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Incorporating Applied Critical Thinking into Computer Information Systems Curriculum under a University-Wide Initiative

Kwok-Bun Yue
yue@uhcl.edu

Wei Wei
wei@uhcl.edu

Computer Information Systems
University of Houston-Clear Lake
Houston, TX 77058, U.S.A

Abstract

Information Systems (IS) educators have long recognized the importance of critical thinking (CT) as an essential element in the success of their curricula. Past research on CT in IS curricula mainly focused on individual courses. This paper discusses our experience in incorporating CT in our Computer Information Systems (CIS) curricula under a university-wide initiative. Our university adopted a formal process for approving Applied Critical Thinking (ACT) syllabi for courses. The approval process is based on incorporating selected CT elements into the Student Learning Outcomes (SLOs), identifying CT-enhancing activities, and setting up a CT assessment plan according to a university-wide evaluation guideline. Six required and four elective courses for CIS students have been approved as ACT courses. This paper reports our activities, experimentation, and preliminary results. It discusses five unique features of our approach of weaving CT into our IS curricula. Our experience indicates that incorporating CT in the program level, and not only in the individual course level, has a good potential to be cost effective. The approaches reported here may also be adopted in individual courses.

Keywords: Computer Information Systems, critical thinking, information systems education, information systems curricula, information systems syllabi.

1. INTRODUCTION

Critical thinking (CT) has long been recognized by Information Systems (IS) educators as an essential element in successful IS education in universities. Many IS problems demand practitioners to think critically in order to construct innovative and cost effective solutions.

Incorporating CT into education in general has been widely studied at various school levels (Pithers & Soden, 2000). Most of the studies focus on traditional scientific domains including natural science such as Biology (Bailin, 2002) and social science such as Sociology (Rickles, Schneider, Slusser, Williams, & Zipp, 2013), as well as some professional domains such as Nursing (Paul & Heaslip, 1995; Peterson &

Bechtel, 1999; Yildirim & Ozkahraman, 2011). While most scientific studies focus on learning about "what is true?", computing related subjects often have emphasis on "what are the processes to devise/find the solution?" (Zendler, Spannagel, & Klaudt, 2011). This distinction makes computing-related subjects including IS perfect candidates for CT. Furthermore, the applicative nature of computing means that the problem is seldom well-defined. Thus, CT is crucial in stipulating the purposes, requirements, and assumptions of the problem. However, the reported efforts on IS have been sparse, with a relatively narrow focus on entry level MIS courses (Mukherjee, 2004; Wang & Wang, 2011) through the applications of some singular course-specific methods. Moreover, these research projects report on studies and experimentation on individual courses but not the general IS curricula. In fact, most of these efforts do not incorporate CT into more than one IS course. Consequently, they forgo the opportunities to seek beneficial synergy among related IS courses.

For university accreditation purpose, the University of Houston-Clear Lake (UHCL) developed and gained approval in early 2013 a Quality Enhancement Plan (QEP) entitled "Applied Critical Thinking (ACT) for Lifelong Learning and Adaptability." A centerpiece of the QEP plan is to incorporate ACT into courses by adopting a formal process for approving ACT syllabi. The approval process is based on incorporating selected CT elements into the student learning outcomes (SLOs), identifying CT-enhancing activities, and setting up a CT assessment plan according to a university-wide evaluation guideline.

Under the university-wide ACT initiative, six required courses and four elective courses for Computer Information Systems (CIS) major have been approved. Besides setting up the required CT-enhanced SLOs, activities, and assessment plans, faculty members have also experimented with supplementary CT methods and studies to use CT as a driving force to improve CIS curricula and courses.

These methods include using CT elements for framing subject matters, employing CT elements and standards for case analysis and question posing, applying CT techniques for iterative learning, and conducting initial pilot surveys on CT. The collective effort represents an attempt to incorporate CT not only in an individual course level but also in a program curriculum level.

This paper reports our CT activities and lessons learnt from this endeavor. Our initial experience indicates that incorporating CT in the curricula level has a good potential to be cost effective. We also envision that some of the experience reported may be useful to instructors of individual IS courses, even if their programs do not approach CT in the program curriculum level.

The paper is organized as follows. Section 2 provides a literature research on previous works on incorporating CT into IS courses and curricula. Section 3 describes the CT foundations of the university-wide approach and the formal ACT syllabus approval process. Section 4 discusses the adoption of CT in CIS courses. It uses an example to illustrate how CT contents and assessments are added to ACT approved CIS courses. Section 5 explains some CT activities and experiments using selected exemplary examples. Section 6 deliberates the lessons learnt and draws our conclusions with direction for future study.

