An experiment on the impact of critical thinking instruction on the understanding of IS implementation problems

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Abstract

Critical thinking is essential for student success in academia and in everyday life events. It is an important topic in Information Systems education but there is little published research measuring how it affects student learning. We present the results from an exploratory field experiment on the impact of teaching limited critical thinking skills in the Systems Analysis and Design course on the understanding of a complex systems implementation problem. The paper provides a brief overview of critical thinking research, and then is presented the design of the experiment, a discussion of the results and few directions for further research.

Keywords: Critical thinking, Systems Analysis and Design, Information Systems Management, Information Systems Education, Field Experiment.

1. INTRODUCTION

Critical thinking is at the heart of tertiary education and is also a key focus of university preparation courses (Wilson, 2018:256). According to Rotherham and Willingham (2010) critical thinking together with communication, Information and Communication Technology literacy, social skills, creativity, collaboration and problem-solving skills are essential for success in the 21st century and such skills need to be taught at universities.

A consensus definition of Critical Thinking was produced by the American Psychological Association as:

> "Purposeful, self-regulated judgment which results in interpretation, analysis, evaluation and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based" (Facione, 1990:2).

According to Strupple, Maratos, Elander, Hunt, Cheung & Aubeeluck (2016:92) this generic definition captures the complex multifaceted nature of the concept of critical thinking which may explain also some of the difficulty students face with understanding its meaning. The same authors provide a detailed analysis of various interpretations of critical thinking in Psychology but they stress also that critical thinking skills

may need to be conceptualized in a subject specific way reflecting the body of knowledge in a discipline and that is one of the motivations for this research.

Another motivation for this work was the fact that critical thinking does not enjoy popularity in the recent literature on Information Systems (IS). Various searches conducted in comprehensive publications databases produced a very limited amount of hits on the topic of critical thinking in Information Systems. That is in contrast with the quantity and quality of critical thinking research in other professional fields like Nursing (for a review of publications on critical thinking in that field see Von Collin-Appling & Giuliano (2017)).

The purpose of this paper is to present results from a field experiment on the impact of introducing limited instruction about critical thinking concepts in a Systems Analysis and Design class on the performance of students in analyzing a complicated case study about an IS project. The contribution of the work is that it describes a field experiment in Systems Analysis and Design on measuring how teaching about critical thinking affects student understanding of an IS implementation problem.

The paper proceeds with a brief review of past research on critical thinking on the topic in the field of information Systems, followed by an explanation of the field experiment on the impact of introducing limited instruction of critical thinking in a Systems Analysis and Design class, the results and their analysis, and a conclusion.

2. RESEARCH ON CRITICAL THINKING IN THE FIELD OF INFORMATION SYSTEMS

It is necessary to point out that critical thinking is used in this paper in the context of the use of the notion in Education and in Psychology (see the previously quoted definition from Facione (1990)). This is quite different from the use of the term critical thinking in Philosophy and in Critical Systems Thinking, usually related to the work of German philosopher Habermas, which has been introduced also to Information Systems and is associated with the notions of emancipation and critical social theory as is explained in Jackson (1992).

Critical thinking defined and its importance

Following Butler, Pentoney & Bong (2017:39), critical thinking involves thinking rationally in a goal oriented manner, it is a collection of skills and strategies that a thinker can use when a situation calls for them. The same authors conclude from their empirical data that critical thinking is more important than intelligence in real life events.

Research on the relevance of critical thinking for academic performance has been summarized by Wechsler, Saiz & Rivas (2018) who focus on investigating the overlap between creative and critical thinking. Similarly, Sola, Hoekstra, Fiore & McCauley (2017) also analyze relationships between creative and critical thinking and various ways to measure those. Their empirical results analyzing the impact of college education on critical thinking of senior engineering students show that there is not enough evidence to claim that they improved compared to freshmen and that is a source of concern.

Critical thinking is quite a complex notion that is hard to define in a concise and comprehensive way. Various definitions are provided in Ennis (1993), Facione (1990), Halpern (1998), Elder & Paul (2011) and elsewhere. Many aspects of research on defining critical thinking, its measurement and its theoretical foundations are summarized in Larsson (2017). He reports empirical results on measuring critical thinking of high school students. He uses a definition of critical thinking (based on Ennis (1993)) as person's ability to:

1. Identify conclusions, reasons and assumptions.
2. Judge the quality of an argument, including the acceptability of its reasons, assumptions and evidence.
3. Develop and defend a position on an issue.
4. Draw conclusions when warranted but with caution (for more details see Larsson, 2017:34).

