DEFINING, DEMANDING, AND DEVELOPING THE CRITICAL THINKER

By

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Abstract

This thesis examines critical thinking (CT) in education. Research includes a comprehensive literature review, focused on defining CT, understanding CT expectations in education, and expounding on how CT is best developed. To better support CT development and subsequent student achievement, a consensus should be reached regarding the definition of CT, and we consider prominent ideas of CT and its nature to offer a potential encompassing definition. This paper also includes analysis of a selection of Ontario's curriculum documents as well as a survey of professors teaching at universities across Ontario to identify CT promotion and expectations. CT is clearly valued in education, and is an important contributor to student achievement and academic success. However, our research demonstrates that explicit secondary school development of CT is often not sufficient considering the demands of higher education.

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CHAPTER 1: INTRODUCTION

This thesis serves as the final requirement of the Bachelor of Independent Studies program at the University of Waterloo, and the culmination of three years of personal study focused on critical thinking (CT) in education. The project was inspired by the thoughts of university professors who outspokenly told first year students that the types of thinking students practiced in high school would not "cut it" at the university level, and by students who became observably stressed when asked to analyse or critically think about provided material.

Consistently, university professors express dissatisfaction with students' abilities in the domain of CT. The Canadian Press (2009) notes that both students and professors believe high schools are not properly preparing students for university level work. Ivor Goodson (1992) observes that curriculum is a primarily social invention, yet its internal form has not been significantly altered since its initial development. Society, on the other hand, has been continuously changing and progressing. University education at one time would only be pursued by a very few, 'elite' set of individuals. Many of these students would have had additional enrichment, outside of the classroom, encouraging the development of higher-level thinking. As college and university education becomes more accessible and increasingly essential to success in modern society, it is important that the secondary school curriculum properly prepares students for CT demands of post-secondary education.

Our research focused on university level expectations of CT abilities, and the requirements fostering development of these principles in the secondary school curricula, guided by the research question: *"Are current critical thinking requirements in Ontario's secondary education system adequately preparing students for the demands and expectations of university*

level studies?" CT abilities are important predictors of success in higher-education, (Williams and Stockdale, 2003) but they are often not directly addressed in secondary educational planning.

To respond to our focus question, we began by considering established research and literature regarding the nature of CT, educational expectations, and methods for CT development. In order to clearly communicate the findings of the literature review, the review was separated into three parts:

Part 1 – Defining the Critical Thinker – proposes a working definition of "critical thinking" to guide further inquiry. This section discusses the history of CT as it relates to education, leading modern perspectives on CT, and some seemingly contrasting positions on the nature of CT. Ontario's use of the term "critical thinking" in education is specifically discussed. In this section, we also review similar competencies that may compliment CT, including metacognitive abilities, and we promote the consideration of both skills *and* character dispositions that can be associated with CT.

Part 2 – Demanding Critical Thinking – looks at the expectations of universities and colleges relating to CT skills and dispositions, and considers the influence of CT development on academic performance. The research suggests that instruction encouraging CT and learning strategies can be remarkably beneficial for students pursuing higher education. CT abilities are linked to higher levels of academic achievement and success, however, explicit CT development seems to be lacking in secondary school education.

Part 3 – Developing a Critical Thinker – considers four separate literature reviews which discuss teaching and developing CT. This section also discusses the transferability of CT, and

promotes the benefits of active learning and explicit instruction to foster successful CT development.

We contribute our own independent research to this field through the conduction of a survey of university professors' perceptions and expectations, and through analysis of a sample of Ontario's secondary school curriculum documents. The survey includes responses from 22 professors from universities across Ontario, significantly supporting the value of CT in education, and suggesting that professors are somewhat unsatisfied with the CT abilities of incoming students. Professors teaching introductory courses in English, Mathematics, and Physics participated in the survey, and we consider whether there are statistically significant differences between participant responses based on faculty affiliation. The survey also produced several insightful, illustrative comments regarding students' CT abilities and CT development.

Our curriculum analysis looked at three separate course documents: considering the most recent versions of ENG4U, MHF4U, and SPH4U. We identified separate components of CT, and examined how each component is developed or practiced in the various curriculum documents. Analysis also allowed us to compare differences in the curriculum's emphasis across different CT components. The completed document analysis suggests that CT development is often not explicit in Ontario's curriculum specifically.

Students who follow a university-preparation stream through high school should be able to confidently begin higher education with an established foundation in CT. This research discusses the discrepancy between current secondary school CT requirements and the demands and expectations of university level studies, suggesting ways to move forwards toward eliminating this gap.

CHAPTER 2: A REVIEW OF THE LITERATURE

CRITICAL THINKING – DEFINING, DEMANDING AND DEVELOPING.

Introduction.

Beginning in November 2012, we set out to review literature related to critical thinking (CT) and its application in educational settings. Specifically, we wanted to answer four focus questions:

1. How might CT be best defined in relation to the goals of education?
2. In terms of CT skills, what does the research literature say is needed for successful university/college study?
3. What is the relation between high school instruction and subsequent student performance at the university or college level, specifically in regards to CT abilities?
4. How can the development of CT be promoted in education?

The literature review developed into three distinct, yet connected sections, each focusing on a different aspect of CT. This research helps provide the foundation for the Independent Studies Honours thesis, allowing us to move a step forward in responding to the guiding thesis question: "*Are current critical thinking requirements in Ontario's secondary education system adequately preparing students for the demands and expectations of university level studies?"*

A total of 51 sources were included in this literature review, including scholarly articles, curriculum documents, literature reviews, news articles, books and other relevant sources. The following sections present the methods and conclusions of this review.

Part 1 – Defining the Critical Thinker

Before further inquiry could be done into the relation between high school development of critical thinking (CT) and subsequent success in higher education, it was necessary to form a working definition of "critical thinking" as an education goal. Accordingly, we conducted a search of educational literature dealing with the definition of CT. Search parameters were designed to limit results to resources that dealt directly with the definition of CT by utilizing the terms "critical thinking", "definition" and related words to search document abstracts. In addition, terms relating to "education" were added to the search so that the results would deal with CT in this particular domain.

Two major databases related to educational studies were selected for exploration: *Education Research Complete* and *Educator's Reference Complete*. These were selected from the main education-related databases available from Wilfrid Laurier University's library. Other education-related databases from the library were not selected because of focuses deemed too narrow; for example, one database dealt solely with physical education safety guidelines. Results from each were limited to English-language sources published in peer reviewed journals within the last 12 years. This limitation was designed to help identify relevant, scholarly documents. Since this search aimed to identify how CT might be defined by education in general, sources that limited discussion to the application of CT in a specific, restricted field were considered irrelevant for this particular research.

Search Methodology.

Search 1: Education Research Complete

- Parameters:
    - Find all search terms: AB "critical thinking" AND AB definition AND AB education
    - Expanders: Apply related words
    - Limiters: Scholarly (Peer Reviewed) Journals, Published Date from: 20010101-20121231, Language: English
- Results: Thirty-two documents were returned when the search outlined above was completed on December 10, 2012. To determine which articles might focus on defining CT, the titles and abstracts of each retrieved source was examined for mention of "critical thinking definition" or a similar term. Results that focused on CT as it related to only one limited field – such as nursing education – were removed. Out of the thirty-two search results originally returned, ten sources showed evidence of a possible direct focus on the definition of CT in education.

Search 2: Educator's Reference Complete

- Parameters:
    - Abstract ("critical thinking") And Abstract (define Or definition Or describe Or explain) And Abstract (education Or learning Or curriculum)
    - Publication Language (English)
    - LIMITS: Peer-Reviewed And Date (> 1999)
- Results: Thirty-six documents were returned when the search outlined above was completed on December 11, 2012. To determine which articles might focus on defining CT, the titles and abstracts of each retrieved source was

examined for mention of "critical thinking definition" or a similar term. Results that focused on CT as it related to only one limited field – such as nursing education – were removed. Out of the thirty-six search results originally returned, four sources showed evidence of a possible direct focus on the definition of CT in education.

Inclusion/exclusion: (Full Texts)

The full texts of the fourteen retrieved documents were analysed for inclusion/exclusion on December 11, 2012. In accordance with the goals of this research, criteria for inclusion were:

- Clear focus on defining "critical thinking"
- Relation to education in general, at primary, secondary, or tertiary levels
- Scholarly (peer-reviewed) resource
- Published in English in or after the year 2000

Out of the fourteen documents originally retrieved from the searches, eight of these were selected for use in this study after application of the inclusion criteria. Some additional sources were retrieved from the citations in the initially selected documents.

Discussion.

Critical Thinking: a brief history.

Early ideas of "critical thinking" and practices involving this concept are traced back to 5th century Greek civilization and philosophers like Socrates (Ozmen, 2008; Staib, 2003). Socrates tried to get people to think clearly, emphasizing the importance of reasoning and evidence, and challenging people to put aside irrational assumptions. Staib notes that

philosophers following Socrates continued in a similar vein of inquiry, supporting beliefs that education should promote examination of and reflection on ones ideas and values (2003).

Lloyd and her colleague found that academic literature on CT dates to the early 1600s, with Francis Bacon's definition of the concept as a "desire to seek, patience to doubt, fondness to meditate, slowness to assert, readiness to consider, carefulness to dispose and set in order; and hatred for every kind of imposture" (as cited in Lloyd and Behr, 2010, p. 1). Later, by the mid-1900s, the definition of CT developed to describe a cognitive skill related to thoughtful consideration of problems and subjects and skill in logical enquiry and reasoning (Lloyd and Behr, 2010).

The modern CT movement holds John Dewey and Benjamin Bloom as significant influences. John Dewey emphasized the distinction between the *processes* of thinking and the *products* of thinking (Ozmen, 2008). He reportedly highlighted CT – which he referred to as "reflective thinking" – as an active process (Ozmen, 2008). Benjamin Bloom would later push for the goal of developing critical thinkers with the introduction of his taxonomy of learning (1956). Bloom's taxonomy is taught in several teacher preparation programs today, and classifies learning skills using a hierarchy with six levels (Easterbrooks and Scheetz, 2004). The highest stages – analysis, synthesis and evaluation – are often thought as of typical of CT. In 2001, Bloom's original taxonomy was revised. The new, revised version renamed three categories, and changed each category name to a verb form as they might be used in statements of educational objectives (Krathwohl, 2002). Two of the three categories associated with CT – 'Analysis' and 'Evaluation' – were retained in their verb forms as 'Analyze' and 'Apply'. The category 'Synthesis' was renamed 'Create', however, and changed to become the top category in the

taxonomy. The sense of a hierarchy in learning processes was retained, though categories could overlap in some dimensions (Krathwohl, 2002).

Out of this compelling historical framework emerged an emphasis on the importance of developing CT skills in education (Malamitsa, Kokkotas, and Kasoutas, 2008). In recent years, several books and articles have been published related to CT, supporting the notion that it is an important goal of education, yet indicating difficulties in producing one encompassing, precise definition of the term. The concept has been found to be *mystifying*, with changing definitions evident in the scholarly literature (Rezaei, Derakhshan and Bagherkazemi, 2011).

The Delphi Report:

One significant achievement towards the production of a sound definition of CT is the *Delphi Report*, produced as a result of a research project that took place from 1988-1990. The Delphi Report is considered to have provided a consensus of current thought about CT (Malamitsa et al, 2008; Ozmen, 2008; Staib, 2003). The report involved a panel of forty-six individuals considered experts in CT, including assessment specialists, teachers, and educational authorities among others. The research project lasted two years, resulting in a comprehensive, conclusive statement describing CT and the ideal critical thinker:

> We understand critical thinking to be purposeful, self-regulatory 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. *CT is essential as a tool of inquiry*. As such, CT is a liberating force in education and a powerful resource in one's personal and civic life. While not synonymous with good thinking, CT is a pervasive and self-rectifying human phenomenon. The ideal critical thinker is habitually inquisitive, well-informed, trustful

> of reason, open-minded, flexible, fair minded in evaluation, honest in facing personal biases, prudent in making judgments, willing to reconsider, clear about issues, orderly in complex matters, diligent in seeking relevant information, reasonable in the selection of criteria, focused in inquiry, and persistent in seeking results which are as precise as the subject and the circumstances of inquiry permit. Thus, educating good critical thinkers means working toward this ideal. It combines developing CT skills with nurturing those dispositions which consistently yield useful insights and which are the basis of a rational and democratic society. (Facione, 1990, p.2, emphasis added)

The description provided by the Delphi Report suggests that CT is not just limited to the practice of certain skills, but connected to an individual's cognitive dispositions and habits. Indeed, the report noted that "each cognitive skill…can be correlated with the cognitive disposition" to use that related skill (Facione, 1990, p. 11). CT skills must accordingly be supported by a state of mind that promotes the motivated, active use of these abilities if it is to be effective in enhancing the individual's potential for success.

Richard Paul and the Center for Critical Thinking:

Around the same time as the publication of the Delphi Report, another influential definition of CT emerged, from the philosophy of Richard Paul, director of the Foundation for Critical Thinking. From 1984-2005, Paul's writings on CT remained a prominent influence in related literature (Flores, Matkin, Burbach, Quinn, and Harding, 2012; Ozmen, 2008; Staib, 2003). Paul promoted a definition of CT as "the art of analyzing and evaluating thinking with a view to improving it" (Paul and Elder, 2006). According to Paul and Elder, an individual thinking in this way will raise and formulate clear, precise and vital questions, will effectively gather and assess information, will test and reason through conclusions, will think open-

mindedly, and will communicate effectively (2006). This definition promoted the intentional nature of CT, and the researchers developed a dichotomous view of CT, encompassing two kinds of processes: *weak* sense CT or *strong* sense CT (Flores et al, 2012 and Ozmen, 2008). Strong sense CT was the evidently stronger and better form of CT, and it included application of CT to even one's own beliefs and ideas, helping to eliminate self-deception and illogical conformity (Ozmen, 2008). Like the Delphi Report, the Foundation for Critical Thinking seemed to stress that one's aptitude in CT skills does not necessarily make him or her a good critical thinker; it is necessary to apply these CT skills to one's own beliefs and ideas, and to the propositions of others, to be a good critical thinker.

Through his studies, Paul looked at the definitions of CT endorsed by various articles, suggesting that any accepted definition should combine aspects of the ideas from several sources. He found that no one definition truly encompassed all the dimensions of CT and by considering combinations of different definitions one could draw from the advantages of each while avoiding the limitations of any one proposition (Ozmen, 2008).

