks, a student selected a topic from those listed in the syllabus and acted as the leader on the topic (see Figure 1 for a list of topics).

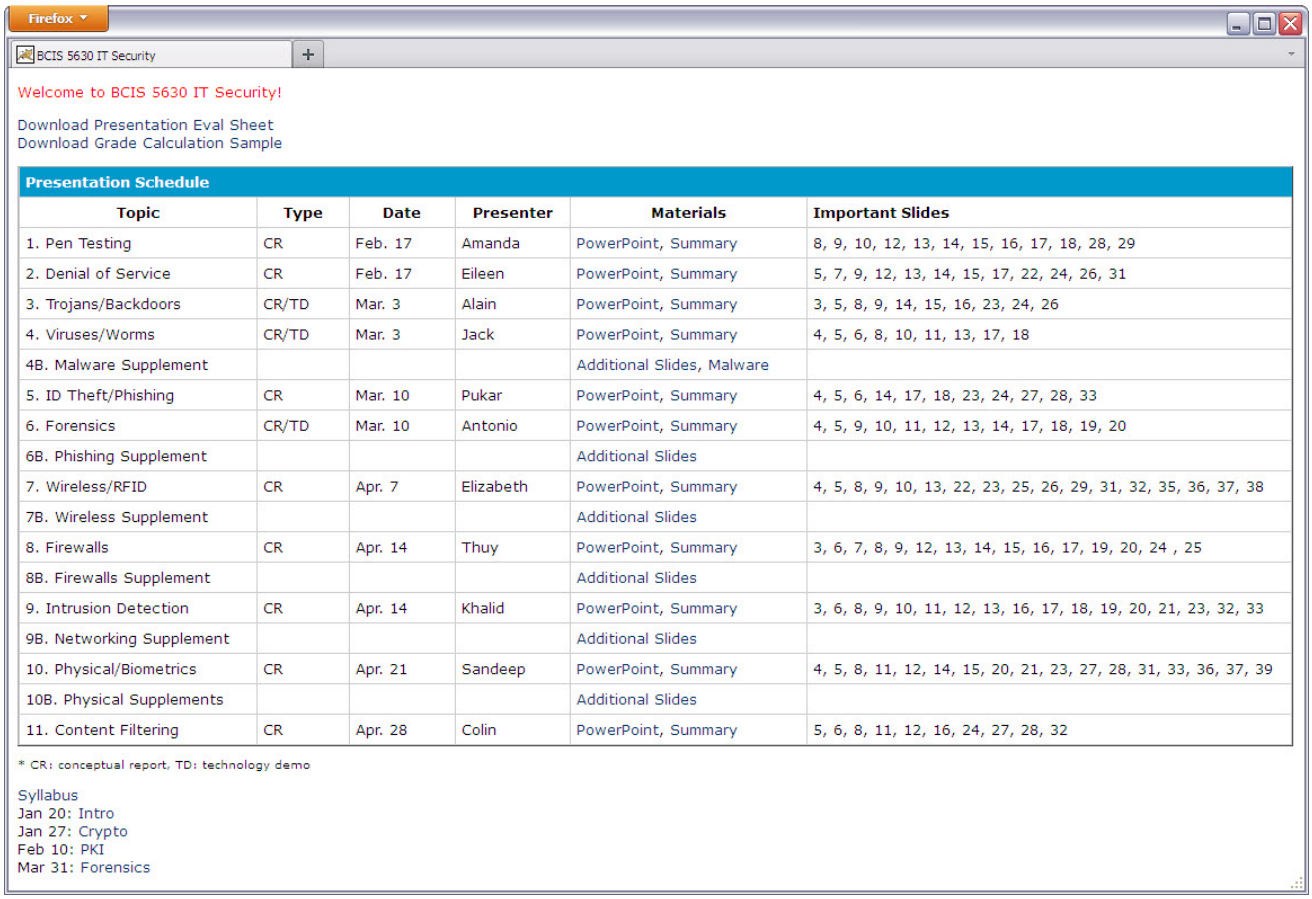
The leader is responsible for conducting an in-depth research on the topic. The main textbook used in the course was *Computer and Information Security Handbook* [16], which was a compendium of 43 chapters written by

Hacking and Countermeasures: Threats and Defense Mechanisms [17] were assigned.

From this point on, the learning environment would be nothing different from the objectivist model if the student simply read the chapter, summarized the key points, and threw in five minutes worth of PowerPoint slides at the beginning of the class. Instead, to enable constructivist learning, I used a number of administrative and logistic measures to ensure that the student constructed the knowledge and took the lead in the ensuing discussion, which was the major mechanism for social construction.

1. Scope of references

In the syllabus, I allocated 150 points out of a semester total of 400 to the presentation so that the students had strong motivation to excel on the presentation. A



Note: Pseudonyms are used for students to protect privacy.