2. LITERATURE RESEARCH

The critical thinking movement in education started as a result of increasing concerns among employers, educators, and public officials about an alarming phenomenon: students are not learning the thinking and reasoning skills. This deficiency causes incompetency of our future workforce in managing the complexity of real world scenarios (Gibson, 1995). During this movement, various theories of critical thinking emerged from theorists such as Richard Paul (Paul, 1995), Linda Elder (Elder & Paul, 2007), Gerald Nosich (Nosich, 2011), and Robert Ennis (R. H. Ennis, 1987), among which Paul's critical thinking framework provides the most complete explanation of how critical thinking should operate across disciplines and within them. As a result, Paul and Nosich have developed a multipart definition for the National Council for Excellence in Critical Thinking Instruction.

Paul's critical thinking framework (Paul, 1995) relies heavily on exemplary elements, standards, traits, and skills of critical thinking, which are believed to be independent of specific disciplines or subject matters. In addition, Paul also advocates that the students must learn how to reason within the characteristic modes of thinking of the various fields of study though there have been debates on the subject specificity of critical thinking (Robert H Ennis, 1989; Perkins & Salomon, 1989). Naturally, this applies to the domain of Information Systems. As a matter of fact, the IS 2010 Curriculum Guidelines for Undergraduate Degree Programs (Topi et al., 2010) lists critical thinking as one of the five foundational knowledge and skills. Information Systems, as a discipline, lie at the intersection of people, organizations, and technology. The overall IS domain endorses two general research paradigms: behavior science and design science (Hevner, March, Park, & Ram, 2004). These two paradigms cover the two aspects of a typical IS curriculum: the practical components and the theoretical components. The theoretical components emphasize organizational issues in acquiring and utilizing systems to help achieve strategic goals. The practical components, on the other hand, focus on solving problems through design in which design is both the process and the product. In order to become an effective practitioner in the IS domain, one must practice systems thinking (Checkland, 1999). For example, systems thinking enables an IS manager to see the holistic view without losing any of the three pillars, i.e., Organization, People, and Technology, thus helping to create a complete picture with all affecting components and their interaction. All of the above greatly increase the chance of making the best decision, which is essential to the survival and prosperity of an organization.

Realizing the importance of CT in IS, educators have made various attempts in promoting CT in teaching. In those efforts, various techniques have been employed to improve critical thinking skills. There are studies that embedded CT-promoting classroom activities such as case study (McDade, 1995; Thomas, 2011), predefined thinking queries (Wang & Wang, 2011), and class exercises (Mukherjee, 2004) into teaching. Bloom taxonomy was also used to redesign certain IS course materials with CT in mind (Eddins, 2006). Review of these work suggests the following: (1) The test beds for those studies are entry level IS courses, all with theoretical aspect of IS as focus; (2) All studies are conducted in the context of MIS courses in typical business school setting; (3) All seem to be individual courses focused without a larger scale or higher level initiative as guidance.

This paper describes our approach of incorporating critical thinking into the Computer Information Systems curriculum at UHCL. Though the study is motivated by the same notion shared by many others—critical thinking is a must-have skill set for a successful IS practitioner and can be taught in college, we argue our approach is unique in the sense that: (1) We strive to weave CT into the whole curriculum instead of individual course, which promotes valuable synergy; (2) The framework of CT adopted is guided by a university-wide initiative; (3) The framework is implemented into various courses taking into consideration subject specificity; (4) Repeated encounters with CT in various courses is expected to enhance students' refinement and retention of the skills; (5) The courses we included in the study cover both the theoretical and the practical aspects of IS education.

3. A UNIVERSITY-WIDE ACT INITIATIVE

The Southern Association of Colleges and Schools (SACS, 2015) requires institutes applying for reaffirmation of accreditation to develop and implement a Quality Enhancement Plan (QEP) to engage the wider academic community for institutional enhancement.

At UHCL, the QEP plan entitled "Applied Critical Thinking (ACT) for Lifelong Learning and Adaptability" was approved by SACS in early 2013. The qualifier "Applied" emphasizes that the university likes to see that students not only learn how to think critically, but also to apply CT on a daily basis.