While the previous definition attempts to define more clearly several distinct dimensions of the notion of critical thinking, we may note that they are similar to the aspects of critical thinking in the APA definition provided in Facione (1991).

Among the numerous publications dedicated to the practice of critical thinking in education we may note the Miniature Guide to Critical Thinking Concepts and Tools (see Paul & Elder (2014)) for its concise explanations of basic notions and practical templates that are easy to use in class.

Past publications on critical thinking in IS

Extensive searches in Advanced Google Scholar and several library data bases about papers exploring research on critical thinking in

Information Systems education showed lack of evidence for considerable number of publications on the topic. Related searches were conducted also for the fields of project management, computing, technology education and the results led to similar outcomes. More results were found for problem solving and critical thinking but those were almost exclusively in mathematics and to some degree in engineering. As many Information Systems programs are within business schools, it might be of interest to point that Bell and Loon (2015:119) provide published evidence that critical thinking is under-emphasized at the business school level. The main points in several relevant papers will be discussed next without claiming that we have covered all important publications on critical thinking related to Information Systems and Technology.

Mucherjee (2004) provides ideas on how to promote higher order thinking by Management Information Systems/ Computer Information Systems (MIS/CIS) students using class exercises. These are for a Decision Support Systems (DSS) course. The paper draws mainly on three previous publications in the Journal of Computer Information Systems between 1992 and 1994 related to promoting higher order thinking along the six categories of cognitive objectives formulated in Bloom (1956):

- knowledge
- comprehension;
- application;
- analysis;
- synthesis and
- evaluation (for definitions see Mucherjee (2004) and Bloom (1956)).

The author uses interchangeably the terms higher order thinking and critical thinking and stresses that the proposed exercises aim at developing the last three skills in the above list claiming that they are insufficiently addressed in computer information systems education. He proposes ten exercises based on reading a short text each from a popular textbook on DSS, then analyzing the text in writing by answering five questions and then following with a discussion. These relate to stating the author of the text given to the students, defining the consequences and the negative consequences from a faulty decision and two lessons derived from the short case. Mucherjee(2004) claims that the proposed class exercises have enhanced the critical thinking abilities of the students but does not provide any measurement of whether this was achieved or not. Next will be discussed a paper exploring critical thinking from the point of view of instructors in technology education.

Schooner, Nordlöf, Klasander & Hallström (2017:1) point that critical thinking and particularly problem-solving have been well researched in technology education, but seldom from the teacher's point of view. They investigate Swedish school technology teachers' views on problem-solving and critical thinking as curriculum components and as skills addressed in teaching. The data was collected through in-depth qualitative interviews of twenty-one teachers. Their results show that teachers might be applying one or a combination of the following teaching approaches: design, systems approach and value analysis associated predominantly with assessment of the impact of technology on society. They concluded that critical thinking is not clearly manifested in the design approach but a little more so in the systems approach, and it is very salient in the values approach. The first finding is interesting as it contradicts somewhat the wide spread claim in the literature that critical thinking is overlapping with creative and design thinking (e.g. see Sola et al. (2017)). Now we will explore a new approach to critical thinking inspired by the agile movement in software development.

Kreitzberg (2013) presented his ideas at an annual conference of the Project Management Institute. The paper title: Agile critical thinking: how to cope with change, complexity, and the unexpected, reveals the goals of agile critical thinking. The starting assumption of the author is that the traditional approach to critical thinking seems too linear, somewhat academic and simplistic and does not fit the characteristics of modern dynamic organizations. Instead he proposes that critical thinking should be taught as an agile, iterative process that incorporates feedback, learning and adjustment — even if it takes IT team back to its underlying definition of the problem, rethinking the assumptions, re-evaluating the data, and reconsidering the conclusions (see Kreitzberg (2013:2)). The author stresses that often decisions in real organizations are taken considering factors other than logic like corporate culture, competing agendas, limited resources, bias and emotion, imperfect information. The author discusses briefly two of the tools that might be used to promote agile critical thinking: 1. Clarify the question and 2. Meet people where they are. It seems that this is an interesting direction for the evolution of critical thinking skills applied in organizational settings but there is a need for considerable further research on the effectiveness

of the proprietary tools in agile critical thinking and their acceptance in organizations before we may judge how suitable and useful they are for IS practice. We analyze next a publication that deals with critical thinking in the popular area of data analytics.