Figure 1. Course Web Site Listing Presentation Topics

different authors on a wide variety of security issues and technologies. The format of the book made selection of reading easy and flexible. For each topic, I assigned 30-40 pages of reading (typically one chapter, but sometimes one chapter supplemented with related sections from other chapters). For two topics, chapters from *Ethical*

requirement for the presentation was that the leader must read the assigned reading for his/her topic ahead of time and consult at least four printed sources (e.g., books, journals, and magazines) and two online sources, in addition to the assigned chapter. They were required to list their references at the end of the presentation. Another

mandate was that, if the student's slides were simply a rehashed version of the assigned reading, he/she would automatically receive a failing grade for the presentation.

On average, a student listed between 6 and 30 references for their research. This represents an average of 14.27 references, more than double the mandatory number of six references. The sources they consulted were very representative of the usual sources IT professionals in the field will go to – books, white papers, corporate websites, product documentation, Wiki pages, trade magazines, and even academic journals.

2. Quality assurance process

True to the spirit of constructivism, I allowed student maximum amount of freedom when it came to the design of the presentation, from structure to contents to look-and-feel. Obviously, two potential issues should be addressed in such an approach – dilution of pedagogical focus and technical errors. The textbook chapters I assigned to the topics were selected for a reason – they contained essential information on their respective subject matters that students were expected to master. Therefore, the essential information should be incorporated into students' presentation one way or the other. Also, since students were new to the topics, it was expected that they might have some technical errors and misconceptions.

Therefore, I set up a strict timeline of quality control before the presentation went "live" on Thursday evenings. The leader must finish the draft of the PowerPoint slides and email them to me before midnight of the previous Saturday. I would then review the draft for pedagogical effectiveness and technical accuracy. Depending on the quality of student's work, I would reply to the students sometime between Sunday and midday Monday. In the email, I instructed the student to: (a) correct the technical errors I caught, (b) conduct more research on the areas in which his/her draft was lacking but which were important from a didactic perspective, (c) adjust the arrangement of some slides so that they were more pedagogically effective, and/or (d) other adjustments to improve readability of the slides. The amount and nature of revision needed varied. Most students were instructed to conduct one revision and passed my "QA" on Tuesday or Wednesday. Some required two revisions that would not complete until Wednesday evening or Thursday morning. On the other hand, there were also cases in which I made the submission of a revised draft optional because the changes needed were immaterial.

Some students have prior interest in or knowledge of the topic they selected. In those cases, they tended to create a presentation that did not necessarily touch on all the didactic elements. Nonetheless the presentation was an excellent discussion of the subject matter in its own right, with coverage of more advanced areas. In order not to stymie the student's creativity and enthusiasm, I would let the student go ahead with his/her version "as is." I then supplemented that with a set of my own slides to ensure that the fundamentals of the topic were covered in class. This also happened when the structure of a student's slides was such that it was difficult to inject pedagogically important information somewhere without negatively impacting the flow of the presentation.

3. Presentation

For all topics, students were allowed to present it as a conceptual report on the focal security issue or technology. For some technical topics, I provided them with the option of performing a hands-on demo of the technology. However, no student took the second option. Students treated the presentation seriously. All of them demonstrated the ability to conduct independent research on the focal topic and created detailed and interesting PowerPoint slides. The graphics and visual layout of the slides were pleasant to the eyes. Some students even incorporated multimedia elements into the presentation. One student included a demo of executing a malicious batch file. Presentation time ranged from 25 minutes to 55 minutes, with 45 minutes being the most usual length.

B. Social Construction with Peers

In a constructivist learning environment, the instructor emphasizes students' opportunities for collaboration with peers. During such activities, students share diverse perspectives and background, build upon each other's ideas, make their learning more meaningful, and achieve a clear understanding of theories [12], [18].

In this phase, a constructivist instructor's function is guidance, facilitation, and support [5], [18]. His/her focus is on determining how the students structure and process knowledge [10].

In my course, the second component of constructivist learning took place after the leader delivered the presentation. Given the role of the presentation in the process, my requirements for the presentation were nothing superficial. The duration requirement was set at a minimum of 30 minutes with 45 minutes expected. The leader also must provide at least two questions to kick off the discussion after the presentation, during which he/she was supposed to take the lead role. To cultivate students' interaction, I allocated to the discussion maximum amount of time after allowing for what was needed to go over my supplemental slides and hands-on demonstration, if any, and my concluding comments.