Opposing Standpoints:

Some competing views of CT seemed to emerge from the reviewed literature. Paul's dichotomous viewpoint framed the *technicist* perspective, which emphasized task accomplishment and purposeful, strategic performance (Papastephanou & Angeli, 2007). This perspective is distinguished from a *rationalist* viewpoint implying an appraisal element in CT and thought guided by logic and empirical evidence (Flores et al, 2012). This difference in definition seems to be based on a focus on either skills – the technicist perspective – or ideals of objective logic, which are promoted by the rationalists. However, these viewpoints do not seem to be mutually exclusive. Consideration of the qualities of each definition described so far

suggest that CT cannot be limited to the use of skills, but that a certain type of character is required for CT skills to be transferred across contexts, enhancing the success of the individual. Papastephanou and Angeli argue that the technicist definition does not encompass all the skills that could be related to CT, and that a reconciliation of technicist and rationalist thinking about this concept can allow for consideration of the ties between theory and practice (2007). A more inclusive perception would describe CT as interactions encompassing the "full play of human thought, feeling, and motivation", reasoning effectively and intellectually adapting goals accordingly (Papastephanou and Angeli, 2007, p.619). While Papastephanou and Angeli do not question the importance of measurable outcomes of CT development, they stress the need to also consider the results of CT that cannot be assessed objectively (2007).

Another discrepancy in the thought about CT comes from the differences in generalist and specifist viewpoints on the definition of this concept. Generalists describe CT as a universal ability, whereas specifists state that CT requires deep knowledge of the particular subject area concerned (Flores et al, 2012). Davies criticizes the debate between generalists, specifically as outlined by Moore (2004), for promoting a fallacy of false alternative; the debate suggests that these ideas are exclusive, so CT should be taught "'as a subject of study in itself', *or* through disciplinary studies, *but not both*" (Davies, 2006, p.180). As an alternative, Davies finds no reason why the generalist and specifist positions cannot be combined to better understand CT, serving as complementary models (2006). This allows for the consideration of CT as outlining general principles of good reason and how these principles are employed "in the service of 'academic tribes'" (Davies, 2006, p. 191).

It has been widely suggested that CT is not clearly understood by academics because of the various definitions of the term, and potential vagueness in its description. In 2010, Margaret

Lloyd and Nan Behr considered this assumption and conducted a study to identify student and faculty ideas of CT and to compare these ideas to established CT definitions. Participants in this study included 47 academics from the Faculty of Education at a university in Australia. The researchers found that the university faculty members were more likely to view CT as a state of mind, or to describe it through techniques and processes, such as orientations to learning, or willingness to consider alternative interpretations. Students, on the other hand, tended towards definitions accentuating outcomes and demonstrable skills, including skills in making inferences from available information, or analysing situations while considering possibilities. Notably, there appeared to be no fundamental difference in participants' conceptual understanding of CT (Lloyd and Behr, 2010). The evident differences between the groups were similar to distinctions between the technicist and the rationalist views of CT. This suggests that understanding of the concepts related to CT may be foundationally similar despite differences in scholarly definitions of this concept. However, generalization of the results of this study is limited by its population: it is possible that all participants adhered to similarity in thought about CT because of the shared academic environment of the education faculty at this one particular university.

A further theme that emerges in the literature about CT is the idea that CT may have intrinsic social ties. Atkinson (1998) and Benesch (1993) suggest that CT cannot be separated from social practice and cultural considerations (as cited in Rezaei, 2011). Similarly, Fox describes CT as "more than just a set of writing and thinking techniques— it is a voice, a stance, a relationship with texts and family members, friends, teachers, the media, even the history of one's country" (1994, p. 125 as cited in Rezaei et al, 2011, p.771). Others argue that CT is more universally relevant than can be encompassed by the confines of a social or cultural practice (Rezaei et al, 2011). In education, CT development can be used as a tool to prepare students for

continuing success, and to assist students in achieving their potential, both in society and in an academic context. CT is here related to the development of one's character (Easterbrooks and Scheetz, 2004), which includes developing as a social being and as a scholar. It seems that these goals would not be in any way diminished based on which view of the relationship between CT and society is accepted.

Similar Competencies:

There are several other competencies and skills that seem to be related to or similar to CT. One of these is metacognition, which is basically defined as "awareness or analysis of one's own learning or thinking processes" (Mirriam-Webster). For educational considerations, metacognition may include awareness of what process might be needed to learn given material, planning and monitoring of cognitive activity, and evaluation of whether or not a learning goal was successfully accomplished. CT ability is not necessary for the practice of metacognition: one does not need to necessarily have skill in evaluating information to monitor one's learning of that information, for example. In the same way, it may not be necessary for an individual to practice metacognitive strategies in order to be a critical thinker. However, aptitudes in metacognition will help individuals understand their own learning, make improvements in learning strategies when needed, and subsequently become better critical thinkers. It seems likely that a skilled critical thinker will want to practice metacognition in order to actively improve his or her learning. While abilities in CT and metacognition are not intrinsically linked, they are tied together as educational ideals and complementary learning strategies.

CT is also clearly related to motivation. While people do not need to be critical thinkers to be motivated to learn, motivation seems to be necessary for the exhibition of CT. CT dispositions involve diligence in seeking information (Facione, 1990) and alternative

interpretations (Lloyd and Behr, 2010). Aptitude in CT skills does not indicate actual CT unless one works to apply these skills when learning and problem solving (Ozmen, 2008), so individuals must not only be able to use CT skills: they must be motivated to do so to the best of their abilities.

Finally, Richard Paul and Linda Elder describe an interdependent relationship between CT and creativity (2008). They hold creativity to be a process of making or producing with an implied critical component of demonstrating imagination or inventiveness. CT in turn involves the creation of an intellectual product, new concepts, and/or modified understanding. High-quality thought, then, requires a combination of production and assessment of ideas, encompassing both creative and intellectual ideals. Paul and Elder support a three dimensional nature of CT: "the analytic, the evaluative, and the creative" (2008, p. 20), which clearly echoes the recent revision of Bloom's taxonomy (Krathwohl, 2002). Creative thinking should accordingly be considered an essential part of CT. Notably, creative and CT are both encompassed in the broader domain of *higher order thinking* which includes skills in "critical, logical, reflective, metacognitive, and creative thinking" (King, Goodson, & Rohani, p. 1).

Current Educational Perspectives:

The research considered in this review holds the development of CT as an admirable goal for education, declaring that "the focus of education should be shifting from teaching content to teaching students how to become critical thinkers" (Flores et al, 2012, p. 215). However, it is important that content knowledge is established as well, to allow for the active development of CT. Carver (2006) notes that deep learning requires integration of knowledge with thinking techniques, encompassing the "full range of competence" described in Bloom's Taxonomy and its later, revised version (p. 206). Education should stimulate deep learning of content so that

developing thinkers can become enthralled with both the processes and the results of learning; accumulating knowledge while advancing through levels of competence.

As education becomes concerned with "processes of inquiry, learning, and thinking rather than in the accumulation of disjointed skills and senescent information" (Facione, 1990, p.1), the value of CT has been articulated across both scholarly and non-academic literature. CT is recognized by teachers, researchers, curriculum developers and others invested in learning outcomes as an important dimension of education (Malamitsa et al, 2008). Even when concepts of CT differ, the high regard for CT is strikingly apparent.

Use in Education - Ontario:

C21 Canada published a 21st Century Learning Framework in May, 2012, which aimed to create models of learning that could be considered when attempting to improve the nation's public education system. In their report, CT was defined as an "ability to acquire, process, interpret, rationalize and critically analyze large volumes of often conflicting information to the point of making an informed decision and taking action" and a capacity to apply associated processes (C21 Canada, 2012, p. 10). The publishers reasoned that the 21st century demands that individuals be able to use higher order thinking skills to analyze problems, to form and test hypotheses and to develop creative solutions. Though the definition provided by C21 Canada focuses on skills and abilities that could be associated with CT, its purposes for demanding CT seem to suggest the need for dispositions like motivation, creativity, open-mindedness, and other characteristics typical of an active critical thinker as historically defined.

A focus on scholarly materials that work to define CT provides a good overview of academic thought on the topic, and on how various definitions might be developed. However, for the purposes of the auxiliary Independent Studies' honours thesis project, it was appropriate to

look more specifically at how definitions of "Critical Thinking" are used in education in Ontario. A search was conducted on the website of the Ontario Ministry of Education (http://www.edu.gov.on.ca) using the term "critical thinking" to retrieve results for this purpose. Any result that provided a definition of CT used in education was to be considered relevant and included for this research. These inclusion criteria left only curriculum documents to be considered; four of these documents were selected to demonstrate different aspects of the definition given to CT by Ontario's Ministry of Education, including both primary and secondary education documents.

Education documents in Ontario stress that even young children are capable of CT (Ontario Ministry of Education, 2004). The elementary curriculum documents designed by Ontario's Ministry of Education define CT as follows:

> Critical thinking includes skills such as questioning, predicting, hypothesizing, analysing, synthesizing, examining opinions, identifying values and issues, detecting bias, and distinguishing between alternatives. It involves an inquiry process of exploring questions about and solutions for issues that are not clearly defined and for which there are no clear-cut answers. (Ontario Ministry of Education, The Full Day Early Learning, 2010, p. 45)

These skills, and related inquiry processes, are to be used to understand ideas and situations fully: guiding judgements and decisions. Secondary curriculum documents extend this definition of CT to include skills in evaluation, in rational judgement, and in making logical connections. CT is also said to require openness to other viewpoints and means of expression, connecting CT to creative thinking. Reportedly, inquiry and research in secondary school should encourage high levels of CT (Ontario Ministry of Education, 2008). Students, using CT, should

be able to gradually form their "personal opinion or stance, or a personal plan of action with regard to making a difference" (Ontario Ministry of Education, 2010, Grades 9-10, The Arts, p. 40). This description enhances the definition provided in the primary documents to include character traits of openness and persistence in forming logical opinions. By describing CT as a process, the curriculum documents also allude to CT as including dispositions, and not simply static skills. However, Ontario's Ministry of Education in these documents highlights CT in terms of skill sets, not seeming to place as strong of an emphasis on related personality traits as evident in the bulk of the literature concerning CT. This discrepancy may be caused by a focus on aptitudes that can be clearly seen and evaluated in education; the Ministry of Education in Ontario helps provide teachers and other stakeholders with a definition of CT that they can concretely assess in the classroom setting.

Summary and Definition.

As this research aims to understand university and college expectations of CT, and how these demands are met in high school education, it is necessary to establish a sound definition of "critical thinking" as it relates to this project. It is evident that definitions of CT should consider both skill development and character traits that are evident in a critical thinker. A critical thinker would have attributes that encourage the application of skills in areas like analysis and evaluation. These skills may relate to one specific domain linked to deep knowledge of the focal subject matter, but an overall definition of CT should also include more universal skills which can enhance learning and understanding across many different situations and domains. While aspects of CT may be tied to ones' society, education focused on the development of CT should concentrate on attributes of CT that directly relate to academic learning and to achieving later success in life. It is clear that CT is considered a highly valuable potential outcome of education.

With these considerations in mind, the following definition of CT was established for purposes of this literature review.

Critical thinking: An important tool of inquiry and an esteemed educational goal. CT encompasses *skills* in analysis, evaluation, creativity, rationalization, hypothesizing, judgement, problem-solving, and decision-making – enabling the individual to form logical personal stances when considering complex issues. CT relates to a *character* that is fair-minded, inquisitive, flexible, confident in reasoning, and open to entertaining diverse viewpoints.

The ideal critical thinker should endorse reason and strive to be well informed, and should be able to communicate ideas clearly and effectively through logical appeals. He or she should demonstrate persistence and motivation in pursuing truth, evidence, and results and should make all attempts to avoid bias and prejudice when considering and accepting ideas.

Part 2 – Demanding Critical Thinking

While establishing an operational definition of CT, we also aimed to determine what the expectations of universities and colleges relating to CT skills and dispositions are, and to see how previous CT development might influence subsequent academic performance in higher education. For these purposes, research took place through November and December of 2012, and was guided by two focus questions:

1. *"In terms of critical thinking skills, what does the research literature say is needed for successful university/college study?"*
2. *"What is the relation between high school instruction and subsequent student performance at the university or college level, specifically in regards to critical thinking abilities?"*

CT, for this study, would be considered according to the definition established in Part 1 of the literature review. However, literature applying a different definition of CT is still considered relevant to the review if the different definition used is similar to or could be contained in the definition previously established.

Search Methodology, Question #1.

First, a search was conducted in November 2012 to respond to the guiding research question: *"In terms of critical thinking skills, what does the research literature say?"*

A concept map, outlining components of the research goals was created to help identify what search terms and parameters would produce relevant literature results (Table 1).

Table 1

Concept map to determine search terms and parameters to guide exploration of Question #1:

WHAT	WHO	HOW	WHEN & WHERE
Critical Thinking and Post-Secondary Success (critical thinking, reasoning, universit*, college, tertiary, achievement, success)	***Undergraduate college/university students*** (university, college, undergrad*, student)	***Literature Reviews, Original Research*** (literature reviews, experiments, primary research, dissertations, opinion articles)	***Recent available research*** Published in English within the past 12 years. Industrialized nations. Publically available or archived.

I then considered what criteria could be used to help determine the relevance of retrieved results. For the purposes of this research question, documents that included information about students pursuing higher education were desired, and limitation of this criteria to those students who had not yet obtained any other post-secondary degree. Research focused only on non-traditional students – including adult learners, individuals with learning disabilities, and individuals in professional programs – were excluded so that the results of this research could be more easily generalized as representative of education trends. Types of literature and intervention types to be included were mostly unrestricted, but results were limited to those that provided pertinent information about post-secondary academic success or expectations, in keeping with the research focus questions.

These considerations resulted in the formulation of inclusion/exclusion criteria outlined in Table 2. The following databases were utilized for this review:

- The Education Resources Information Center (ERIC.
- Scopus.
- Google Scholar.
- Education Research Complete

Table 2

	Inclusion criteria	Exclusion criteria
Population	Undergraduate University Students Undergraduate College Students People ages 17-26 Normally developing or gifted	All participants under age 16 Graduate students Students in professional programs Adults over age 26 Individuals with learning disabilities Animals
Intervention	No restrictions	No restrictions
Method of Review	Literature reviews: • Narrative reviews • Systematic reviews • Meta-analyses Primary research Scholarly articles Dissertations	Books Introductions to studies or articles Book or product reviews Proposals for research How-To Guides Computer programs Machine readable data files
Outcomes	Academic achievements and success at a post-secondary level. Information on university/college demands or expectations for CT.	Economic only Social only Moral only Emotional only Religious or spiritual Not concerned with CT Only focused on evaluating CT

Initial Search: Conducted November 15 - November 19, 2012:

Search terms and restrictions were designed based on the inclusion/exclusion criteria and the concept map previously established.