The plan called for faculty and staff professional development in CT and the use of a formal process for approving ACT syllabi to drive university-wide ACT adoption. The CT model of the Foundation of Critical Thinking (FCT) was selected as the basis of the entire initiative. Based on the works of Paul, Elder, and Nosich, FCT is a popular 35 years old non-profit educational organization aims "to promote essential change in education and society through the cultivation of fair minded critical thinking" (Foundation of Critical Thinking, 2015a).

FCT's model of CT calls for the explicit analysis of thinking using eight Elements of Thought. These elements cover the essence of CT and can be used to systematically think about a topic effectively. The eight *CT elements* are (Foundation of Critical Thinking, 2015b; Paul & Elder, 2012, 2014):

1. Purpose: goal, objective.

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2. Question at issue: problem, issue.
3. Information: data, facts, observations, experiences.
4. Interpretation and Inference: conclusions, solutions.
5. Concepts: theories, definitions, axioms, laws, principles, models.
6. Assumptions: presupposition, taking for granted.
7. Implications and Consequences
8. Point of View: frame of reference, perspective, orientation.

Furthermore, FCT promotes the uses of *CT standards* to gauge the quality of thinking with CT elements. The nine CT standards it explicitly advocates are (Foundation of Critical Thinking, 2015b):

1. Clarity
2. Accuracy
3. Precision
4. Relevance
5. Depth
6. Breadth
7. Logic
8. Significance
9. Fairness

After going through the required formal training, instructors interested in the ACT approval of a course are required to submit a syllabus that satisfies a specific format for consistency. Among other requirements, the syllabus needs to clearly elaborate the following required components:

1. A description of how critical thinking shows up within the course or profession.
2. At least three student learning outcomes (SLOs) that are based on a unique CT Elements of Thought and a CT standard (ACT-SLOs).
3. Course assignments and activities that clearly promote the ACT-SLOs.
4. An assessment plan that rates the CT performance of each student in three levels in each of the ACT-SLOs.

To be approved, the submitted syllabus goes through iterative rounds of review by a peer committee until it reaches the desired quality. The rationale of using the same CT model and set of vocabularies throughout all approved ACT courses within the university is to enhance the chance of student adoption and application of CT through multiple encounters during their studies.

4. CIS ACT COURSES

The CIS program offers both B.Sc. and M.Sc. degrees. Approved ACT courses taken by CIS students were first prepared in 2012 and first taught in Fall 2013. By Fall 2015, the following CIS undergraduate courses have an approved ACT syllabus:

1. Information Systems Theory and Practice (required)
2. Data Structures (required)
3. Design of Database Systems (required)
4. Computational Statistics (elective)
5. Operating Systems (elective)

Likewise, the following five courses for CIS graduate students have an approved ACT syllabus:

1. Strategic Information Systems (required)
2. Advanced Systems Analysis and Design (required)
3. Database Management System (required)
4. Concepts of Programming Languages (elective)
5. Advanced Operating Systems (elective)

We use the course Strategic Information Systems to illustrate the essence of an ACT CIS course and its syllabus. Major components of the course syllabus can be found in Appendix 1.

Strategic Information Systems is a core requirement for the M.Sc. in CIS program. Though CT is highly desirable and had been used and encouraged by the instructor, CT had not been formally defined and specified in teaching before. To develop an ACT version of the course, the instructor went through the complete set of ACT training sessions by Nosich, who conducted workshops at UHCL. She combined the FCT model with her domain knowledge and teaching experience to develop a new ACT syllabus. The development process consists of several components that can be summarized as follows: (1) A deep retrospective investigation on previous course content and delivery, including the identification of deficiencies; (2) A summative study of the FCT model and ACT requirements; (3) Survey and research on specific techniques that promote CT; (4) The development of a list of guidelines/rules to abide by, such as accreditation requirements; (5) The design and adoption of certain techniques to fulfill all requirements while bridging the gap between "teaching" and "teaching with CT".

This course takes the "infusion approach" in teaching CT, i.e. critical thinking is infused into the teaching of subject matter with critical thinking principles made explicit to the learners. For example, the syllabus is branded with QEP label and an "Applied Critical Thinking Statement" is clearly displayed upfront. At a subject-specific level, the instructor explains what IS entails as a profession and how important it is to be able to learn and apply critical thinking. In addition, the instructor also introduces FCT model in lecture and illustrates the importance and benefits this practice can bring. Examples and demonstrations of how critical thinking can help with learning of this subject are given during class such as using Elements of Thought to guide case studies.