Many white papers and blog postings contain the claim that critical thinking is vital for data analytics but there is little published research to support the claim or to investigate various aspects of it. One of the exceptions is a paper presenting two case studies of applying critical thinking in data science education (see Chen (2016). The author starts with the proposition that behavior mining is a new discipline in data science and asserts that its needs can be served well by critical thinking and concludes that the latter should serve as the foundation for today's data science education (Chen, 1916). The author presents then two cases of Behavior Mining for Big Data through critical thinking that shows the potential of the use of critical thinking in this important direction of many MIS/CIS programs.

The limited scope of the above papers indicates on the one hand the scattered and under-developed current publications on the topic and the potential for growth of research on critical thinking in IS and Information Technology education. Next, we will present an exploratory field experiment on the role of critical thinking instruction in an undergraduate course in Systems Analysis and Design.

3. A FIELD EXPERIMENT LINKING CRITICAL THINKING TO THE UNDERSTANDING OF A SYSTEM IMPLEMENTATION PROBLEM

A controlled field experiment was carried out to illustrate the impact of introducing basic critical thinking concepts in an undergraduate junior level Systems Analysis and Design (SAD) course at a North East state university on the understanding of an IS implementation problem.

Task

The task for the students was to analyze a case study on system initiation and implementation at Canadian Data Systems (CDS), the only case used from a collection of teaching cases in MIS by Schell & McLeod (2001), which can be considered as "fair use" according to Stanford University Library (2018). The case was about the complex project management issues associated with the introduction of a marketing information system in the company that was presented to the IT steering committee initially as a decision support system of limited scope. As a result, the existing company policy on approval of large projects was not applied and the project was not scrutinized properly by the IT steering committee. There were other problems in requirements gathering as well. The project failed. The description of the case study is not structured making it more realistic. The situation can be categorized as a complex problem and therefore was considered suitable for testing the critical thinking skills of the students.

Method

The task was assigned to students in two sections of students in Systems Analysis and Design after covering the material on project initiation and management in the course. Both sections were taught by the first author. One section was taught in the spring semester of 2017 while the second – in the spring of 2018. Both classes were taught in two sessions a week following the same syllabus and course content. The two sections were using the same textbook by Dennis, Wixom & Roth (2012). The 2018 group was however provided in addition with limited instruction on critical thinking concepts as will be described later.

1. The main goal of this article is…….
2. The key question that the author is addressing is……
3. The most important information in this article is……...
4. The main inferences/conclusions in this article are…….
5. The key concepts we need to understand in this article are…
6. The main assumptions underlying the authors. Thinking are…
7. If we take this line of reasoning seriously, the implications are…
8. If we fail to take this line of reasoning seriously, the implications are…
9. The main points of view presented in this article are…….

Table 1. Template for the analysis of the logic of an article (based on Paul & Elder, 2014)

This field experiment explored the ability of students to read critically a complex case study and describe their findings. This is justified by Wilson (2016:257) who points that reading underpins all university study. The experimental group in 2018 worked under the same conditions as the control group from 2017 with the difference that their critical reading ability was

enhanced by introducing them to basic concepts of critical thinking in advance. Their analysis of the case was supported by the Template for analyzing the logic of an article from the Miniature Guide to Critical Thinking (Paul & Elder, 2014:11) shown in Table 1.

One may come easily to the conclusion that the above template is reflecting to a large degree the dimensions of the definition of critical thinking by Ennis (1993) quoted in section 2. We used the template in table 1 to stimulate critical reading skills in the experimental group.

The assignment for both groups had the same scope and goals. The next issue we will discuss was the assessment of student performance. A suitable approach is a descriptive scoring scheme known also as a scoring rubric (see for details Moskal (2001)). There are two types of rubrics, holistic and analytic (Mertler, 2001). However according to Mertler (2001) a holistic rubric is more appropriate when it is important to judge the over quality of the answer and when students are expected to provide a response. Hence we chose to use a holistic rubric.