- Search Parameters – ERIC: *all((“critical thinking”) AND (university OR college OR tertiary OR “post-secondary” OR undergrad* OR “higher education”) AND (success* OR prepared* OR achiev*)) AND IF(critical thinking) AND YR(2000-2013).* Duplicates not included.

- Search Parameters - Scopus: *("critical thinking") AND (university OR college OR tertiary OR "post-secondary" OR undergrad* OR "higher education") AND (success* OR prepared* OR achiev*) AND KEY(critical thinking) AND PUB YEAR>1999.* Subject Areas "Physical Sciences" "Health Sciences" and "Life Sciences" not included.

Table 3

Results of initial search. November 19, 2012.

Activity:	Resulting Number of Citations:
Search of the ERIC database	12
Search of Scopus database	24
Duplicate documents deleted	36
Inclusion/exclusion criteria applied to titles and abstracts	11 (Appendix B)

Search of Google Scholar: Conducted on November 19, 2012.

A search of Google Scholar, using the same terms described above, produced over 30,000 results. While it was not feasible to review the titles and abstracts of each of these documents to determine if they could be included in the study, we reviewed titles found on the first twenty results pages to identify relevant sources. Relevancy was determined by reading the title and brief provided descriptions of the retrieved sources, and comparing the information provided in these with the research goals and inclusion/exclusion criteria established for this literature review. Specifically, we looked for resources that mentioned both "critical thinking" and "higher education" or a synonymous term, and that appeared to consider a relationship between these subjects. Based on these considerations, three sources were selected for retrieval:

1. Ahern, A., Mac Ruairc, G., McNamara, M., O'Connor, T. (2010) Critical thinking in the university curriculum. Presented at the 3rd International Symposium for

Engineering Education (ISEE), 1-2 July 2010, *University College Cork, Ireland*. Retrieved from: http://hdl.handle.net/10197/2874

2. Choy, S. C. and Rahman, T.A., (2009) Teacher perceptions of critical thinking among students and its influence on higher education. *International Journal of Teaching and Learning in Higher Education*, 20(2), 198-206. Retrieved from: http://www.isetl.org/ijtlhe/pdf/ijtlhe336.pdf
3. Williams, R. L., and Worth, S.L., (2001). The Relationship of Critical Thinking to Success in College. *Inquiry: Critical Thinking Across the Disciplines*, 21(1), 5-16. Retrieved From: http://secure.pdcnet.org/inquiryct/content/inquiryct_2001_0021_0001_0005_0016

When reviewing the citations and "related documents" for the three selected resources, we identified one other potentially significant document. This document was selected based on apparent focus on the relationship between CT and higher education or on perceptions of CT by university/college faculty.

4. Stedman, N. L., & Adams, B. L. (2012). Identifying Faculty's Knowledge of Critical Thinking Concepts and Perceptions of Critical Thinking Instruction in Higher Education. *NACTA Journal.* p. 9-14. Retrieved From: http://www.nactateachers.org/attachments/article/1972/Stedman_NACTA_June_2012.pdf

Each of these documents was added to the spreadsheet to be coded for inclusion/exclusion on November 19, 2012 (Appendix B).

Secondary Search of Scopus: Conducted November 22, 2012.

This search was completed following the recommendation of Dr. Kathleen Bloom (The University of Waterloo). It used the following parameters: *TITLE-ABS-KEY(critical AND thinking) AND TITLE-ABS-KEY(university OR college OR post-secondary) AND TITLE-ABS-KEY(faculty attitudes) AND PUB YEAR>1999.*

Fifty-one documents were returned through this search. These sources were coded for inclusion/exclusion. Unfortunately, none of the results proved relevant to this review's research objectives (Appendix C).

Search of Education Research Complete: Conducted December 16, 2012.

The Education Research Complete Database was added to the study after completion of the searches above, following the recommendation of Dr. Dawn Buzza (Wilfrid Laurier University). This database could provide scholarly information that was more relevant to the field of education and that might have been missed by the previous searches. The parameters of this search were:

- Search Terms: *KW critical thinking AND AB (university or college or higher education) AND AB (success or preparedness or achievement)*
- Expanders: *Apply Related Words*
- Limiters: Scholarly (Peer Reviewed) Journals, Published Date from: 20000101-20121231, Language: English.

This search produced 30 results; however, two results were identified to be duplicates from previous searches. The abstracts and titles of the 28 remaining documents were coded to

determine inclusion/exclusion, and four documents were selected for retrieval of full texts (Appendix D).

Inclusion/Exclusion with full texts.

Based on the searches described herein, 19 potentially relevant documents were designated for retrieval. Out of the designated documents, 13 were retrieved on November 22, 2012. Four documents were retrieved on December 17, 2012. The two documents that were not found initially were requested using Scholars Portal, RACER, and returned on November 27, 2012. When the nineteen retrieved documents were marked for inclusion/exclusion based on the full text, seven sources were identified as relevant and retained for the literature review (Appendix E).

Search Methodology, Question #2.

Next, we conducted a review aimed at determining what previous literature and research may help answer the second focus question: *"What is the relation between high school instruction and subsequent student performance at the university or college level, specifically in regards to critical thinking abilities?"* Some sources offering responses to this question were previously identified by pre-thesis work in preparation for the ongoing Independent Studies thesis project, under the supervision of Dr. William Abbott (The University of Waterloo). Relevant sources identified through this preliminary exploration include:

- Slavin, Alan (2007). Has Ontario taught its high-school students not to think? *University Affairs*. Retrieved From: <http://www.universityaffairs.ca/has-ontario-taught-its-high-school-students-not-to-think.aspx>
- Dooley, M. D, Payne, A. A., Robb, L. A. (2011). Understanding the Determinants of Persistence and Academic Success in University: An

Exploration of Data from Four Ontario Universities. *Toronto: Higher Education Quality Council of Ontario: McMaster University*.

- The Canadian Press (2009) Students not prepared for university, says survey. *CTV News*. Retrieved From: http://www.ctv.ca/CTVNews/TopStories/20090921/dropout_university_090921/
- Henry, N. (2006). Perceptions of college students and instructors on students' preparedness for the literacy demands of college. *Queen's University. ProQuest Dissertations and Theses*.
- Steinberg, L. (2008). Adolescence, 8th Ed. *New York, NY: McGraw-Hill.*

It was deemed necessary to conduct another scoping literature review to determine if there was any additional literature that could aid in answering this second guiding research question. Thus, beginning on November 28, 2012, the following research steps were conducted:

1. Created Concept Map: The concept map shown in Table 4 was designed to help clarify this study, and to identify search terms that might be useful in retrieving information.
2. Developed Inclusion and Exclusion Criteria (Table 5): This part of the study focused specifically on links between high-school and university, especially where related to CT skills and dispositions. Accordingly, included results were limited to those that contained information about both high school and post-secondary student populations. Several different types of scholarly literature could prove relevant, so would be included, and no restrictions were placed on intervention methods (or even a lack of intervention). The study attempted to identify literature that provided ideas about how high school may be related to higher education, including evidence related to student transitions and the potentially transitive nature of CT.

Table 4

Concept map developed to guide exploration of Question #2.

WHAT	WHO	HOW	WHEN & WHERE
High school CT Development and University/College Success (critical thinking, reasoning, universit*, college, tertiary, achiev*, success, transition, readiness, high school, secondary)	***Undergraduate college/university students and High school students*** *(university, college, undergrad*, student, secondary, high school)*	***Literature Reviews, Original Research*** *(literature reviews, experiments, primary research, dissertations, opinion articles)*	***Recent available research*** *Published in English within the past 12 years.* *Industrialized nations* *Publically available or archived.*

1. Database Selection: ERIC, SCOPUS and Education Research Complete were again selected to be used for this second research review. An additional informal search on Google Scholar would be conducted to identify supplementary material.
2. Search Conduction: Based on the developed concept map, keywords including “critical thinking,” reasoning, university, success, “high school” and related terms were used to conduct several searches. Results were also limited to literature published in English within the past 12 years.

Initial Searches - November 29, 2012:

- Search Parameters - ERIC: *AB(("critical thinking") AND (university OR college OR tertiary OR undergrad*) AND ("high school")) AND ALL(achieve* OR success OR transition OR readiness) AND YR(2000-2013)*
- Search Parameters – Google Scholar: *"critical thinking" and "high school" and (university or college or tertiary) and (success or achievement or transition). Return articles dated between 2000-2013.*

- Search Parameters - Scopus: *TITLE-ABS-KEY((("critical thinking") AND (university OR college OR tertiary OR undergrad) AND ("high school"))) AND (achieve OR success OR readiness OR transition) AND PUBYEAR > 1999*

Table 5

Inclusion and exclusion criteria applied to results from searches for material relevant to Question #2.

	Inclusion criteria	**Exclusion criteria**
Population	Undergraduate University Students or Undergraduate College Students and Secondary School Students. People ages 13-26 Normally developing or gifted	Primary or Elementary Students Graduate students Only university or college students Adults over age 26 Individuals with learning disabilities Animals
Intervention	No restrictions	No restrictions
Method of Review	Literature reviews Primary research Scholarly articles Opinion papers Theses and Dissertations	Books Book or product reviews Proposals for research How-To Guides Computer programs Machine readable data files
Outcomes	Information linking high school achievement or instruction to subsequent student performance in university or college. Information about the transition from high school to university or college. Information regarding the transitive nature of CT.	Any outcome not included by the given criteria. Non-academic in nature.

Additional Search – December 17, 2012:

- Search Parameters – Education Research Complete:
    - Search Terms: *AB "critical thinking" AND AB (university OR college or tertiary or undergrad) AND AB High school AND TX (achieve OR success OR transition OR readiness)*
    - Expanders: *Apply Related Words.* Limiters: *Scholarly (Peer Reviewed) Journals, Published Date from: 20000101-, Language: English.*

Table 6

Search results for Question #2.

Activity:	**Resulting Number of Citations:**
Search of the ERIC database.	27
Search of Google Scholar	About 1,780 total. 11 sources subjectively selected.
Search of Scopus	13
Search of Education Research Complete	16
Total Results	67
Duplicate documents deleted.	60
Inclusion/exclusion criteria applied to titles and abstracts.	19 (Appendix F and Appendix G)

For the search of Google Scholar, documents were selected based on reading the titles and brief provided descriptions of the search results, and looking for evidence of a focus on CT and its relationship to student success. Sources focused on a non-academic outcome, such as the influence of CT on moral development, were excluded, as well as those focused only on graduate students. Additionally, sources that focused on CT as an outcome, rather than as a cause, were not included. From this search, 19 potentially relevant documents were selected for retrieval. Thirteen of these sources were retrieved on November 30, 2012, and six were retrieved on

December 17, 2012. Eight documents were chosen for inclusion in the literature review after the inclusion/exclusion criteria were applied to the full texts retrieved (Appendix H).

Book Review:

A review was conducted in January, 2013, to identify relevant full length books that might contribute to answering either of the two mentioned focus questions, as books were not included in previous search results. For this purpose, a search of the University of Waterloo's library was conducted through Primo Central, using the term "critical thinking" to search subject areas and limiting results to those published in English in the past 12 years. The previous inclusion/exclusion criteria were not used for this review: instead, any book returned by the search that considered both CT and post-secondary education was selected for retrieval. This search did not turn up any relevant results; however, it was limited by the books available through the University of Waterloo's library. Additional searches for pertinent full-length books were not completed because of the time limitations of the current review, and the associated thesis project. This study could thus be extended in the future with a more thorough search for books and periodicals related to CT expectations in higher education.

The Canadian Perspective:

When considering the bulk of the literature retrieved in the early searches, we realized the need to identify more information from Canada and Ontario specifically to contribute to the guiding thesis project. Thus, a final search was conducted on January 8, 2012, utilizing the Education Resources Information Center (ERIC) and Education Research Complete databases. This search aimed to contribute to responses to both of the guiding research questions, so the search terms were designed to be related to both of these queries, as follows:

- Search Parameters, ERIC*: ((Keywords: "Critical thinking") and (Keywords: Ontario OR Keywords: Canada) and (Keywords: university OR Keywords: college OR Keywords: post-secondary)) and Peer Reviewed. Publication Date: 2000-2013*
- Search Parameters, Education Research Complete: *KW "critical thinking" AND (Ontario OR Canada) AND (university or college or post-secondary). Limiters: Scholarly (Peer Reviewed) Journals. Published Date from: 20000101-. Language: English.*

In total, 45 results were retrieved from the searches; however, six documents were duplicates. The remaining 39 files were assessed for inclusion, dependant on whether they related to any of the following outcomes:

- Academic achievements and success at a post-secondary level.
- Information on university/college demands or expectations for CT.
- Information linking high school achievement or instruction to subsequent student performance in university or college.
- Information about the transition from high school to university or college.
- Information regarding the transitive nature of CT.

Of the original 45 results, only two were selected to be discussed in this literature review, based on identification of the listed outcomes. This suggested a scarcity of available Canadian based scholarly literature on CT and its relation to university expectations and academic success. A few other relevant documents were retrieved through the search, but these others had been previously identified. Some complementary information about educational achievement in Canada was retrieved from the Program for International Student Assessment (PISA) Canada.

Discussion.

In 2007, David Conley's paper, *Redefining College Readiness* was published to provide an operational definition of college readiness as related to cognitive and metacognitive abilities of students. This definition was formulated to move away from previous definitions focused on courses taken, high school grades, or standardized test results. Conley notes that these skills – including skills in analysis, interpretation, precision, reasoning, and problem solving – are often identified by college instructors as being of equal or even greater importance than any specific content taught in high schools. Conley describes dramatic changes in schools' expectations for independent work, intellectual development, and academic engagement as students begin post-secondary education. According to Conley's report:

> College instructors are more likely to emphasize a series of key thinking skills that students typically *do not develop extensively in high school.* They expect students to make inferences, interpret results, analyze conflicting explanations of phenomena, support arguments with evidence, solve complex problems that have no obvious answers, draw conclusions, offer explanations, conduct research, engage in the exchange of ideas, and generally think deeply about what they are being taught. (Conley, 2007, p.6, emphasis added.)