Student Learning Outcomes (SLOs) are compiled with the FCT model in mind. This is much more than a rewording task since applicable Elements of Thought and intellectual standards need to be identified and deemed feasible. More importantly, the outcomes have to be measurable. Behind a list of ACT-SLOs, is a well thought-through set of teaching tools complementing each other: (1) A list of content to be covered and their relative significance in achieving the learning goals; (2) A set of effective tools/activities to deliver content, encourage learning, and promote critical thinking in order to help students reaching the SLOs; (3) A series of assignments and examinations which are designed with explicit purposes that are no longer added as afterthoughts.

In addition, assessment plan is created to ensure that the level of critical thinking in selected ACT-SLOs can be quantifiable. This is feasible because the desired CT elements at various levels can be embedded in the design of assessment tools.

In Strategic Information Systems, we talk extensively about the importance of effective decision making and the role data and its management play in this process. Before CT teaching, we have a generic SLO stating: "Describe how to use information technologies to support decision making and business intelligence". In the new ACT syllabus, it is revised to an ACT-SLO: "Understand a *breadth* of *concepts* on how business intelligence *solutions* are used within an organization." The new ACT-SLO incorporated two Elements of Thoughts (concepts and solutions) and one intellectual standard (breadth). The instructor justifies the new ACT-SLO as follows: (1) Business intelligence and its applications are meant to be used to solve real problems, and understanding this is essential for students to appreciate the importance of the topic and see relevance to real world scenarios; (2) There is a wide spectrum of information and knowledge to comprehend; (3) The "within an organization" part refers to the people and organization factors in addition to the technology. The ACT-SLO helps the instructor to organize and deliver teaching content with clearly defined focus, which will later be evaluated using various tools including homework assignment and test questions, such as the following: (1) Multiple choice questions are designed to see if students will be able to identify the most proper and comprehensive definition of "Business Intelligence"; (2) An individual assignment asks students to conduct research and give examples of how Business Intelligence solutions have been designed and helped in solving problems; (3) A short question in an examination asks students to list several major components of a Business Intelligence solution.

5. CT ACTIVITIES AND EXPERIMENTS IN CIS

The QEP leadership team recognizes that instructors are the key in incorporating CT into university courses. They need to be fluent in CT and mindful of integrating CT into course activities. By the time faculty members started to prepare syllabi for ACT approval, they should have taken 4 to 5 days of workshops, spreading through two to three semesters, on the theory and practice of CT in courses. The rigorous approval process and the four CT syllabus requirements are designed to ensure that the instructors have thoroughly thought the course through the lens of CT, particular via ACT-SLOs, activities, and assessment. This was discussed in Section 4. Like other ACT courses, approved ACT courses for CIS students satisfy these four ACT requirements. This section discusses various activities of CIS courses that go beyond the minimum ACT requirements by examples.

5.1 Applying Elements of Thought to Topics

Publications by the Foundation of Critical Thinking include many examples of applying the eight CT Elements of Thought on a specific topic to reveal the underlying logic of the topic. The logic of many topics, such as science, engineering, physics, sociology, love, fear, etc. have been constructed (Elder & Paul, 2007; Foundation of Critical Thinking, 2015b; Paul & Elder, 2012, 2014). This provides a balanced and holistic framework on the topic to enhance well thinking. Although not required by our QEP ACT guidelines, Elements of Thought have been applied by instructors on various topics to construct its underlying logic, for examples:

1. The logic of Information Systems in Business in ACT Elements: curriculum level.
2. The logic of Relational Databases in ACT Elements: course level.
3. Applying ACT elements to mappings from the Object-Oriented Data Model to Relational Schema: course topic level.

As an example, Appendix 2 shows the current version of the logic of IS in business. Although this has very unlikely been done before, its value does not lie only on how well it has been constructed. In fact, this is already the third draft discussed among instructors and it is expected to be refined further. More importantly, this kind of refinement exercise will keep the instructors on constantly updating their understanding of the topic using CT and then using their results in courses and curricula to benefit the students.

5.2 Utilizing Fundamental and Powerful Concepts to Provide Central Themes

As discussed in subsection 5.1, CT elements can be used as different lens to understand and analyze a subject matter. To provide a central theme for their courses, some instructors constructed fundamental and powerful concepts (FPC) and included them in their syllabi. Suggested by Nosich (Nosich, 2011), FPCs are the core concepts that ground other concepts. FPCs provide a context for students to reason through a large number of problems, questions, theories and information. New information and concepts can then be viewed and analyzed through their relevance with FPC.