1.In what way has CDS done a good job of establishing a policy of information resource management? In what way or ways has CDS not done a good job?
2. Does CDS give a good example for its customers in terms of how it uses its own products. Support your answer.
3. What are the advantages of any of the CDS policy that requires organizational systems to be implemented in a top down fashion, and individual user or work group systems to be implemented bottom-up? What are the disadvantages?
4. If there is a problem at CDS what is it and where does it exist within the organization?
5.Was the Marketing manager right in maintaining that the marketing information system that was built more of a DSS than a MIS?

Table 2. Questions at the end of the CDS case that the students had to answer after reading the case

In both semesters students' understanding of the case was evaluated based on their answers of 5 questions at the end of the case as is shown in Table 2.

Student performance was rated on each question in Table 2 using a four-point scale (see Appendix 1) that is usually used in rubrics for assessment in education: beginning, developing, accomplished and exemplary. Further inspection of Table 2 shows that questions 3 and 4 are capturing the essence of the case study of concern and both questions can be used as a holistic rubric for assessment of critical thinking skills as the answers are related to points 1,2,3,4,5,6,7,8,9 in the template stimulating critical reading (Table 1). Question 5 is more about understanding of the types of information systems and hence is more of a technical question. The first two questions in Table 2 do not relate directly to the elements of the template for the analysis of the logic of an article. Hence, we may conclude that the evaluation of the answers to questions 3 and 4 using the rubric in Appendix 1 can be used as a holistic rubric for assessment of the critical thinking abilities of the students working with the case about Canadian Data Systems.

Population sample and treatment

The population sample involved two sections of similar size, the control 2017 group had 29 students divided in 9 teams and the experimental 2018 section included 27 students divided in 8 teams. The course is a required component of the Business Information Systems major. The students had similar previous educational background; similar number of credit hours taken at the university, similar gender composition and similar exposure to IS knowledge from past courses in the major. They had similar previous exposure to concepts about critical thinking in other classes.

The only significant difference in the treatment of the groups was that the spring 2018 experimental group was taught for about an hour the basic concepts of critical thinking as described in Paul & Elder (2014). The class session on critical thinking included explanation of the types of reasoning, some of the major concepts in critical thinking like assumptions and inferences, how to use the template for analysis of the logic of an article from Paul & Elder (2014). To nurture students' critical thinking disposition was used scaffolding along the recommendations of Wilson (2016) as the students had to apply in a preliminary assignment the template for analysis of the logic of an article for interpretation of a short paper about ethics in practicing data analytics. Later they had to apply the template in the case about Canadian Data Systems as part of the field experiment. The control group in 2017 had to answer the five questions in Table 2 directly after reading the

case without any introduction to critical thinking concepts in the class.

The answers of the students in the case study reports were independently evaluated by the first and the second author using the rubric in Appendix 1. If there was a difference in the results that was discussed further. The data in Appendix 2 and 3 reflect the final evaluation of the student case reports after reconciling any differences between the two evaluators.

The ***null hypothesis*** was that there is no difference between the control and the experimental group or also that the control group was better in its understanding of the problem. It can be interpreted also that the group which was not taught the foundations of critical thinking obtained results that are equal or better than those of the group which got instruction on critical thinking and applied first the template for analysis the logic of an article in its work.

The one tail t-test for the means of two independent samples with similar variances was applied to test this hypothesis for each of the five questions using the statistical functions of Microsoft Excel (see also Pollard, 1977:129) and especially for questions 3 and 4.

Discussion of the results

The results from the evaluation of the Spring 2017 reports regarding the answers to the five questions from Table 2 comprised the data for the control group in our field experiment (see Appendix 2).

The detailed results from the application of the earlier discussed rubrics (see Appendix 1) to evaluate the student answers in the spring 2018 experimental section are shown in Appendix 3.

The acceptance or rejection of the null hypothesis defined earlier (applied for each of the five questions) depends on how statistically significant are the results in appendices 2 and 3. This was tested by applying the one tailed t test to the data for each question and those results are shown in Appendix 4. As is evident from it, the absolute value of the t-statistic for questions 1,2 and 5 was smaller than the critical value corresponding to 15 degrees of freedom (n1+n2-2) (the degrees of freedom depend on the number of projects in both sections under concern). Hence, following Pollard (1977), we may conclude that the null hypothesis cannot be rejected for data associated with these three questions and that the student answers to them did not show any influence of coverage of critical thinking concepts. This is not surprising given the earlier analysis showing lack of relationship of questions 1,2 from Table 2 to the elements of the Template for the analysis of the logic of a paper in Table 1. As was pointed earlier, question 5 may also be considered as a more narrow technical question.