Notably, these expectations fall in line with the skills and dispositions associated with CT as defined, which is generally held as a predictor of post-secondary academic success (Williams and Worth, 2001; Stupnisky et al., 2008). College and university faculty readily highlight the importance of these skills (Stedman and Adams, 2012), but do not seem to believe that entering freshmen students have proficiently developed CT abilities. Indeed, one of the major problems facing higher education in today's society appears to entering students who are simply "not

academically prepared for the rigors of college-level work" (Tinnesz, Ahuna and Kiener, 2006, p.302). Recently, Peer Review highlighted data in the United States from The National Assessment of Educational Progress, the Educational Testing Service, ACT Test results, and faculty and student surveys to provide information about learning goals and student achievement. According to this US-based study, only 36% of full-time faculty members at colleges and universities said students were well prepared academically for higher education, and many (41%) reported that students lacked even basic skills needed for work in higher education (Peer Review, 2007). According to Fletcher (2007), research suggests that entering college and university students have basic literacy skills, for example, but demonstrate inadequate *analytic* literacy skills: "inability to read and write about nonfiction in sustained, sophisticated, and informed ways" (p.19).

High school success has been shown to be intrinsically linked to subsequent performance at the university or college level; however, high school students are expected to experience a significant grade drop in post-secondary education (Dooley, Payne & Robb, 2011). This discrepancy does not seem to be caused by a lack of potential for CT development during students' high school years. Kevin Flores et al. note that the educational value placed on CT suggests a need to consider developmental stages in order to enhance individuals' CT abilities (2012). Research in psychology supports the notion that CT abilities can be developed at the secondary level or even earlier. According to Steinberg (2008), research indicates that it is possible for educational systems to "stimulate the development of formal-operational thinking" in the junior or senior high-school classroom (p.90). Deductive reasoning is seen as the "major intellectual accomplishment of adolescence" (Steinberg, 2008, p. 64) and is a higher order thinking skill related to the development of the ability to think hypothetically. Adolescence is

also marked by the development of metacognition, including the use of conscious strategies to improve one's own knowledge, and metacognition has been shown to aid in the potential for students to become good critical thinkers.

Nonetheless, education in North America seems to have limited opportunity for the development of CT during a student's adolescent years. Many students in post-secondary education who should perform well academically based on natural ability, work ethics, and interests instead perform poorly, apparently because of a lack of CT abilities as related to the higher rungs of Bloom's original taxonomy (Warner, 2004). The foundation for higher education must be laid in earlier years, and Warner claims that many students are not able to bridge the gap from rote memorization used in primary and secondary schools to the advanced types of reasoning required for deeper understanding, lamenting that many high school graduates do not realize that "levels of thinking above memorization and basic comprehension exist" (2004, p. 1413).

It seems clear that instruction encouraging CT and learning strategies can be remarkably beneficial for students pursuing higher education. During the 1980s, the University at Buffalo, State University of New York devised a course considered unique at the time: a "Methods of Inquiry" course aiming to teach students learning strategies and to develop CT (Ahuna, Tinnesz, & VanZile-Tamsen, 2011). In 2011, the implementation of this course was studied by Ahuna, Tinnesz and VanZile-Tamsen to determine the course's impact on student retention rates at the university. For the purposes of their research, the authors described successful students as those who earned a C- grade or higher at completion – thus passing the course. Interestingly, they found that students who completed the Methods of Inquiry (MOI) course generally came from demographics considered "disadvantaged" in higher education, and they enrolled in college with

average GPA and SAT test results significantly below those of the students who did not complete the MOI course. Regardless, students who took the MOI course were twice as likely to stay in college and more likely to graduate than students who did not take the course, despite apparent demographic and academic disadvantages. The most substantial effects of the course appeared in students' second year, so it may be important for students to take courses like MOI during their first year at college to obtain noteworthy results. Students who completed MOI, learning CT strategies that others might not have been exposed to, had a 77.3% five year graduation rate. To compare, the national average college graduation rate in the United States is only 55% in six years (Ahuna et al., 2011).

Significant research has also considered students' perceptions of the gap between high school education and the expectations of university or college. One study examined students' transition to higher education from high school through interviews with freshmen students enrolled in university in Portugal (Dias & José Sá, 2012). One of the factors emphasized by the participants in this study was the expectation for students to develop new, demanding study habits for higher education. The academic changes, according to the researchers, must be made in the context of a life transition involving personal and social concerns as well. During the interviews, one student noted that, in his opinion, "high school isn't able to prepare students for HE" (Dias & José Sá, 2012, p. 283). Other students noted difficulty with time management, and with social changes associated with the transition to higher education. Notably, adaptation appeared to be a "painful and challenging process" (p. 285) for virtually all of the participants, regardless of their academic success at the university. This study found a gap between high school and higher educational academic practices and expectations particularly in areas of communication skills, seriousness, research skills, decision-making skills, and CT. One student

concisely described this difference: “While in high school we just had to agree with teacher, now we must show that we are able to think” (p. 286).

Tracey Lo (2011) conducted a similar study at a university in Hong Kong to learn more about students’ transition to university, and what barriers to success might be caused from the gap between high school and higher education. She identified a few major learning barriers, including lacking proficiency in time management and study skills, and motivational concerns. The students participating in the study also indicated difficulties adjusting to the demands of learning in English, and Lo notes that this issue is the only concern that does not seem to be universal in nature. Participants claimed that they were not adequately trained in secondary school for the skills expected by the university, and accordingly had trouble adjusting to post-secondary education. Many students were apparently willing to put additional effort into improving their competency, yet did not know how to start improving or where to find help.

Robert Finnegan (2011) examined whether high school graduates in New Jersey were prepared for the challenges of college-level expectations, particularly regarding academic writing. For this study, instructors examined essays from graduating high school students to see whether the writing samples demonstrated college readiness. Finnegan discussed previous literature that had pointed out gaps between high school assessments and the criteria for university success (2011, p. 36). His results were specific to an administered State test, so many of his findings cannot be generalized to relate to high school education as a whole. However, Finnegan’s results and discussion did provide further support of the existence of a gap between academic high school demands and university expectations. Similarly, Karen Pittman found that many parties with interests in high school graduates suggest that “the college-and work-readiness rates of high school seniors and high school graduates are appallingly low” (Pittman, 2010).

Largely due to inadequate student preparation for modern, evolving demands of higher education, 73% of college deans in the United States are reporting increases in the numbers of students who begin college while needing remedial education (Tinnesz et al., 2006).

Suraya and colleagues studied students in Malaysia to see how different factors might correlate to academic success in higher education (2007). They qualified academic success based on students' currents GPAs and identified previous high school GPA and current CT skills – as measured by a 30-item test the researchers created – as significant predictors of success. The researchers noted that CT abilities of the participants were relatively low, yet these skills and tendencies were "emphasized in almost all of the courses offered in higher educational institutions" (Suraya et al, 2007, p.53). This study described CT as an intellectual process related to analysis, evaluation, application, interpretation and conceptualization of information, and skills in making inferences and explaining ideas (Suraya et al, 2007). This idea encompasses many of the abilities considered necessary for good CT according to the definition established in this literature review, so the study's conclusions appear applicable.

In an Ontario study, Henry (2006) found that students often reported they were inadequately prepared for university writing demands; high schools did not teach these students sufficient writing techniques and did not place adequate emphasis on the development of reading strategies. University instructors in turn highlighted the importance of literacy development before entering post-secondary education, noting that the focus of the higher education courses was not to develop these basic skills (Henry, 2006). Reading literacy has been defined by the Program for International Student Achievement (PISA) as "the ability to understand, use and reflect on written texts, in order to achieve one's goals, to develop one's knowledge and potential, and to participate in society" (OECD, 2006). This definition encompasses ideas related

to CT and higher order thinking, including understanding skills and conscious development of knowledge. In comparison with other countries, Canadian secondary students perform well in reading literacy according to the 2009 PISA report; with a mean score of 524. For comparison, this score is expressed on a scale with an average of 500 and a standard deviation of 100 among participating countries, and about two-thirds of all participating students scored within one standard deviation of the mean (Statistics Canada, 2010). Students with higher levels of reading literacy are more likely to graduate from high school, to attend a university or college, and to remain successful in school at the post-secondary level (Bussière, Hébert and Knighton, 2009).

When considering education in Ontario, Alan Slavin rests the blame for the academic gap on high school educational policies, criticizing content-laden curriculum for encouraging simple rote-memorization, rather than teaching analytical and conceptual thinking strategies needed for university-level work (2007). Slavin stresses that memorization and reiteration of facts are not sufficient skills in analytical university fields, including physics, mathematics and philosophy among others. Slavin's article concludes by calling for educational reform to deal with what has caused "Ten [10] years of students who have been taught not to think" and to move resolutely towards reversing the effect (2007).

Summary.

An article in The Canadian Press recently highlighted a problem of an educational gap in Canada, declaring that both students and professors believe high schools are not properly preparing students for the transition into their first-year at university (2009). Although Canadian high school students measure up well against those in other countries according to the 2009 PISA report – and Canada's own results have been relatively stable – the country's ranking has declined since the previous report in 2000. Based on the PISA results, Canada does not seem to

be adequately improving in reading literacy, and Canada has actually experienced a decrease in proportions of high achievers (Statistics Canada, 2010). CT skills are clearly important contributors to achievement in post-secondary education. The current literature thus suggests a need to re-evaluate the learning abilities of students in Ontario to ensure high school curriculum adheres to the development of cognitive ability: giving students room to cultivate comprehensive analytical skills, knowledge, and learning techniques, and to build foundations for advanced CT.

It is clear from this literature review that CT ability is seen as a valuable asset to students pursuing higher education; CT is linked to higher levels of academic achievement and success. CT can be developed beginning at the high school level, or even earlier, yet explicit CT development through high school instruction is often lacking around the world. Available scholarly literature related to Canada and Ontario specifically was limited in the context of this review, so inferences about the effectiveness of Ontario's secondary school program in developing CT cannot be conclusively drawn at this point. More research is needed to identify aspects of Ontario's secondary school curriculum that specifically relate to CT development. Also, it would be beneficial to review how CT might be successfully taught, in order to allow relevant analysis of secondary school CT instruction and development. Overall, this section highlights the value of CT in education, encouraging direct, purposeful development of CT beginning in adolescence or prior to help bridge the apparent academic gap between high school and higher education in Canada.

Part 3 – Developing a Critical Thinker

Four reviews of research on teaching CT have been published in the past 12 years. In 2000, Pithers and Soden reviewed literature on CT in education, and methods that might inhibit or enhance CT. They focused on discovering what might be required to improve students' thinking skills and to advance related teaching methods. The researchers associated CT with skills in information analysis, organization, planning, problem solving, communication, argumentation, reflection, reason, inductive and deductive logic, and evaluation. They also described dispositions linked to CT, including open-mindedness, caution in drawing assumptions, and an encompassing 'spirit of inquiry'.

According to Pithers and Soden, literature at the time of their review suggests that lack of clarity regarding the nature of CT leads to confusion about how to develop and assess CT. Much of the available published literature focused on methods that might hinder CT:

> For example, any teacher, no matter at what level, who simply agrees or disagrees, just demonstrates and explains, cuts off student responses, uses reproof rather than praise, shakes the learner's confidence in the value of new ideas or uses basically only retrieval or recall types of questions inhibits thinking (Pithers and Soden, 2000, p. 242)

The research suggests that teachers accordingly should be receptive to new ideas, and should often assume the role of a facilitator for problem-based learning, rather than acting strictly as a traditional instructor. This paper emphasized that persons involved in education need to avoid focusing strictly on the "right" answer, and instead must realize that a student's thinking and reasoning behind his or her answer is more important. The importance of the development of metacognition to complement CT development was also highlighted. To enhance CT, students

should be encouraged to consciously reflect on and analyze their ideas, devising questions, finding information, discussing topics, and gradually coming to reasonable conclusions. When students cannot move forward with inquiry on their own, because of difficulties understanding related information or struggles with more advanced reasoning, teachers could then continue to facilitate learning and CT development through scaffolding. For example, the teacher might point out assumptions underlying an idea and then ask questions to help students understand potential problems. One described study, conducted by Bliss, Askew and Macrae, (1996) considered video data from high school classes, suggesting teachers did not notice many of the opportunities that came up to scaffold student thinking.

Pithers and Soden did not document their research methods, and it is possible that the information they discussed is now out dated. Nevertheless, their study introduces ways CT might be inhibited in education, and supports the need to promote an encompassing, understandable definition of this concept for educational reference. The review also suggests that success in CT development relies on the skills and knowledge of those who interact with students directly. If teachers do not understand CT or ways to develop it in their classrooms, one cannot expect CT to be sufficiently developed in education, regardless of whether or not it is mentioned in curriculum documents. Additionally, teachers with student-centered orientations are more likely to use the outlined approaches for developing CT, and to assume the role of a facilitator to help promote CT and self-regulated learning – which concerns a process of evaluating and purposefully developing one's own learning strategies.

More recently, Abrami et al. conducted a systematic meta-analysis to summarize research on the impacts of instruction for enhancing and developing CT skills (2008). The research aimed to contribute to academic knowledge regarding CT, and was specifically

concerned with what methods or steps can be taken to ensure CT is best developed. For this purpose, Abrami and his colleagues asked the research question: "What instructional interventions have an effect on the development and effective use of CT skills and dispositions, and to what extent, and under what circumstances?" (2008).

The researchers selected 117 relevant studies for inclusion. This selection was based on the decisions of two independent coders. To be included, studies had to:

- be publically available or archived
- be relevant to issues of CT improvement, development, and/or active use
- include some kind of instructional intervention
- compare outcomes from different types of treatment or treatment level
- include data that would enable effect size extraction/estimation
- include treatments that lasted at least three hours
- include participants no younger than three years old

Geographically, the research considered studies from around the world with the highest concentration from North America. Each study was coded by intervention type. General interventions included those where CT development was the explicit course objective; infusion methods included interventions embedding CT instruction into a specific course's content as an explicit objective; mixed method interventions included CT instruction as an independent track embedded in another course, and the immersion method regards CT as a by-product of instruction.

The authors found that research supported the suggestion that instruction enhances CT skills and dispositions, though the results were not consistent. Mixed instructional approaches –

combining course content with CT instruction – were significantly more effective than other instructional types. The general approach and infusion approach showed moderate positive results, and the smallest instructional influence was documented in immersion approaches when CT was not an explicit objective. Benefits of any intervention type were substantially greater when the interventions included instructor training in implementation of the intervention or in CT development methods. Overall, the interventions accounted for 32% of the variance in CT effect sizes indicated in the research, suggesting a need to make CT instruction and objectives explicit in curriculum. The conclusions of this study are fairly reliable because of the research methods used by Abrami et al., which should have included all relevant research literature of the period. It is hard to draw many concrete recommendations or conclusions from this meta-analysis, however, because of the inconsistencies reported.