For example, the FPCs envisioned by the instructor for the undergraduate course Information Systems Theory and Practice are:

1. Businesses/Organizations need to have alignment between their IS strategy, business strategy, and organizational strategy to achieve maximum competitive advantages.
2. Information systems, if successfully implemented, have a paramount position in helping businesses/organizations to obtain and sustain competitive advantages.
3. Taking technologies out of their context is meaningless and sometime dangerous.

The course is the first IS course taken by undergraduate CIS major and contains a potpourri of topics seem to be loosely related to many students. Applying FPC throughout the course brings focuses and relevance.

5.3 Applying the CT Technique SEE-I for Iterative Learning

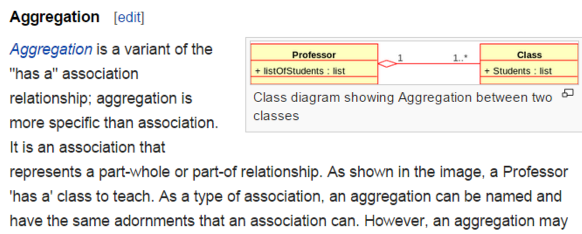
The CT elements and standards required by our ACT courses describe the nature of good critical thinking. They do not directly specify how good critical thinking can be acquired and then applied to important tasks such as learning. Some instructors experimented with applying various CT techniques to enhance learning within courses.

One such example is using the SEE-I method in iterative learning (Nosich, 2011). In this method, learners iteratively and correctively build deeper and more refined understanding of a concept by performing the following tasks on the concept:

1. State (S) the essence of the concept in a sentence or two.
2. Elaborate (E) the concept in the learner’s own words with greater details.
3. Exemplify (E) the concept by providing concrete illustrative examples.
4. Illustrate (I) the concept with diagrams, pictures, analogies, etc.

The advance of the Web provides huge volumes of information of varying quality. Incorrect, ambiguous, obsolete, inaccurate, and irrelevant information hinder students to develop correct understanding of a concept.

For example, in the graduate course DBMS, the instructor conducted a 40 minute classroom exercise to illustrate how SEE-I can be applied to learn a new concept critically. The class worked together to apply SEE-I on the concept of aggregation based on an entry on class diagram in Wikipedia (Wikipidia, 2015).



Aggregation [edit]

Aggregation is a variant of the "has a" association relationship; aggregation is more specific than association. It is an association that represents a part-whole or part-of relationship. As shown in the image, a Professor 'has a' class to teach. As a type of association, an aggregation can be named and have the same adornments that an association can. However, an aggregation may

Figure 1. Description on aggregation at Wikipedia

During the exercise, the class added annotation to the description from Wikipedia and iteratively worked through rounds of SEE-I. For example, the first take on "stating the problem" was something like "Aggregation is a 'has a' association." This was modeled directly on the first sentence from Wikipedia. Subsequent work on elaboration and exemplification with examples indicated that aggregation models a-part-of relationship such as "an arm is a part of a person". Later discussion on refining the defining statement revealed that "has a" is ambiguous. It has at least two meanings: a-part-of or ownership. The sentence "Tom has a car" means that Tom owns a car but not that a car is a part of Tom. In fact, the class saw that the example diagram in Wikipedia is a poor one as it indicates that a class is a part of a professor. Thus, 'has a' is a poor defining term for aggregation. The defining statement was thus changed to "Aggregation is a binary association modeling a-part-of relationship" in the second iteration. This correction illustrates many similar refinements and corrections in the SEE-I process in the classroom exercise.

As a result, students not only gained some concrete examples of how to use CT/SEE-I to iteratively learn a concept. They also acquired first-hand experience on the poor quality of information and how one can critically process them.

5.4 Using CT Elements on Case Analysis

Case studies have been known as a great teaching tool to promote critical thinking (Grossman, 1994; Herreid, 2004). Using well-written cases in IS curriculum is considered effective since they provide the students with opportunities to see real business problems getting solved with theories, frameworks, methods, and technologies they learned about in class. However, this effectiveness is greatly impacted by the way the case study is conducted. When conducted as out-of-classroom assignments, the case study task usually comes with a list of pre-defined questions, which restrict the way students explore, think, and organize. The instructor is oblivious of the thought process and has no opportunity to provide interactive guidance. On the other hand, when case studies are conducted in classroom settings, instructors often run into problems like: (1) Outcome often relies on how the questions are posed; (2) Tight teaching schedule often does not allow instructors to dwell and explore on questions deeply; (3) The atmosphere inside the classroom may discourage students to speak up.