1. Discussion Questions

The questions were expected to be based on the leader's digestion of the knowledge he/she gleaned while preparing for the presentation. The main function of the

questions was to get students into active discussion immediately after the presentation. As such, they should not be quiz-like questions, such as "What is an RFID tag?". Instead, I instructed the leader to come up with questions that were thought-provoking, even provocative. To continue with the previous example, a better question to ask might be, "What are the primary privacy concerns caused by the use of RFID tags? Why?". The leader was required to include the questions, however unpolished at the moment, with the draft of his/her presentation. They went through the same review/revision process as did the draft itself. Again, the aim was to ensure their quality and didactic value. The process also prevented inappropriate questions from being asked.

In addition, the leader was to write a two page, bulleted outline of his/her presentation and distribute it to the other students at the beginning of the presentation.

2. Discussion process

A common pitfall when taking a constructivist approach is to let it slip back into the traditional instructor-led mode [6]. Therefore, I consciously contained my involvement in the discussion, only acting as a subtle moderator and occasionally "rebooting" the discussion with follow-up questions.

Overall, students were very active during the discussion. Many questions were asked to clarify and deepen their understanding of various aspects of the focal security issue or technology. The metaphor I gave students at the beginning of the semester was that of a security team meeting. The leader is the "content expert" in a particular area (the presentation topic) of which other team members (the other students) only have passing knowledge. To develop a deeper understanding of the subject matter so that they can solve a security problem at hand together, the team members go to the content expert and "pick his/her brain." This appeared to be what occurred during the discussion. Since the leader remained at the podium after the presentation and I purposefully occupied an inconspicuous seat in the classroom, the atmosphere was one in which the leader, not the instructor, was in charge. Feeling that they were talking to their teammates, students were more ready to ask question and to request repetition of an answer if it was not immediately clear, and the wording of questions was more causal, as compared with my experience in the previous three semesters teaching the same course in the traditional mode.

A larger portion of the discussion time was spent on the ramifications of the focal security issue or technology. For certain subjects, it could evolve into a debate on sensitive issues, with diverse viewpoints taken by different groups of students. However, since students were interacting with their peers, they did not experience the pressure to ostensibly bow to the viewpoints of some authority, such as the objectivistic instructor, who is supposed to be an all-knowing conveyer of knowledge [5], [7]. Neither did the students feel the rivalry and pressure that would stem from dealing with adversaries in a debate competition. Throughout the discussion the atmosphere was friendly, even when the most polarized views were pitched against each other.

The dynamics and intensity of the discussion varied depending on the leader's skills and the nature of the subject matter. Typically the discussion would run its course 45-60 minutes after the end of the presentation. However, for some topics, the discussion could have run indefinitely as any debates on sensitive security issues would in the field. If that seemed to be the case, I would conclude the discussion at about 75 minutes into it.

IV. Assessment

Students' involvement in the constructivist environment was evaluated with two assessment instruments: the security presentation grade and the participation grade. Together these represent almost 50% of the total points they could earn during the semester.

A. Presentation Grade

In this course, 400 was the total of grades from all assessments, e.g., exams, presentation, etc. The largest portion (37.5%, or 150 points) was allocated to the security presentation.

At the end of the class in which a student presented, both the instructor and the student's peers (not the presenter) filled out an evaluation form (see Appendix). The student was evaluated based on 12 criteria that included the major dimensions of the constructivist experience: (a) quality of knowledge presented, (b) effectiveness of the delivery of presentation, (c) helpfulness for other students' learning of the topic, and (d) quality of the discussion questions. The evaluation form also provided spaces for open-end comments, one under each of the 12 criteria.

The scores assigned to the presenter by each peer as well as by me were then summed and averaged. Student grades ranged from 135 to 145, with a mean of 141.82. I then prepared a detailed grade report for the presenter and emailed it to him/her on the Saturday following the presentation. The report listed the individual scores for each criterion assigned by each rater, as well as comments.

B. Participation Grade

All non-presenting students were required to complete the anonymous evaluation sheet for the presenter. More importantly, they were expected to be active participants

in the discussion. Failure to do so could cause deduction in the 40 points allocated to participation. Fortunately, most students did not need to be motivated by this mechanism of negative empowerment.

V. Success and Potential Drawbacks

The course did achieve many of intended results. Overall, students detected the different approach to teaching and learning, as commented by some students:

> "…it was a pleasantly different level of approach to teaching."

> "The most interactive approach w/ students I have experienced in grad school."

> "My current experience in a course where students present chapters from the text without prior review reveals the importance of your approach."

They were supportive of the change in approach:

> "My experience [in the course] was very positive and I endorse your approach."

> "I would definitely keep that research aspect of the course."

Students found working on the presentation a rewarding learning tool:

> "Although I'm not a fan of presentations (especially not a 45 min one) I actually learned a lot about my topic (intrusion detection systems) while preparing for my presentation."

They also enjoyed and learned from the peer-learning, social constructivism component:

> "I enjoyed the structure of [the course] and in particular the open discussions of the topics."