Also, in 2005, Barbara Brunt published a study reviewing research literature related to CT in a nursing context. Though Brunt focused on CT as it relates to only one particular profession, some of her findings can be generalized for CT development in education as a whole. She considered CT to be a process of purposeful thinking, concerned with examining practices, beliefs and ideas, and associated with dispositions supporting inquiry, logical reasoning, application of standards, and discrimination. Brunt's definition is limited considering the CT description earlier developed in this review; nevertheless, it does encompass some important aspects of CT. Brunt reviewed 18 studies conducted between 1992 and 2003, and noted that many of the articles did not include an operational definition of CT, suggesting a need for clarification of the concept. All of the included studies focused on nursing education and individuals training to become nurses, so caution must be used when attempting to apply Brunt's suggestions to diverse fields. Brunt highlighted a strong correlation between academic

achievement and CT, but noted that many of the research findings were inconclusive or challenged by other research results, so the review could not provide conclusive information regarding CT development. Brunt did suppose that CT is a lifelong process, and that development should include willingness to cultivate a critical spirit, not just CT skills (2005).

Most recently, Linda Behar-Horenstein and Lian Niu reviewed 42 studies concerning CT teaching in postsecondary education and student outcomes. They included research published from 1994-2009, describing CT as self-regulated judgement allowing interpretation, evaluation, inference, analysis and explanation: integrally linked to metacognition, reasoning skills, and individual motivation. Included studies were limited to those that focused on promoting college students' CT skills, involved one or more instructional interventions, and assessed changes in CT using one of three CT measures: the Watson-Glaser Critical Thinking Appraisal, the California Critical Thinking Skills Test, or the Cornell Critical Thinking Tests. Some studies included research that involved more than one measure of CT, and Behar-Horenstein and Niu state that many authors did not explain why they selected any particular CT test or measurement tools Berhar-Horenstein and Niu called for future research to adopt more precise, fine-tuned methods to study CT in educational environments.

In their review, Behar-Horenstein and Niu found that interventions to develop students' CT generally included instructional methods of concept mapping, scenario-based exercises, inquiry learning, guided practice, question approach, or web/computer-based instruction. None of these instructional methods proved to be consistently effective or ineffective in promoting CT, possibly because of differences in how the instructional methods were implemented in the various studies. In keeping with the conclusions of Abrami and his colleagues, these researchers promoted the need to make teaching of CT skills explicit and to consider the importance of

instructor training for successful CT development. Additionally, this review highlighted a need to use more than one measure to assess CT, including both quantitative and qualitative evaluations.

Transferability.

One particular concern made evident in the discussed literature review involves the ability for CT skills and dispositions to be transferred across domains and even through different school courses. In 2007, a review by David Billing examined cognitive science literature on the transferability of "core" higher education skills, including many facets of CT. Billing surveyed over 700 papers, selecting articles that were analytical and evaluative, that provided empirical evidence, and that involved tasks with high cognitive content. He notes that the literature included in his review focused mainly on problem-solving ability, though other areas investigated included CT, metacognitive skills, and communication skills. Billing distinguished between transfer of principles and transfer of dispositions, noting that the latter is more difficult. He argued that transfer of higher-order thinking skills, including those associated with CT, is possible from learning experiences, yet it often does not occur. Billing then looked at conditions that allowed for successful transfer of key cognitive abilities.

Billing found that transfer depended on how knowledge and skills were acquired, noting that active engagement in learning fostered successful transfer (2007). Transfer also seemed to depend on the individual's mental disposition, as certain beliefs can filter knowledge acquisition and affect a person's ability to control or engage in CT. The review resolved that teaching for CT transfer should emphasize metacognitive strategies and deep learning, stimulating reflection and learning management strategies. Billing also found that instruction involving performance feedback and linking old and new knowledge was effective in promoting transfer. In contrast,

rote learning of facts seemed to discourage effective transfer of cognitive skills, as did high context specificity. Billing concluded that transfer of CT relied on the coupling of abstract principles and ideas with concrete examples, and that transfer is promoted by a social context for learning and by the development of meta-cognitive strategies. According to his findings, CT and other higher order abilities are transferable; however, successful transfer depends on the conditions of the learning context, the instruction or guidance provided, and the dispositions of the individual learners (Billing, 2007).

Summary.

The available literature concerning the development of CT skills and dispositions provides several important points for consideration. Perhaps foremost is the need to promote one clear, understandable definition of CT as it relates to education, reducing confusion about its nature and how to address CT in the classroom. Hopefully, the study on defining CT included in the beginning of this literature review will help to contribute to the creation of such a definition.

CT must also be promoted as a valued part of education, and teachers should be trained to use classroom methods that encourage the use and development of CT: promoting the value of new ideas, inquiry, and active student involvement in learning. The knowledge and skills of individuals who are directly interacting with students plays an important role in students' academic success. This was made clear through Abrami's meta-analysis, which stated that it was difficult to conclude that any particular intervention significantly promoted CT, yet the benefits of every intervention type were substantially greater when instructor training was included (2008). The literature also promoted the need to make CT development objectives and the teaching of CT skills explicit in education, and research stressed the importance of metacognition in facilitating successful CT development.

Education must also consider conditions and methods that can foster successful transfer of CT skills, though it appears that many of the methods used to promote CT development will also promote CT transfer. For example: strategies that promote CT and subsequent transfer in education may include providing feedback on student performance and work, promoting metacognitive strategies and reflection, and avoiding excessive rote learning.

This section of the literature review could be expanded with a supplementary analysis on scholarly literature regarding CT interventions that might have been missed by the previously completed reviews. An original review of such sources could not be completed in the time frame of this project, so these conclusions are limited by exclusion of potentially relevant recent research. Nevertheless, the summaries completed and included in this report provide a well-developed overview of research on CT development, providing several considerations for education and for the related thesis project.

Conclusions.

Though the scope of this literature review was limited because of research time constraints, the retrieved literature did provide valuable insight into the four focus questions:

1. **How might critical thinking be best defined in relation to the goals of Education?**

Defining "critical thinking" is one of the most important steps in moving forward for successful CT development in educational settings. The literature points out that definitions of CT can be very diverse; though CT is valued in education, educators do not always agree on what constitutes effective CT. Still, there are several themes that emerge from this research. One must consider both CT skills and CT dispositions in order to provide a comprehensive definition

of the term. Additionally, CT is generally associated with higher order thinking abilities, and is connected to metacognition, creativity, and self-motivation. After reviewing many perspectives on CT and how it is described, the following definition was formulated:

Critical thinking: An important tool of inquiry and an esteemed educational goal. *CT* encompasses *skills* in analysis, evaluation, creativity, rationalization, hypothesizing, judgement, problem-solving, and decision-making – enabling the individual to form logical personal stances when considering complex issues. CT relates to a *character* that is fair-minded, inquisitive, flexible, confident in reasoning, and open to entertaining diverse viewpoints. The ideal critical thinker should endorse reason and strive to be well informed, and should be able to communicate ideas clearly and effectively through logical appeals. He or she should demonstrate persistence and motivation in pursuing truth, evidence, and results and should make all attempts to avoid bias and prejudice when considering and accepting ideas.

2. In terms of critical thinking skills, what does the research literature say is needed for successful university/college study?

The literature emphasizes that certain cognitive and metacognitive abilities are often identified as more valued in higher education than much of the specific content that is taught in secondary schools. These abilities fall in line with most of the skills and dispositions associated with the established definition of CT, including skills involved in analysis, inquiry, reasoning, communication, and problem solving, for instance. A precise level of CT ability necessary for success in higher education was not identified. However, it did seem clear that the CT abilities with which students begin post-secondary education are often insufficient. Many post-secondary institutions report that entering students regularly need remedial instruction to meet the demands

of higher education, as students' expected basic thinking skills were not adequately developed. It is clear that CT is an important contributor to academic achievement, especially at the post-secondary level.

3. What is the relation between high school instruction and subsequent student performance at the university or college level, specifically in regards to critical thinking abilities?

CT, as defined, is generally held as a predictor of post-secondary academic success (Williams and Worth, 2001; Stupnisky et al., 2008). However, the research suggests that secondary schools in North America, and on a global scale, are not adequately developing the CT abilities expected by higher education. It is even obvious to students that "high school isn't able to prepare students for [higher education]" (Dias & José Sá, 2012, p. 283). Accordingly, high school students are expected to experience a significant grade drop when they begin post-secondary education. Instruction encouraging CT and learning strategies can be remarkably beneficial for students pursuing higher education, but there is not much documentation of interventions used at the secondary school level and their subsequent effects. CT skills remain a strong predictor of post-secondary success.

4. How can the development of critical thinking be promoted in education?

Though CT is valued in education, the literature suggests that it is not currently sufficiently developed before students begin post-secondary studies. A large part of the problem is caused by a lack of clarity regarding the nature of CT and a potential deficiency in instructors' understanding of how best to develop students' CT abilities. CT development can be hindered by instruction that suppresses discussion and downplays the process of developing new ideas and

arguments. Teachers who simply demonstrate and explain concepts without allowing interaction and student involvement may also be inadvertently inhibiting students' CT development. Notably, this type of CT suppression can occur at any level of education. Alternatively, to foster CT, teachers should encourage beneficial discussion and should be receptive to new ideas, often serving as a facilitator for learning. The student's reasoning behind an answer is often more connected to his or her overall success than whether the particular answer was right or wrong. The literature also stresses the importance of developing students' metacognitive abilities in order to complement CT.

CT should not be seen as a "by-product" of other teaching or of education as a whole. For successful development, CT ought to be taught explicitly as a clear curriculum objective. Approaches that combine subject matter content with explicit CT instruction seem to be the most effective method for developing CT in the classroom setting. The teachers' knowledge and understanding of CT also plays an important part in the success of developing students' abilities, so specific teacher training can help produce more substantial results. The transferability of CT should also be considered in education and can be enhanced through the promotion of active student involvement in learning. Successful transfer is also encouraged by the development of learning strategies, metacognitive abilities, and a social learning context. Similar to CT, successful transfer can be inhibited by emphasis on rote learning of facts.

These considerations may help promote the educational development of CT, fostering enhanced student success and both academic and practical achievement. CT can be taught to some extent, but secondary schools may need to advance their educational methods to successfully develop students' abilities and prepare students to reach their potential following graduation.

CHAPTER 3: RESEARCH METHODS AND ANALYSIS

Research Questions.

The overall focus question of this thesis was, *"Are current critical thinking requirements in Ontario's secondary education system adequately preparing students for the demands and expectations of university level studies?"* To address this question, several more specific research questions were established which provided direction for data collection and analysis. Three research questions were established which focused on university level expectations of CT abilities and the requirements fostering development of these expectations in the Ontario secondary school curriculum.

First, the study asks what level of CT abilities university or college professors expect and want from undergraduate students in their first year of university studies. The literature review provided some insight into this inquiry, emphasizing the value of higher level thinking in post-secondary education, and the importance of CT as a contributor to academic success. However, specific, current views of university professors were not provided through the literature review. Further research on this topic accordingly aimed to help to provide answers to the following questions:

1. Do current professors agree with the definition of CT established in the accompanying literature review?
2. Do current professors value CT, and see it as necessary, or highly important, for students' success in college or university?
3. Do current professors support the idea that CT can be developed before students begin university or college, which is usually before these students have become adults?

4. What skills or abilities related to CT are most emphasized by professors who are currently involved in teaching undergraduate students?

Next, the research aimed to identify the perception of university or college professors regarding the CT abilities of average students beginning post-secondary education for the first time. The literature review has suggested that CT abilities with which students begin post-secondary education are often insufficient, creating a need for students to undergo remedial instruction, which frustrates both students and professors. To better understand how this trend affects higher education, specifically in Ontario, we asked if professors believe that students enter post-secondary education with satisfactorily developed CT skills.

Finally, this study is concerned with factors in Ontario's secondary school curriculum that explicitly encourage the development of CT abilities. For this reason, we analysed official curriculum documents to identify goals related to CT, and activities that would be expected to promote CT development. The literature review had helped to identify methods that might promote CT skills and dispositions; we now asked:

1. What activities, goals, or other factors in the official curriculum documents are designed to explicitly support the development of CT abilities or dispositions?
2. What activities, goals, or other factors in the official curriculum documents might indirectly contribute to CT development?
3. Do the official curriculum documents contribute to teachers' knowledge and understanding of CT and of beneficial practices for its successful development? If not, are there accompanying documents that do this?

4. How do the CT skills and abilities emphasized by professors compare to those emphasized in Ontario's secondary school curriculum documents?

Data Collection and Approach to Analysis

To narrow the investigation of these questions, we choose specific areas of focus. English Grade 12 (ENG4U) is the course required by most, if not all university and college programs in Ontario. Virtually every student pursuing higher education through a traditional route will need to demonstrate sufficient mastery of this course. Accordingly, this was first course selected for investigation. To expand the study, we also selected a Grade 12 Mathematics course, which is a prerequisite for most technical or scientific undergraduate areas of study. These areas of study also often require completion of an advanced secondary science course; Physics Grade 12 was selected in consideration of this common requirement. Qualitative analysis of these curriculum documents would provide an opportunity to address the guiding questions related to secondary school preparation.

Next, to increase coherence in the study, we decided to focus on the expectations and perceptions of professors who were teaching corresponding courses – English, Mathematics and Physics – at the university level. We also wanted the professors to be familiar with students' abilities as these are demonstrated when students *first* begin undergraduate study, so we limited investigation to those faculty members who were involved in teaching first-year introductory courses. The study was limited to eight universities in Ontario who agreed to participate, including Brock University, McMaster University, Queen's University, the University of Guelph, the University of Toronto, the University of Waterloo, the University of Western Ontario, and Wilfrid Laurier University. To discover the perceptions and expectations of

professors who volunteered to participate, we asked them to complete a short survey with room for written comments and an option to expand on or to illustrate answers through a follow-up interview. This study received ethical clearance from the University of Waterloo as well as required additional clearance from research ethics boards at other participating universities. The survey took place over a 20-day period. The option to participate was sent to each eligible faculty member at the participating universities, though not every eligible individual completed the survey. The study did not involve any deception, and each question was asked in a straight-forward manner, as clearly as possible. We wanted participants to completely understand what opinions they were being asked to provide.

The following sections detail the curriculum document analysis methods used and the methods used to analyse responses to the completed surveys.

Curriculum Document Analysis.