Based on the FCT model, a graduate level CIS core course Strategic Information Systems experimented with applying CT in in-class case study questioning. According to (Wood & Anderson, 2001), a teacher's questioning techniques correlate with enhanced achievement, and should include a balance of convergent and divergent questions, probing questions, listening to student responses, redirecting student responses to other students, providing respectful feedback, and allowing for appropriate wait time after asking a question. The instructor adopted this approach and incorporated the Elements of Thought and CT standards into probing questions to guide the discussion.

The old practice is as follows. A short case is given in class together with several high level and broad questions such as: (1) What is the key problem described in this case? (2) Can you summarize the solution described in the case? (3) How do you evaluate the soundness of the solution? However, students were frequently found to be lost in thought, or to quickly provide incomplete or naive answers without deep reflections.

The new practice is as follows. The instructor conducts a brief analysis of a short case using the Elements of Thought, showing how we can organize our thoughts and do best in covering all the bases. Then, students are given a case and allowed to voice their answers/findings/opinions for an extended period of time, during which multiple probing questions will be asked whenever appropriate (the related CT elements and standards are highlighted within the parentheses below) : (1) Could you be more specific on that (clarity)? (2) Can you show us how is that related to what we are discussing here (relevance)? (3) Why do you think that is important (significance)? (4) Do any of you think there might be other explanations to that

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(breadth and fairness)? (5) I am having trouble seeing the connection. Could you elaborate on that (logic)? (6) Would you mind giving me an example to elaborate on that (depth)? (7) Let me get it straight, so what you are saying is…(precision and accuracy). Probing questions are also issued by the instructor to remind the students of the usage of the CT Elements of Thought as follows: (1) What are the *assumptions* we are making in our discussion? (2) Will the *solution* still be valid if one of the *assumptions* changes? If so, why? (3) Who are the stakeholders in this case? Will your *conclusion* change if your *perspective* changes from one kind of stakeholders to another? (4) Are there any *theories* and frameworks we can apply to this case? The students greatly appreciated this effort and they claimed the new practice helps them to "see" others' thinking, and therefore, "help to shape and perfect theirs".

6. LESSONS LEARNT AND CONCLUSIONS

Although we have only offered ACT approved courses for about two years, some initial observations can be drawn. It took significant effort for an instructor to design and teach an ACT approved course. This is likely due to the learning curve for the instructor to acquire the CT model used by the university and apply it to redesign the course. It seems that the effort for an instructor to offer a second ACT course is significantly less than the first one. Thus, once an instructor overcomes the initial barrier, subsequent marginal cost is considerably lower. Thus, it may be wise for IS programs to encourage instructors to incorporate CT into multiple courses just from the perspective of ameliorating the initial effort.

We also found that the initial student responses are positive. We have conducted small scattered pilot surveys on critical thinking with encouraging results. For example, Appendix 3 shows the survey result on the course DBMS in the third week of the Spring 2015 semester, immediately after we conducted the SEE-I classroom exercise as its first CT activity. Among the 26 respondents, the students think about how they think, and how they can improve their thinking about once every several weeks. This indicates that students care about their thinking skills. The students also clearly regard CT to be more important than the average skills and topics in CS and CIS. Furthermore, they consider the CT SEE-I classroom exercise (discussed in subsection 5.3) as important, useful, and interesting. This promising result is supportive of our supposition that incorporating CT into IS curriculum can be effective.

Overall, our experience indicates that incorporating CT in the program level has a good potential to be cost effective. Many students have shown good understanding of some components of critical thinking even before taking our ACT courses. However, they may not be mindful of applying CT when the situations call for it. Their understandings of CT also tend to be piecemeal and not solidly grounded. Thus, it is essential to provide both a strong theoretical foundation and a collection of practical techniques for the students to apply CT for an extended period of time on a wide range of problems. This will help students to form a habit of frequently applying CT. For a rich methodology like CT, it may take multiple complementary courses to effectively build up student expertise and form a lasting habit of applying CT. This is similar to, for example, the scientific method, which is another rich methodology central to many science subjects. Many science programs offer and require a set of courses applying the scientific methods in various ways. An important goal is for these mutually reinforcing courses to build up students' expertise and habit of applying the scientific method when they graduate. Incorporating CT in the program level uses the same approach to provide the same benefit that doing so in a single course may not provide. As the marginal cost (resource and cognitive wise) for the instructors to teach CT and for the students to learn CT decreases through multiple exposures under a program level approach, it can also be cost effective.