Now we will focus our attention to the data related to questions 3 and 4 from Table 2. We concluded earlier that they can be used as holistic rubrics to evaluate the impact of critical thinking instruction on the understanding of the complex case study about CDS. The absolute value of the calculated t-statistic was 2.536 for the third question and 2.329 for the fourth question. They are greater than the critical t-value (1.753) corresponding to 15 degrees of freedom. Hence, we may conclude that the null hypothesis is rejected at the 0.05 level of confidence for those question. Therefore, we may conclude that the limited instruction on critical thinking concepts in the spring 2018 experimental section in SAD had a positive impact on improving the student understanding of the complex IS implementation case about CDS.

4. CONCLUSIONS

This paper provided a brief literature review of some aspects of critical thinking research and of its presence in publications about teaching Information Systems and Technology. To demonstrate the relevance of critical thinking for that we conducted an exploratory field experiment on the impact of introducing critical thinking concepts in the Systems Analysis and Design course on student understanding of a complex IS implementation case study.

We may point as a potential limitation of the paper the exploratory nature of our research due to the small number of projects in the control and in the experimental sections. Further statistical analysis of future larger field studies is needed to provide a better answer with respect to whether covering basic critical thinking concepts in the Systems Analysis and Design course improves the understanding of complex IS implementation problems.

A potential problematic issue is the fact that while the main ideas of the case that was used in the experiment are as relevant today as they were at the time of its publication in 2001, the details of the case relate to somewhat dated technology. We had to use this case however

because of the lack of other suitable current texts describing complex IS problems. This points to a possible direction for future work associated with the development of more appropriate contemporary cases dealing with complex project contexts which may be used to assess student critical thinking skills in Systems Analysis and Design and more broadly in Information Systems and Technology.

The lack of recent published papers on critical thinking in information systems, computer information systems and information technology shows among other things that IS faculty do not have an answer to the question whether the critical thinking skills of students in those areas are adequate or in need of improvement. Another area in need of further research is agile critical thinking and its prospects to be labelled as a temporary fad or to become mainstream characteristic of IT practice.

Other future work may be linked to the possibilities for refining of the experimental tasks and the type and structure of assessment rubrics used to measure critical thinking in Information Systems to enable its conceptualization in a subject specific way as advocated by Strupple et al. (2016). Nevertheless, we believe that the reported work is a modest contribution to the understanding of the role of critical thinking in Systems Analysis and Design.

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6. REFERENCES

Bell R. & Loon M. (2015). The Impact of critical thinking disposition on learning using business simulation, *The International Journal of Management Education*, (Elsevier), 13, 119-127.

Bloom, B.S. (1956). *Taxonomy of educational objectives: The classification of education goals. Handbook 1: Cognitive Domain*, McKay, New York.

Butler, H.A., Pentoney, C. & Bong, M.P. (2017). Predicting real -world outcomes: Critical thinking ability is a better predictor of life decisions than intelligence, *Thinking Skills and Creativity*, (Elsevier), 25, 38-46.

Chen, Z.(2016). Behavior Mining for Big Data: Promoting Critical Thinking in Data Science Education, *Proceedings of the International Conference on Frontiers in Education: Computer Science and Computer Engineering (FECS);* Athens: 1-5. Athens: The Steering Committee of The World Congress in Computer Science, Computer Engineering and Applied Computing (World Comp).

Dennis, A., Wixom, B.H., Roth, R.M. (2012) *Systems Analysis and Design*, 5th Ed. John Wiley &Sons.

Elder, L. & Paul, R. (2011). *Critical Thinking: Tools for Taking Charge of Your Professional and Personal Life,* (3rd ed). Foundation for Critical Thinking Press.

Ennis, R.H. (1993). *Critical Thinking Assessment*, *Theory and Practice*. 32 (3), 179-186.