We systematically analyzed the Ontario Secondary School Curriculum to isolate and to evaluate content featuring CT goals. Three official *Ontario Secondary School Curriculum* documents were examined, including Physics 12 (2008), English 12 (2007), and Advanced Functions 12 (2007). The University Preparation form of each curriculum document was considered. These courses were selected to provide a range of subject areas with a focus on options commonly selected by students planning to pursue higher education after graduation. The analysis of ENG4U provides particularly useful insight, as satisfactory completion of this course is required for admission to most university programs in Ontario.

Specifically, this investigation includes analysis of the *intended* secondary school curriculum, which is described by Porter as the “content target” for the enacted – or taught – curriculum, and involves statements concerning what students must know and what they must be

able to do at the end of a certain period (2004, p. 1). Analysis of other dimensions of curriculum, such as subject specific knowledge goals, is also important, and can provide a more complete view of the educational system in Ontario; however, this additional analysis is outside the scope of this particular research project.

Qualitative data analysis is distinguished by its focus on text; the interpretation and meaning given to any particular text might be influenced by the goals and perspectives of individual researchers (Schutt, 2012). Historically, qualitative analysis is concerned with realizing the setting and people involved in the production of the text: the original influencing social context. For this particular document analysis, however, investigation focused on a particular aspect of the text instead of on an attempt to discover an interpretation for the entire document. First, distinct learning goals, comprised of demonstrable aspects of CT, had to be identified. Based on the definition of CT previously identified in the literature review, eight learning goals were identified, including student development of:

- Analysis skills
- Evaluation skills
- Creativity
- Hypothesizing skills
- Judgement and decision making abilities
- Inquisitiveness
- Confidence in reasoning
- Open, fair-mindedness and flexibility in reasoning

These factors are by no means inclusive of the many learning objectives that are to be covered by the selected curriculum documents. In addition, the previous literature review did not indicate a clear level of these learning goals to be expected of students beginning post-secondary education. It did, nevertheless, make it clear that students are expected to develop skills in CT

before beginning higher education. Accordingly, this analysis is not concerned with specific benchmarks for the listed goals, but instead is an attempt to identify and evaluate the curriculum's focus on developing each factor.

Analysis began by looking at each curriculum document as it is written to locate and record places where the development of the learning goals is explicitly targeted or implicitly advanced. Based on our literature review, we accepted that approaches combining subject matter content with explicit CT instruction would likely be the most effective methods for developing CT in the classroom setting. A learning goal would be considered *explicitly* targeted when its development or practice is the direct, unambiguous focus of the curriculum section (Archer and Hughes, 2011). Explicit instruction often includes "clear statements about the purpose and rationale… demonstrations of the instructional target, and supported practice with feedback" (Archer and Hughes, 2011, p. 1). In contrast, *implicit* instruction methods might include a vague or implied reference to the learning goal, yet would not clearly target its development. This search also aimed to identify any places where the curriculum might actually hinder students' overall CT development.

This preliminary analysis step is supported by the process for analyzing curriculum established by Project 2061 of the American Association for the Advancement of Science (AAAS, 1998). Project 2061 considers one of the integral first steps of curriculum analysis to be a preliminary inspection of the curriculum materials to see whether they are likely to address targeted learning goals (AAAS, 1998). This step is also related to what is often considered the first formal analytical stage of qualitative data analysis: documentation (Schutt, 2012). It allowed creation of a record of significant evidence, while encouraging ongoing reflection and

conceptualization. Additionally, this step allowed coding and categorization of the evidence, a process which can further facilitate subsequent or more intensive analysis.

Next, a more in-depth analysis was conducted to assess the level of CT development required in each documented case. In this analysis, we considered whether CT development is specific or general in nature, and attempted to identify where development of different aspects of CT overlap in the curriculum.

To analyse the curriculum for evidence of a contribution to teachers' knowledge and understanding of CT and of beneficial practices for successful CT development, we focused on how well the material explained CT and supported lesson development, assessment methods, and learning enhancement. This included provision of guidelines or recommendations for potential student activities and for instructional approaches. Where instructional materials or suggestions were not found in the specific curriculum document, we also searched for evidence of related supporting material provided by the Ministry of Education.

For the purposes of this paper, an exemplary curriculum document would demonstrate:

- Clearly identified learning goals explicitly related to each CT factor. This type of clear identification would require inclusion of a definition/description of each goal and information regarding how it might relate to a factor of CT or to CT as a whole. The learning goals and their relation to CT should be easy for readers to recognize and understand.
- Clear and precise connections between assessments and CT learning goals. Connections should be purposefully drawn and directly stated in the curriculum document for this objective to be met. Readers should not need to make assumptions regarding connections between CT learning goals and assessments if

the connections are clear. To assess whether this objective was met, we looked specifically for terms related to CT as a whole or to separate abilities associated with CT, and for direct connections from these terms to assessment guides.

- Instructional recommendations, notes, and guidelines consistent with beneficial CT development strategies. To determine whether this objective was met through the curriculum documents, we searched for evidence of explicit CT development, encouragement of student reflection and active learning, and scaffolding-type instruction (based on the conclusions in our literature review).

Survey Design and Analysis.

To address questions about university/college professors' expectations and perceptions of undergraduate student CT ability, a 21 item survey was designed to directly elicit opinions. The survey was sent to professors from eight Ontario universities who teach an introductory undergraduate English, Math, or Science course. In all, 22 individuals participated in the study, including 10 faculty members from English departments, 8 from math departments, and 4 from Physics departments. Two returned surveys were unusable because of incomplete responses – one from a Math faculty member and one from a Physics faculty member. To allow comparison of the data, participants completed parallel surveys depending on their faculty affiliation. Participants also indicated how long they have been involved in teaching first-year undergraduate students, and how many first-year classes and students they teach on average each year. The survey employed possible responses following the form of a Likert scale for most questions. There were two sections in the survey; Section 1 asked participants to indicate their

personal level of agreement with statements about CT, and Section 2 asked participants to indicate perceived importance of several observable aspects of CT.

For Section 1 in the survey, retrieved data was replaced with labeled ranks from 1 (Completely Disagree) through 7 (Completely Agree). This transformation was employed in order to decrease analysis sensitivity to outlying observations and to allow responses to be used with minimal assumptions regarding distribution (Moore, Notz and Fligner, 2013). This section of the survey contained eight items; two items considered the value professors placed on CT, two focused on perceived student ability to develop CT skills before beginning post-secondary education, and three dealt with professor satisfaction regarding the CT abilities of average incoming undergraduate students. In addition, one question asked participants to indicate their level of agreement as to whether the given definition encompasses their ideas of CT.

The second section of the survey asked participants to rank several components of CT from 1 (of little to no importance) to 5 (of extremely high importance). These components were not inclusive of every skill and disposition associated with CT, based on the definition we established through the literature review, but included several observable facets of CT:

- Analysis and evaluation skills
- Creativity
- Skills in problem-solving and decision making
- Ability to rationalize information to draw hypotheses
- Inquisitiveness and motivation to seek evidence and to be well-informed
- Confidence in reasoning
- Open, fair-mindedness and flexibility in reasoning
- Ability to avoid biased/prejudiced thinking
- Ability to communicate clearly and effectively

Space was provided for participants to comment after completing the ratings and participants could also choose to skip rating any or all of the given items. Discovering which facets of CT professors focus on or see as more important may help draw conclusions regarding which abilities might need to be further developed through secondary education. Responses from this section were compared with findings from the curriculum document analysis to identify similarities and differences.

The results of this survey were not normally distributed and the sample size was too small to justify assuming sufficient representation of the population. In addition, while the items on the survey contained ordinal variables, they were not based on interval or ratio measurements. Accordingly, we selected analysis methods based on non-parametric tests and procedures, independent of population distributions and related parameters. The Kruskal-Wallis test was used to determine whether there were significant differences between responses on Section 1 of the survey from different faculty groups. Data were summarized by finding the *mode* of responses on each item, as the *mean* – though a more common measure of central tendency – is typically calculated only when the data is interval or ratio in nature (Sheskin, 2004). To determine whether results were statistically significant, a Mann-Whitney test was performed, which evaluates whether there is a significant difference between response distributions using rank-orders (Sheskin, 2004). The data from each question thus was ranked and compared with a null hypothesis that each possible response will be selected randomly and equivalently. The difference between the rank totals is reflected in the value of the Mann-Whitney test statistic *"U"*, and obtained values of *U* are analysed using a table of critical values for *U* which shows the likelihood that the particular value was obtained purely by chance. Responses for separate items from Section 2 were also compared using modes.

CHAPTER 4: RESULTS

This study examined evidence of CT in samples Ontario's secondary school curriculum documents and faculty expectations and perceptions regarding the CT abilities of first-year students across Ontario. The results of each part of the study are outlined below.

Curriculum Analysis.

English 12 Curriculum - ENG4U.

Preliminary inspection. The complete results of the preliminary inspection of the particular section of the English curriculum document are provided in table form in Appendix I. Table 7 provides a subset of the full chart, to show the types of examples found to illustrate various CT component skills. The table categorizes findings and supports descriptions with direct quotes from the original text.

CT Component Summaries. The following summaries indicate the number of identified instances of development for each considered component of CT, and designate the development as explicit or implicit.

- *Analysis skills:* Analysis skills are promoted in 18 separately identified places in the curriculum document. Most support for this learning goal is through practice, and "analysis" or a synonym is explicitly mentioned in many cases.
- *Evaluation skills:* Skills in evaluation were related to 20 activities in the curriculum document, usually related to implicit development.
- *Creativity:* The implicit development of creativity was identified in 7 locations in the text, and this CT learning goal was also explicitly focused on in one instance.
- *Confidence in Reasoning:* Two overall objectives in the curriculum were related to the development of confidence in reasoning. It is possible that student confidence will be

promoted simply through the practice of various reasoning activities, though this cannot be conclusively presumed.

Table 7

Example subset of documented preliminary inspection of ENG4U

ENG4U		
Factor of CT	**Example:**	**Description**
Analysis skills Evaluation skills Creativity Hypothesizing skills Judgement and decision-making abilities Confidence in reasoning Inquisitiveness Open, fair-mindedness and flexibility in reasoning	*"emphasizes the consolidation of the literacy, communication, and critical and creative thinking skills necessary for success in academic and daily life" (p.91)*	The curriculum describes an overall objective to focus on development of CT as necessary for academic and daily success. This implies development of each of the identified components of CT, though only creativity is mentioned directly in this case.
Analysis skills Evaluation skills Creativity	*"Students will analyse a range of challenging literary texts…interpret and evaluate informational and graphic texts… create oral, written, and media texts in a variety of forms." (p.91)*	This overall goal explicitly relates to practice of analysis and evaluation. Creativity may also be implicitly developed, through practice of creating a variety of literature and media.
Evaluation skills Judgement and decision-making abilities Confidence in reasoning	*"An important focus will be on using academic language coherently and confidently, selecting the reading strategies best suited to particular texts and particular purposes for reading" (p.91)*	Here, the curriculum describes an overall focus on developing student confidence and the selection of learning strategies, which is related to the development of both evaluation skills and judgement and decision-making abilities.
Overall CT development	*"reflect on and identify their strengths as listeners and speakers, areas for improvement, and the strategies they found most helpful in oral communication situations" (p.92)*	The described expectation of reflection can be related to the development of metacognition, which can promote overall CT abilities.

- *Hypothesizing skills:* There were 8 places identified as instances where the curriculum supported the practice and implicit development of hypothesizing skills.
- *Judgement and decision making abilities*: There were 12 objectives identified that would encourage students to use good judgement and decision making abilities. These cases did not include direct, explicit development of the learning goal.
- *Inquisitiveness:* There were 3 instances identified where the curriculum content may promote student inquisitiveness.
- *Open, fair-mindedness and flexibility in reasoning:* Explicit, focused development of open, fair-mindedness and flexibility in reasoning did not appear to be included in the examined material. However, 7 identified instances imply promotion of this CT learning goal in the English curriculum.

Results of ENG4U Analysis. "Critical thinking" is mentioned in one part of the course objectives, and is mentioned again in the achievement chart included as part of the English curriculum. Practice of each CT learning goal was discovered in the English curriculum. In most cases, the curriculum seemed to indirectly encourage development of these learning goals, and many instances showed overlap in the development of CT components.

It seems that a strong emphasis is placed on practice of analysis and evaluation skills in the curriculum document. Inquisitiveness and confidence in reasoning were the learning goals identified least in the review. The differences in curriculum emphasis of the different CT components are illustrated in Figure 1.

There is substantial evidence of examples of possible student activities in the document, and of potential teacher prompts to encourage student learning. Other instructional recommendations, notes, and guidelines consistent with beneficial CT development strategies are

not clearly included in the examined English curriculum; the document focuses on overall learning objectives, observable practice, and performance goals. Overall CT development is supported in several identified instances in the curriculum, through the development and practice of metacognitive strategies.

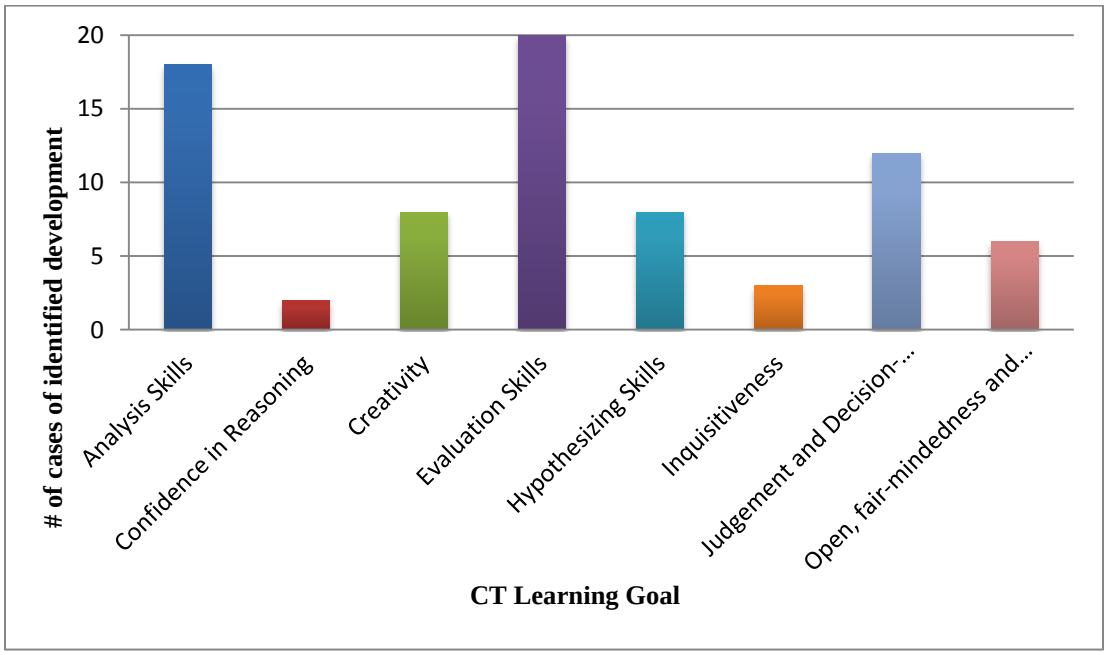

Figure 1: Differences in emphasis on separate CT learning goals in ENG4U

Mathematics 12 Curriculum - MHF4U.