This paper is an initial report on a curriculum level approach on incorporating CT into IS education that may be useful to IS educators with similar interest in CT. There are many limitations and more works need to be done.

We expect that a curriculum level approach provides more repetitious exposures and should thus be more effective than an individual course approach in helping students acquiring CT and applying it into their daily problem solving. However, there is no concrete quantitative evidence to support it. We are planning to conduct a quantitative analysis to see how CT performance changes as CIS students go through their study. This requires a larger student sample which we expect to gain as more

ACT courses are offered for a longer period of time.

The planned quantitative study will entice us to work on overcoming a second limitation. Currently, the boundary for evaluating the subject matter and CT elements is not clearly defined. For example, the grade of selected questions in an examination may be used to assess the ACT-SLO "Demonstrate, in depth, the capability to discuss information systems' role in promoting collaboration and partnership in global economy, from various stakeholder's point of view." The assessment will be used to evaluate both subject matter (roles of information system) and CT element (point of view). Although they are correlated, what is desirable is the development of an assessment tool that targets CT element only. That will allow us to conduct quantitative study on the effects of various approaches on CT.

Furthermore, our experience with CT techniques for learning is limited to few general approaches such as SEE-I. It is desirable to experiment with subject-specific techniques that may be more suitable for the nature of our discipline. For example, the SEE-I approach is basically textual in nature, which can be less effective in capturing some of the complexity in the IS field. The authors are currently experimenting with concept map, a high level visual technique, to help students to acquire CT skills and apply them in learning.

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Appendix 1 Strategic Information Systems ACT Syllabus (Partial)

1. **A description of how critical thinking shows up within the course or profession.**
Information Systems, as an applied discipline, studies the processes of the creation, operation, and social contexts and consequences of systems that manipulate information. Information systems implemented/supported by various information technologies have progressed from a means to improve business operation to become an integral part of everyday life, a disruptor of business models, organizations, and society. The IS discipline articulates theoretical and analytical perspectives that integrates the technical and social aspects of business practice. System concepts and systems thinking are central to vital IS activities including the design, development process, operation, updating, and the control and security of systems. Critical thinking is an integral part of understanding, applying, and executing the system approach.

2. **At least three student learning outcomes (SLO) that are based on a unique CT Elements of Thought and a CT standard (ACT-SLO)**
SLO1: Have **deep** understanding of the *concepts and models* of business, organization, and IS strategies and the **significance** of have IS strategy aligned with business and organizational strategies.
SLO2: Identify and apply, with **clarity**, **relevant** information systems *theories and models (concepts)* to help business achieve competitive advantage.
SLO3: Demonstrate **deep** understanding of the *mechanism* how organizational decisions impact IS decisions and the *implications* of the impact.
SLO4: Understand the **significant** role of Information Systems in supporting business process and business transformation/reengineering.
SLO5: Understand **breadth** of *concepts* on how business intelligence *solutions* are used within an organization.
SLO6: Describe and analyze **accurately** the ethical and moral *models and principles (concepts)* that bind the uses of information in business.
SLO7: Describe **accurately** the Information Systems governance *approaches*.
SLO8: **Precisely** describe *concepts* of Information Systems architecture and infrastructure.
SLO9: **Clearly** describe the lifecycle of IT projects and the *solution* to technical, managerial, political *issues* during the lifecycle.

3. **Course assignments and activities that clearly promote the ACT-SLOs.**
Four case studies (25% of overall grade) will be given to the students throughout the semester. A typical study requires the following:
(1) In-depth reading of the case including acquiring of all relevant information. The objectives/goals of the study should be clearly identified and problems/issues should be precisely described.
(2) Thorough collection of data/information and analysis of the case following the given guideline with clearly identified assumptions, utilize proper theories, models, and apply principles correspondingly;
(3) Logically formulate thoughts/discoveries into professionally written report. A great focus in the report should be given to discussion of the findings, potential solutions to identified problems, possible implications and consequences of certain solutions.
(4) Communicate findings/conclusions through formal presentations. The students should demonstrate their capability of delivering content in clear, relevant, precise, and interesting manner.

4. **An assessment plan that ranks the CT performance of each student in three levels in each of the ACT-SLOs (partial).**
Midterm and final Exam: Both exams will be individual, in-class, closed-book, closed-notes. Exams are non-cumulative. Modules will be built into the exams to assess student's learning on the technical background of Information Systems. The details are as follows.