Facione, P.A. (1990). *Critical Thinking: A Statement of Expert Consensus for Purposes of Educational Assessment and Instruction*. Millbrae, CA, California Academic Press. (Eric Document ED 315-423)

Halpern, D.F. (1998). Teaching critical thinking for transfer across domains: Disposition, skills, structure training and metacognitive monitoring, *American Psychologist*, 53 (4), 449-455.

Jackson, M.C. (1992). An integrated program for critical thinking in Information Systems research, *Information Systems Journal*, 2(2), 83-95.

Kreitzberg, A. P. (2013). Agile critical thinking: how to cope with change, complexity, and the unexpected. *Proceedings of PMI® Global Congress 2013—North America*, New Orleans, LA. Newtown Square, PA: Project Management Institute.

Larsson, K. (2017). Understanding and teaching critical thinking - a new approach, *International Journal of Educational Research,* (Elsevier). 84, 32-42.

Mertler, C.A. (2001). Designing scoring rubrics for your classroom. *Practical Assessment, Research & Evaluation,* 7(25).

Moskal, B. M. (2000). Scoring rubrics: what, when and how?. *Practical Assessment, Research & Evaluation,* 7(3).

Mukherjee, A. (2004). Promoting Higher Order Thinking In MIS/ CIS Students Using Class Exercises, Journal *of Information Systems Education*, 15 (2) 171-179. ABI/INFORM Collection.

Paul, R. & Elder, L. (2014). *The miniature guide to critical thinking concepts and tools*, 7th ed., Foundation for Critical Thinking Press.

Pollard, J. H. (1977). *A Handbook of Numerical and Statistical Techniques*. Cambridge University Press, Cambridge.

Rotherham R.J. & Willingham, D.T. (2010). 21st century skills: The challenges ahead. *Educational Leadership*, 67(1), 16-21.

Schell, G. & McLeod, R. (2001). Canadian Data Systems Case, in *Management Information Systems Case Book*, 8th ed., 97-106, Prentice Hall.

Schooner, P., Nordlöf, C., Klasander, C. & Hallström, J. (2017). Design, System, Value: The Role of Problem-Solving and Critical Thinking Capabilities in Technology Education, as Perceived by Teachers, *Design and Technology Education*, 22 (3), 1-16. (Eric).

Sola, E., Hoekstra, R., Fiore, S., & McCauley, P. (2017). An Investigation of the State of Creativity and Critical Thinking in Engineering Undergraduates. *Creative Education*, 8, 1495-1522.

https://doi.org/10.4236/ce.2017.89105

Stanford University Libraries, (2018). *Copyright and Fair Use Guide.* Available online at: https://fairuse.stanford.edu/overview/academic-and-educational-permissions/non-coursepack/

Strupple, E.J.N., Maratos, F.A., Elander J., Hunt, T.E., Cheung, K.Y.F. & Aubeeluck, A.V. (2017), Development of the Critical Thinking Toolkit (CriTT): a measure of student attitudes and beliefs about critical thinking, *Thinking Skills and Creativity*, (Elsevier), 23, 91-100.

Von Collin-Appling, C. & Giuliano, D. (2017). A concept analysis of critical thinking: a guide for nurse educators, *Nurse Education Today* (Elsevier), 49, 106-109.

Wechsler, S.M., Saiz, M. & Rivas, S.M., (2018). Creative and Critical Thinking: Independent or Overlapping Components, *Thinking Skills and Creativity*, (Elsevier), 27, 114-122.

Wilson, K. (2016), Critical reading, critical thinking: Delicate scaffolding in English for Academic Purposes (EAP), *Thinking Skills and Creativity*, (Elsevier), 22, 256-265.

APPENDIX 1. A rubric for assessment of answers to questions at the end of the case study Canadian Data Systems (Schell and McLeod, 2001)

Questions at the end of the case Study about IS implementation at Canadian Data Systems	Definition of rubrics on a scale of proficiency (1-4)			
	Beginning 1	Developing 2	Accomplished 3	Exemplary 4
1.In what way has CDS done a good job of establishing a policy of information resource management? In what way or ways has CDS not done a good job?	Inappropriate answer, not dealing with information resource mgt	Partial answer	Well-defined answer	Answer supported by analysis
2. Does CDS give a good example for its customers in terms of how it uses its own products. Support your answer.	Inappropriate answer focusing only on hardware	Partial answer	Well-defined answer	Answer supported by analysis
3. What are the advantages of any of the CDS policy that requires organizational systems to be implemented in a top down fashion, and individual user or work group systems to be implemented bottom-up? What are the disadvantages?	Inappropriate answer, not discussing the essence of top-down and bottom-up approach.	Partial answer	Well-defined answer	Answer supported by analysis
4. Assuming that there is a problem at CDS what is it and where does it exist within the organization?	Inappropriate answer pointing to irrelevant issues	Partial answer	Well-defined answer	Answer supported by analysis
5.Was the Marketing manager right in maintaining that the Marketing Information System that was built was more of a DSS than a MIS?	Inappropriate answer, claiming he was right	Partial answer	Well-defined answer	Answer supported by analysis