Preliminary inspection. The complete results of the preliminary inspection of the particular section of the Mathematics curriculum document are provided in table form in Appendix J. Table 8 provides a subset of the full chart, to show the types of examples found to illustrate various CT component skills. The chart categorizes findings and supports descriptions with direct quotes from the original text.

Table 8

Example subset of documented preliminary inspection of MHF4U

MHF4U		
Factor of CT:	**Example:**	**Description:**
Analysis skills Evaluation skills Hypothesizing skills Judgement and decision-making abilities Open, fair-mindedness and flexibility in reasoning Confidence in reasoning	*"The mathematical processes are to be integrated into student learning in all areas of this course… develop and apply reasoning skills… demonstrate that they are reflecting on and monitoring their thinking" (p. 86)*	The math curriculum begins with descriptions of seven mathematical processes that relate strongly to CT. These learning goals are supported by reflection and by practice of monitored thinking, which is likely to improve students' metacognitive abilities. Development is considered to be explicit in this case for each learning goal *except* for "open, fair-mindedness and flexibility in reasoning".
Hypothesizing skills Judgement and decision-making abilities Open, fair-mindedness and flexibility in reasoning	*"including those in problems arising from real-world applications" (p.87)*	In this instance, the curriculum connects equation solving in the classroom to real-world problem solving, implying development of judgement, flexibility in reasoning, and hypothesizing skills. This practice may also promote transfer of the CT components.
Analysis skills Evaluation skills Hypothesizing skills Judgement and decision-making abilities Open, fair-mindedness and flexibility in reasoning	*"make connections between related logarithmic and exponential equations… between the laws of exponents and the laws of logarithms… with or without technology" (p.87)*	To make connections as described, students may be required to practice analysis skills, evaluation skills, hypothesizing skills and judgement and decision making abilities. Requiring the students to develop reasonable connections with or without technological assistance can help them to practice flexibility in reasoning. Here, CT development is considered implicit.
Analysis skills Evaluation skills Hypothesizing skills Judgement and decision-making abilities Open, fair-mindedness and flexibility in reasoning	*"Sample problem: Give examples to show that the inverse of a function is not necessarily a function… pose problems based on real-world applications of exponential and logarithmic functions" (p.88)*	The described activities implicitly require students to practice several CT skills, as listed.

CT Component Summaries. The following summaries indicate the number of identified instances of development for each considered component of CT, and designate the development as explicit or implicit.

- *Analysis skills:* Analysis skills are promoted in 13 separate identified places in the curriculum document. This development is generally implicit.
- *Evaluation skills:* Development of skills in evaluation was identified in 9 places in the curriculum document, consisting of implicit promotion.
- *Creativity:* Implicit development of creativity was identified in 3 locations in the text.
- *Confidence in Reasoning:* The development of confidence in reasoning is not clearly promoted in this curriculum document. It is possible that student confidence will be promoted simply through the practice of various reasoning activities, though this cannot be conclusively presumed.
- *Hypothesizing skills:* There were 17 different places where the curriculum promoted the implicit development of hypothesizing skills through practice and problem-solving.
- *Judgement and decision making abilities*: The curriculum supported problem solving and application practices that often implied development of judgement and decision making abilities; this was identified in 17 separate cases in the course.
- *Inquisitiveness:* There was only one case where the curriculum was found to promote inquisitiveness, and this development was identified as implicit.
- *Open, fair-mindedness and flexibility in reasoning:* The curriculum document implicitly supports the development of open, fair-mindedness and flexibility in reasoning in 16 identified instances.

Results of MHF4U Analysis. The Mathematics curriculum begins with a description of "Mathematical Process Expectations" (p.86) which are meant to be integrated into instruction and learning throughout the curriculum. These processes are strongly related to CT, and include problem-solving, reasoning and proving, reflecting, selection of tools and strategies, making connections and representations, and skills in communication. Each of the processes is described in detail in a separate part of the encompassing curriculum document as well. They are described as interconnected, and driven by the process of problem-solving. Their focused development does seem evident through the rest of the document, which allows many of the developed CT Learning Goals to be supported substantially in the MHF4U curriculum.

In most cases, the CT learning goals are not mentioned directly or explicitly focused on, so development is considered implicit. The curriculum does not provide much identifiable support for the development of inquisitiveness, confidence in reasoning, and creativity; however, these specific learning goals may be enhanced implicitly through student success and development in other areas of CT. Differences in curriculum emphasis on various CT components are illustrated in Figure 2.

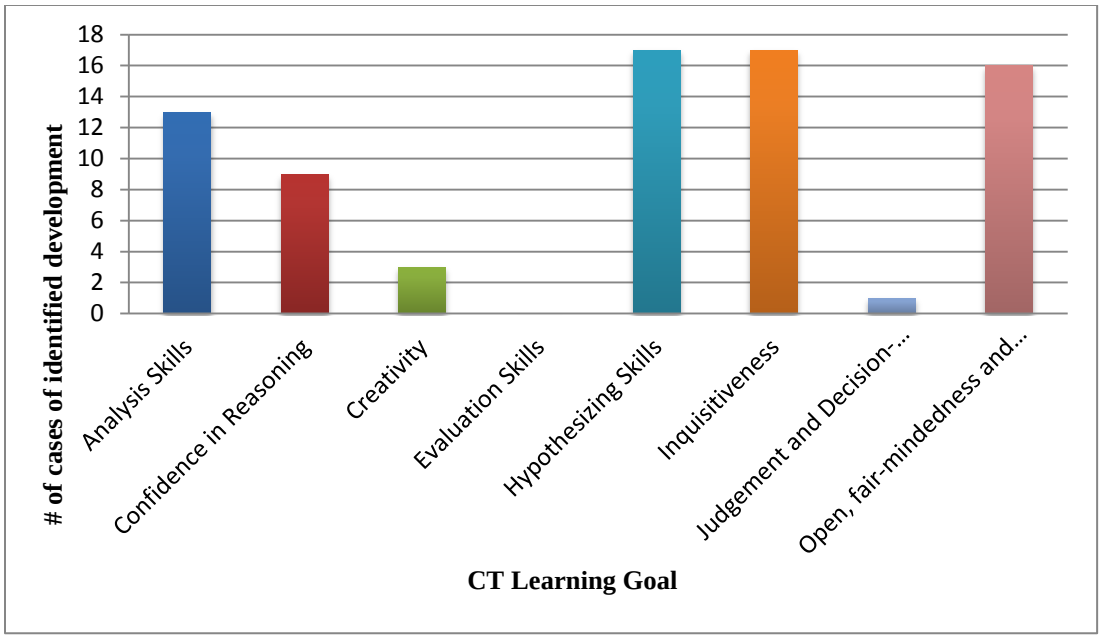

Figure 2: Differences in emphasis on separate CT learning goals in MHF4U

The Mathematics curriculum also seems to emphasize the development of metacognition and to promote self-regulated learning, which are both identified in our literature review as beneficial to students' overall CT development. The additional section explaining the listed mathematical processes enhances the emphasis on metacognition by urging teachers to encourage students to justify solutions, communicate them in different ways, and reflect on alternatives. The curriculum supports this practice to encourage students to "begin to think about their own thinking (metacognition) and the thinking of others, and to consciously adjust their own strategies in order to make their solutions as efficient and accurate as possible" (p.18). Further, the MHF4U curriculum often requires students to make connections between book work and real life application, which may help students successfully transfer developed skills and abilities to new contexts. The described cognitive techniques are held by the curriculum as more meaningful when integrated with mathematical knowledge and skill development.

Physics 12 Curriculum - SPH4U.

Preliminary inspection. The complete results of the preliminary inspection of the particular section of the Science curriculum document are provided in table form in Appendix K. Table 9 provides a subset of the full chart, to show the types of examples found that illustrate various CT component skills. The chart categorizes findings and supports descriptions with direct quotes from the original text.

Table 9

Example subset of documented preliminary inspection of SPH4U

SPH4U		
Factor of CT:	**Example:**	**Description:**
Analysis skills	*"They will further develop their scientific investigation skills, learning, for example, how to analyse" (p.194)*	Here, the course introduction mentions a learning goal explicitly related to the development of analysis skills.
Analysis skills Evaluation skills Hypothesizing skills Judgement and decision-making abilities	*"demonstrate scientific investigation skills… initiating and planning, performing and recording, analysing and interpreting, and communicating" (p.196)*	The scientific investigation skills described include mention of analysis. They may also involve practice of judgement and decision-making abilities to facilitate planning, and evaluation or hypothesizing skills to interpret data.
Analysis skills Evaluation skills Creativity Hypothesizing skills Inquisitiveness	*"formulate relevant scientific questions… make informed predictions, and/or formulate educated hypotheses to focus inquiries" (p.196)*	This curriculum goal may involve practice of analysis skills and/or evaluation skills in order for students to make predictions. Hypothesizing skills are mentioned directly. Students may implicitly develop inquisitiveness and creativity as well when formulating questions.
Judgement and decision-making abilities	*"apply knowledge and understanding… when planning investigations" (p.196)*	To correctly apply knowledge and understanding in planning, as described, students may need to practice good judgement and decision-making abilities.

CT Component Summaries. The following summaries indicate the number of identified instances of development for each considered component of CT, and designate the development as explicit or implicit.

- *Analysis skills:* Analysis skills are promoted in 33 separate identified places in the curriculum document.
- *Evaluation skills:* In 11 places in the curriculum document, evaluation skills were implicitly developed.
- *Creativity:* Implicit development of creativity was identified in 2 locations in the text.
- *Confidence in Reasoning:* The development of confidence in reasoning is not clearly promoted in this curriculum document. It is possible that student confidence will be promoted simply through the practice of various reasoning activities, though this cannot be conclusively presumed.
- *Hypothesizing skills:* There were 19 different places where the curriculum promoted the implicit development of hypothesizing skills through practice and problem-solving.
- *Judgement and decision making abilities*: The curriculum supported problem solving and application practices that often implied development of judgement and decision making abilities; this was identified in 7 separate cases in the course.
- *Inquisitiveness:* There were 4 cases where the curriculum was found to promote inquisitiveness; this development was identified as implicit.
- *Open, fair-mindedness and flexibility in reasoning:* There was only one place identified where the curriculum document – implicitly – supports the development of open, fair-mindedness and flexibility in reasoning.

Results of SPH4U Analysis. The Physics Grade 12 curriculum strongly emphasizes the development of analysis skills in comparison to other identified components of CT (Figure 3).

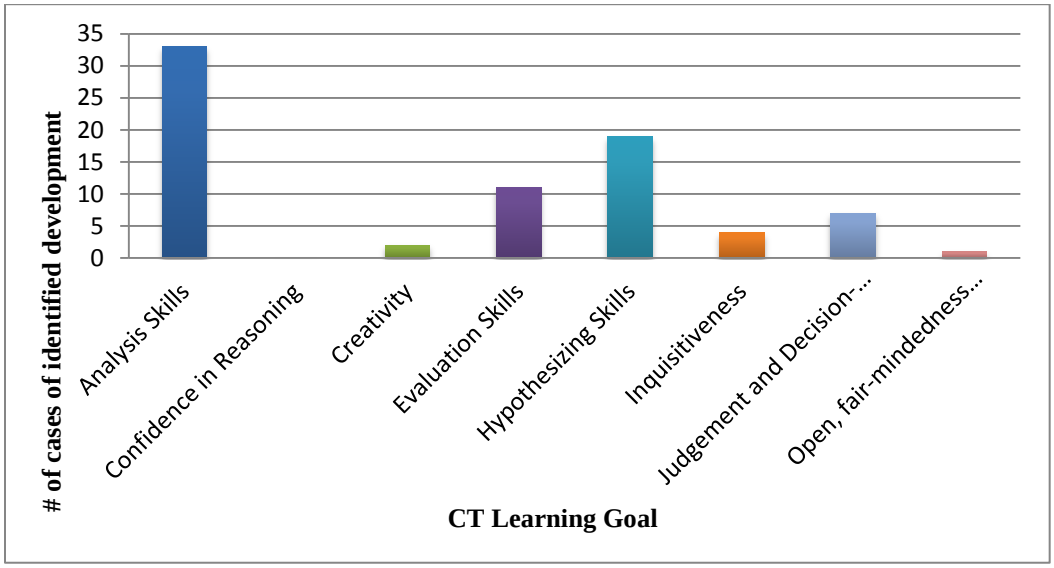

Figure 3: Differences in emphasis on separate CT learning goals in SPH4U

Several of the CT learning goals are not well supported by the Physics curriculum. These include confidence in reasoning, creativity, open, fair-mindedness and flexibility in reasoning, and inquisitiveness. However, these goals may be developed implicitly through instruction or activity factors that are not covered in the document. In most cases, CT development is implicit and the overall term "critical thinking" itself is not found in this particular part of Ontario's science curriculum. Investigation skills are a significant focus of the course, however, and many of the skills involved in investigation may be related to CT.

Survey Data Analysis.

Testing for differences in responses across disciplines.

Using the Kruskal-Wallis test (Sheskin, 2004) on responses from Sections 1 and of the survey, we examined the data to determine whether responses were significantly different across the three disciplines. The Kruskal-Wallis test is based on the sums of ranks of the different

samples being compared. If responses are systematically larger in some groups than others, then the differences between the sums of ranks will also be larger. A probability of 5% is considered significant; if the test returns a *P*-value higher than or equal to 0.05, than the responses from members of the different disciplines were not significantly different, and the data can be combined for consideration. The combined data were summarized by finding the mode of responses on each item. Sample calculations used for this test can be found in Appendix L. The results appear in Table 10 and Table 11.

Table 10

Summary of Kruskal-Wallis test results, showing modes of combined results and whether or not the null hypothesis is supported, used for Section 1 of the survey: statements of agreement/disagreement.