Artifacts	Artifacts detail	Targeted SLO
Midterm Questions in format of: Multiple choice, filling blanks, short answers.	Students will be assessed on their capability to: (1) **Clearly** *define* business intelligence (2) Explain with **clarity** how business intelligence can be used to provide *solutions* to business *problems* (3) Demonstrate **breath** of *information* on current business intelligence technologies and their application (4) Design **relevant** business intelligence *solutions* to emphasize business/organization *issues*	**SLO5**: Have breadth of knowledge on how business intelligence solutions are used within an organization.
Final Exam Questions in format of: Multiple choice, filling blanks, short answers.	Students will be assessed on their capability to: (1) **Accurately** *define* and describe Information Systems architecture (2) **Accurately** *define* and describe Information Systems infrastructure (3) With **clarity** identify the major *components*(*information*) of IT infrastructure (4) Demonstrate **in-depth** and **precise** *understanding* (*information*) of the technical elements of IT infrastructure components	**SLO 8**: **Precisely** provide *definition* of Information Systems architecture and infrastructure

The artifacts will be graded and an aggregate score for evaluation how well a student is doing on both learning outcomes. The following assessment levels will be considered:
Excellent: 90% and above
Acceptable: 70% to 89%
Unacceptable: 69% and below
…

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Appendix 2 The Logic of Information Systems in Business in ACT Elements of Thought

[a] Purpose: To effectively use information systems to support the missions and business strategies of the organization.

Notes:

- IS can be used to gain and sustain competitive advantages.
- IS can be used to expand and optimize business performance.

[b] Question: How do we design and implement information systems solution to solve business problems?

Notes:

- How do we identify the needs, challenges and opportunities of an organization, and use information systems to effectively satisfy the needs and challenges, and exploit the opportunities?

[c] Information: relevant information about the problem domains and the information systems solutions.

Notes:

- Information about the problem domains includes that of the organization, industry and economy.
- Information about the IS solution includes concepts and theories of information systems and information technologies.
- Knowledge of people, technology, and organization factors in the context of the information systems. Up-to-date exposure to real world cases in which information systems play significant role.
- This includes an understanding of the context of the collected information and the uncertainty and partiality of the information.

[d] Interpretations and inferences: Design, develop, evaluate, and manage effective information systems.

Notes:

- This includes policies, guidelines, and cultures that support business functions and decision making.
- The evaluation results may translate into maintenance, correction, upgrade or starting a new life cycle.

[e] Essential concepts: IS, IT, management, business and other relevant concepts and theories that guides the design, management, use, and assessment of information systems.

Notes:

- This includes a thorough understanding of relevant technical, managerial, and organizational concepts and theories.

[f] Assumptions: It is possible to devise cost effective information systems to support various needs of an organization.

Notes:

- No business/organization can afford to forgo information systems as solutions to their problems.
- Since information systems are very applicative in nature, without a good grasp of all assumptions of the problem domains, the IS solution will be ineffective.

[g] Implications and consequences: Well-designed IS solution to well-defined problems can be effective. Poorly designed IS solutions can be detrimental.

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[h] Point of view: Numerous possible considerations within an organized need to be considered and balanced to capture and model the problems, and design and evolve effective IS solutions.

Appendix 3 Result of an Example Critical Thinking Survey

CSCI 5333 DBMS, Spring 2015, Number of respondents = 26

[1] In the past, how often did you think about how you think? **Average response: 3.92**

(1) Nearly never.
(2) Once about every several years.
(3) Once about every several months.
(4) Once about every several weeks.
(5) Once about every several days or even more frequently.

[2] In the past, how often did you think about ways to improve your thinking? **Average response: 3.65**

(1) Nearly never
(2) Once about every several years
(3) Once about every several months
(4) Once about every several weeks
(5) Once about every several days or even more frequently

[3] Comparing to the average skills or subjects, how important do you think critical thinking is for CS and CIS? **Average response: 1.81**

(1) Much more important
(2) More important
(3) About the same
(4) Less important
(5) Much less important

[4] How useful and important was the iterative SEE-I and annotation classroom exercise (aggregation and composition with Wikipedia material as the source of information)? **Average response: 1.85**

(1) very useful and important
(2) useful and important
(3) neutral
(4) unuseful and unimportant
(5) very unuseful and unimportant

[5] How interesting was the iterative SEE-I and annotation classroom exercise (aggregation and composition with Wikipedia material as the source of information)? **Average response: 2.08**

(1) very interesting
(2) interesting
(3) neutral
(4) uninteresting
(5) very uninteresting