Appendix 2. Results on answers to five questions on the case study by the teams in the control (Spring 2017) group which was not taught anything related to Critical Thinking during the course in Systems Analysis and Design

Questions	T1	T2	T3	T4	T5	T6	T7	T8	T9	Avg
1.In what way has CDS done a good job of establishing a policy of information resource management? In what way or ways has CDS not done a good job?	2	1	3	2	3	2	1	3	3	2,22
2. Does CDS give a good example for its customers in terms of how it uses its own products. Support your answer.	3	2	2	2	2	2	1	2	3	2,11
3. What are the advantages of any of the CDS policy that requires organizational systems to be implemented in a top down fashion, and individual user or work group systems to be implemented bottom-up? What are the disadvantages?	2	2	3	1	3	2	2	2	2	2,11
4. Assuming that there is a problem at CDS what is it and where does it exist within the organization?	2	1	3	1	2	2	1	1	2	1,67
5.Was the Marketing manager right in maintaining that the Marketing Information System that was built was more of a DSS than a MIS?	1	1	2	1	3	2	1	1	3	1,67

DEFINITIONS OF ACHIEVEMENT	Beginning	Developing	Accomplished	Exemplary
	1	2	3	4

Appendix 3. Results on answers to five questions on the case study by the teams in the experimental (Spring 2018) group which was taught the basic principles of Critical Thinking and the Template for analysis of the logic of an article in Paul and Elder (2014)

Questions	T1	T2	T3	T4	T5	T6	T7	T8	Avg
1.In what way has CDS done a good job of establishing a policy of information resource management? In what way or ways has CDS not done a good job?	3	2	2	2	2	3	1	3	2,25
2. Does CDS give a good example for its customers in terms of how it uses its own products. Support your answer.	3	2	2	2	2	3	2	2	2,25
3. What are the advantages of any of the CDS policy that requires organizational systems to be implemented in a top down fashion, and individual user or work group systems to be implemented bottom-up? What are the disadvantages?	4	3	3	2	2	3	3	3	2,88
4. Assuming that there is a problem at CDS what is it and where does it exist within the organization?	2	2	3	2	3	3	2	2	2,38
5.Was the Marketing manager right in maintaining that the Marketing Information System that was built was more of a DSS than a MIS?	3	1	1	1	3	1	3	3	2,00

DEFINITIONS OF ACHIEVEMENT	Beginning	Developing	Accomplished	Exemplary
	1	2	3	4

Appendix 4. Statistical results from calculating in Excel the one tailed t-test for two samples assuming equal variances applied to the data for both groups for each of the five questions (Q1…Q5) at the end of the case on Canadian Data Systems

	Q1		Q2		Q3		Q4		Q5	
	CG	EG	CG	EG	CG	EG	CG	EG	CG	EG
Mean	2.222	2.250	2.111	2.250	2.111	2.875	1.667	2.375	1.667	2.000
Variance	0.694	0.500	0.361	0.214	0.361	0.411	0.500	0.268	0.750	1.143
Observations	9.000	8.000	9.000	8.000	9.000	8.000	9.000	8.000	9.000	8.000
Pooled variance	0.604		0.293		0.384		0.392		0.933	
Hypothesized Mean Difference	0.000		0.000		0.000		0.000		0.000	
df	15.000		15.000		15.000		15.000		15.000	
T Stat	-0.074		-0.528		-2.536		-2.329		-0.710	
P(T<=t) one-tail	0.471		0.302		0.011		0.017		0.244	
t Critical one-tail	1.753		1.753		1.753		1.753		1.753	

The questions Q1. Q5 can be found in the first column of Appendix 1.
CG - Control group
EG – Experimental group