> "[The action of] asking us to present, and the classroom discussions, did bring different perspectives than what a book could provide."

> "I also found the other students presentations interesting and informative."

One student mentioned that the course piqued his interest in information security:

> "Overall, I think the class was a great learning experience and it further increased my interest in IT security which I'm actually beginning to get involved with in my current job. I hope my career path will allow me to further delve into the IT security field."

On the other hand, during the implementation I noticed some potential pitfalls in implementing a constructivist model, although they did not present major problems in my experiment. I avoided the drawbacks by essentially instituting what Karagiorgi and Symeou [9] refer to as "moderate constructivism."

First, since most courses from grade school to college still are delivered in the traditional mode, students may not be accustomed to the substantial shift in pedagogical model. Efforts are needed to persuade students of the merits of a constructivist model and to provide motivation for self-directed research and learning. In my implementation, this did not become a problem, because the majority of the class was Master's students who had full-time jobs. They were used to conducting independent research and were mature enough to maintain high level of motivation. To some of them, the presentation was no much different from what they might have to do at work occasionally.

Second, poor choice of mechanisms for construction could undermine a constructivist experiment. In my implementation, the central knowledge construction tool was the full-length presentation. The requirements of the presentation appeared to be intimidating to the students in the beginning. Some of them showed a lot of concern. However, after the first two presentations the concern was dissipated. Students found out that, to effectively convey the fundamentals of a particular security topic, 30-40 minutes were indeed the amount of time it should take. Most reported later that it was fairly easy to "lecture" for that long without using filler slides, off-topic talk, or other types of padding of contents. As commented by a student:

> "The course required … a 45 minutes presentation on one of the security topics which really seemed to be intimidating at first but as I worked through it, it went really good."

Of course, presentation was not the only mechanism and might not even be the optimal. To construct knowledge, security labs are a good tool, as a student remarked after the semester:

> "I know the course was designed to be more theory and less hands-on but I would [like to have] a lab portion or tutorial and some hands-on [homework] or something like that."

In hindsight, a combination of a shorter presentation and some hands-on labs could have been more effective.

Third, lack of instructor focus and control could impact a constructivist implementation negatively. Constructivism encourages student experimentation and interaction to create and share knowledge. However, students can easily lose focus and they are not aware of the pedagogical aims for each topic. The job of the instructor is to monitor their progress and subtly intervene when necessary to guide the

student experimentation and interaction toward the goals of the class. In this course, I achieved this by: (a) reviewing the draft PowerPoint slides and guiding the presenter's revision; (b) during discussion, interjecting questions that led students toward the key points they should take away from that class; (d) presenting supplemental slides or performing hands-on demo on the topic, usually for 30 to 45 minutes; (e) commenting on the subject matter after the discussion, and (f) when posting the student's PowerPoint file after presentation, listing slide numbers of those slides containing essential information on the topic. Needless to say, the monitoring and guidance efforts easily take as much, if not more, time and energy than what is required to deliver a traditional, objectivist course.

Overall, my personal observations mesh with the challenges that Karagiorgi and Symeou [9] suggest may occur in an extreme constructivist implementation. The advices for instructors are to practice constructivism in moderation [9] and to be mindful of their roles in the constructivist process and selection of constructivist pedagogical materials [19].

VI. Conclusion

In retrospect, my implementation of constructivist learning in the Master's elective in information security was a worthy experiment. Student enjoyed self-directed learning and social interactions with their peers in constructing knowledge. The security presentation served as an effective tool to stimulate and motivate individual construction of knowledge and students turned out quality work. Social construction of knowledge was equally satisfactory, with active participation observed. However, I did note a few potential pitfalls that call for careful action plans before implementing constructivist learning.

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APPENDIX. PRESENTATION EVALUATION SHEET

BCIS 5630 Presentation Evaluation Sheet

Presenter: **Date**:

Based on the scale from 0 to 10, 10 being the highest, please evaluate the presentation based on the following criteria. Write the scores you assign in the shaded squares. Write your comments, if any, in the rectangular boxes.

1. Overall, the presentation provides a good overview on the subject matter.
2. The additional materials other than the textbook chapter(s) are relevant and helps my understanding.
3. The presenter's synthesis of info from various sources shows his/her understanding of the subject matter.
4. The presenter appears to be interested in teaching the subject matter to us.
5. The presentation is neither too long nor too short.
6. The organization of the PowerPoint slides is easy to follow.
7. The graphics are pleasing and words on each slide easy to read.
8. I learn a lot about the main aspects of the subject matter from the presentation.
9. I become acknowledgeable about the state-of-the-art of the subject matter from the presentation.
10. The executive summary is well written with a structure easy to follow.
11. The executive summary is informative and helps me understand the presentation better.
12. The presenter's discussion questions get me to think about the subject matter with new perspectives.

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