Statement:	*H*	*P-value*	*Supports Null Hypothesis*	*Mode*
The definition above clearly encompasses my idea of critical thinking.	0.574796	0.75	*YES*	6
Critical thinking, as defined above, is of high value in education.	2.18285	0.25 $P<$ 0.5	*YES*	7
Critical thinking can be developed before students begin university/college.	6.15539	0.01 $<P<$ 0.05	*NO*	*n/a*
Only adults can be good critical thinkers.	3.34952	0.1 $<P<$ 0.25	*YES*	2
Critical Thinking abilities are necessary for students to be successful in university.	9.38132	$P<$0.01	*NO*	*n/a*
Stronger critical thinking skills should be developed before students begin university.	2.34013	0.25 $<P<$ 0.5	*YES*	6
I am satisfied with the critical thinking abilities of the average student entering my university class.	0.90051	0.5 $<P<$ 0.75	*YES*	3
In my opinion, most students begin university with sufficiently developed critical thinking skills, abilities and dispositions (as listed above and described in the included definition of critical thinking).	0.16585	0.9 $<P<$ 0.95	*YES*	3

Table 11

Summary of Kruskal-Wallis test results, showing modes of combined results and whether the null hypothesis is supported. Used for Section 2 of the survey: ranked values of CT components.

CT Component	*H*	*P-value*	*Supports the null hypothesis*	*Mean*	*Mode*
Analysis and Evaluation Skills	0.20626	0.9 <*P*< 0.95	YES	4.7	5
Creativity	2.7165	0.25 <*P*< 0.5	YES	4.05	4
Skills in problem-solving and decision making	1.3707	0.5 <*P*< 0.75	YES	4.25	4.5
Ability to rationalize information and draw hypotheses	0.27551	0.75 <*P*< 0.9	YES	4.45	5
Inquisitiveness and motivation to seek evidence and to be well informed	2.3155	0.25 <*P*< 0.5	YES	*4.55*	5
Confidence in reasoning	0.73728	0.5 <*P*< 0.75	YES	4	4
Open, fair-mindedness and flexibility in reasoning	3.3878	0.1 <*P*< 0.25	YES	4.5	4.5
Ability to avoid biased/prejudiced thinking	0.80952	0.5 <*P*< 0.75	YES	4.25	4.5
Ability to communicate clearly and effectively	2.9299	0.1 <*P*< 0.25	YES	4.5	5

Separate modes for each sample were found in the two identified cases where the null hypothesis was rejected. The discrepancy between responses, by faculty affiliation, is shown in Figure 4. Reviewing Figure 4, we hypothesized that responses from Math and Physics faculty members might not be statistically different for the statement “Critical Thinking abilities are necessary for students to be successful in university.” We accordingly compared responses from these two datasets for this particular item and found a P-value between 25% and 50%. This demonstrates that the responses between math faculty members and physics faculty members were not significantly different for the given question.

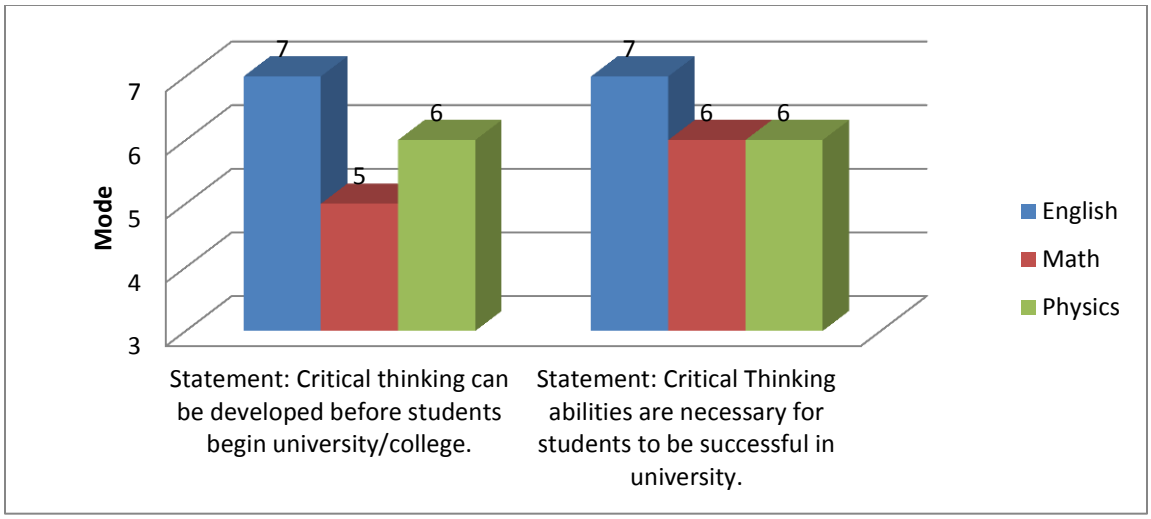

Figure 4: Discrepancy in Central Tendencies by sample population.

Testing for significance compared to random response.

Next, a Mann-Whitney test was performed to determine whether combined responses were systematically higher or lower than random where the Kruskal-Wallis test showed no significant discrepancy between populations. All responses were not combined in the two cases where they were shown to be statistically different. English and math population responses to the statement "Critical thinking can be developed before students begin university/college." For this question, the Mann-Whitney test was not applied to responses from the Physics discipline, as the sample size was too small to yield accurate results: there is no critical value for the Mann-Whitney *U* statistic when sample sizes are below 4 (Sheskin, 2004, p. 1161). Responses from the Physics sample and the Math sample were combined when considering the item: "Critical thinking abilities are necessary for students to be successful in university." This test allows us to determine whether the actual responses hold statistical significance. We compared actual responses retrieved from the survey to a created dataset where each possible answer was selected evenly to simulate random response distribution. An example of how the test was conducted is provided in Appendix M. The results are outlined in Table 12 and Table 13.

Table 12

Summary of Mann-Whitney test results for Section 1 of the survey: statistical significance of statements of agreement/disagreement in comparison to a hypothetical random sample. Here, "higher" results suggest that the surveyed professors agree with the given statements more strongly than random, while "lower" results indicate stronger than random disagreement.

Statement:	*U*	Comparison to critical U-values	Are actual responses significantly different then random?
The definition above clearly encompasses my idea of critical thinking.	107	**107** < 127	Yes - higher
Critical thinking, as defined above, is of high value in education.	57	**57** < 127	Yes - higher
Critical thinking can be developed before students begin university/college. (English)	9.5	**9.5** < 12	Yes - higher
Critical thinking can be developed before students begin university/college. (Math)	34.5	8 < **34.5** > 41	**No**
Only adults can be good critical thinkers.	313	**313** > 273	Yes - lower
Critical Thinking abilities are necessary for students to be successful in university. (English)	8	**8** < 14	Yes - higher
Critical Thinking abilities are necessary for students to be successful in university. (Math and Physics)	21	14 < **21** > 56	**No**
Stronger critical thinking skills should be developed before students begin university.	98	**98** < 127	Yes - higher
I am satisfied with the critical thinking abilities of the average student entering my university class.	221	127<**221**< 273	**No**
In my opinion, most students begin university with sufficiently developed critical thinking skills, abilities and dispositions (as listed above and described in the included definition of critical thinking).	221	127<**234**< 273	**No**

Table 13

Summary of Mann-Whitney test results for Section 2 of the survey: statistical significance of ranked values of CT components in comparison to a hypothetical random sample. Here, "higher" results suggest that the surveyed professors placed more importance on the given CT component that what may have been observed at random.

CT component:	*U*	Comparison to critical U-values	Are actual responses significantly different then random?
Analysis and Evaluation Skills	64	**64** < 127	Yes - higher
Creativity	116	**116** < 127	Yes - higher
Skills in problem-solving and decision making	100	**100** < 127	Yes - higher
Ability to rationalize information and draw hypotheses	92	**92** < 127	Yes - higher
Inquisitiveness and motivation to seek evidence and to be well informed	76	**76** < 127	Yes - higher
Confidence in reasoning	120	**120** < 127	Yes - higher
Open, fair-mindedness and flexibility in reasoning	80	**80** < 127	Yes - higher
Ability to avoid biased/prejudiced thinking	100	**100** < 127	Yes - higher
Ability to communicate clearly and effectively	80	**80** < 127	Yes - higher

Responses for each item in Section 2 were found to be significantly different from those found in a hypothetical random dataset. The actual response data from Section 2 are illustrated in Figure 5, using modes of responses with distinct values for each population sample.

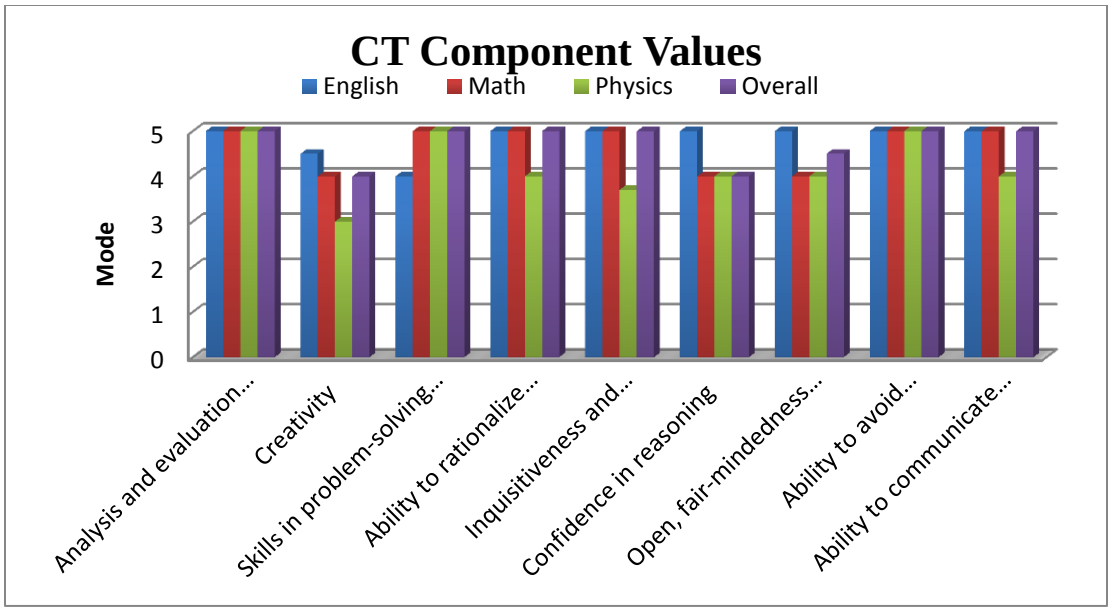

Figure 5: Ranked values of CT components, overall and by faculty affiliation. (Note: for responses with more than one mode, the average of the mode is used).

Summary of Survey Analysis Results.

Through the conducted survey analysis, we found that the three sample populations were often similar in their responses. There were two cases where the populations were found to be too divergent to be combined, yet even in these cases responses were usually positive: the professors generally all expressed agreement with the given statement, just to different degrees. In most cases, the responses were also very different than what might have been observed if each option was selected randomly, indicating that significant conclusions can be drawn from the data. In the next chapter, we will discuss what the retrieved responses indicate about the views of faculty members regarding aspects of CT.

CHAPTER 5: CONCLUSION

Discussion.

The completed literature review provided a good foundation of knowledge regarding CT development and expectations, and allowed us to create a specific definition of "critical thinking" for use in this investigation. Original research was then conducted to gain insight into several remaining questions.

CT development in Ontario's secondary school curriculum.

We analyzed Ontario's secondary curriculum in an attempt to understand how CT is developed in Ontario's high schools. Based on the conducted literature review, we understood that CT development is fostered by instruction methods that encourage beneficial discussion and that are receptive to new ideas. The literature also highlighted the contributions of metacognition and active learning in promoting CT development, and expressed a need to ensure that CT is taught explicitly as a clear curriculum objective. Emphasis on rote factual learning was shown as potentially inhibiting to the development and transfer of CT.

Unfortunately, the vast majority of CT development in the three examined curriculum documents was not explicit. For example, "critical thinking" as a whole was mentioned in the ENG4U course objectives, yet it mainly seemed to be connected to practice of identification and analysis skills, which are related to CT, but do not nearly encompass the range of abilities and dispositions associated with this educational goal. However, both the ENG4U curriculum and the MHF4U curriculum emphasized the importance of developing metacognition and promoting self-regulated learning, both of which can enhance students' development and use of CT.

The Mathematics curriculum provided the strongest support for CT out of the three examined course documents, centering learning on "Mathematical Process Expectations" that are

strongly related to CT. The mathematics curriculum also strongly emphasized the connection between classroom learning and real life application, which can aid in successful transfer of developed CT skills and abilities. Contrastingly, the grade 12 Physics curriculum – SPH4U – did not seem to place a significant emphasis on the development of CT, or of metacognitive abilities that might facilitate CT development. In fact, the term "critical thinking" was not even found in this part of Ontario's science curriculum. It is important to note that while CT development was found to be the most substantial in the mathematics curriculum – compared to the other examined courses – the MHF4U course is not required for secondary school graduation, and is not required for entrance into many university programs.

In the MHF4U curriculum, there was some evidence of consideration of teaching methods as well; teachers were expected to encourage students to justify solutions, to discover and think about alternatives, and to communicate ideas in different ways. Otherwise, the curriculum documents did not seem to substantially contribute to teachers' knowledge and understanding of CT and of instruction methods that could foster successful CT development. It is possible that instruction methods and considerations for teaching CT are examined in supplementary documents, or developed through teacher education. However, the prevailing belief is that most students do not sufficiently develop CT skills before beginning university. Consequently, the absence of instructional considerations in the curricula may be indicative of an overall lack of consideration for the support of teacher understanding of CT and its development in Ontario's education system. Indeed, teachers' knowledge and understanding of CT, and of practices that can help or hinder its development, plays a vital part in shaping student CT development.

It is important to note that the curriculum in Ontario does show evidence of improvement in the area of critical thinking development. A supplementary examination of a previous ENG4U curriculum document – from 2000 – suggests that the revised version promotes a better balance of development of the various identified CT goals, as illustrated in Figure 6. The 2007 revision document also includes expectations regarding of student reflection which were not found in the earlier version of the curriculum. For example, the current English curriculum document expects students to "demonstrate insight into their strengths and weaknesses as listeners and speakers, and practise the strategies they found most helpful" (2007, p.94), which can be related to the development of metacognition and the promotion of overall CT abilities. This type of encompassing objective, focused students' reflection and self-improvement, was not identified in the 2000 version of the English 12 curriculum. While there may be more to do to ensure CT development is successfully integrated in secondary school instruction, education in Ontario does show signs of improvement with the revised English curriculum documents.

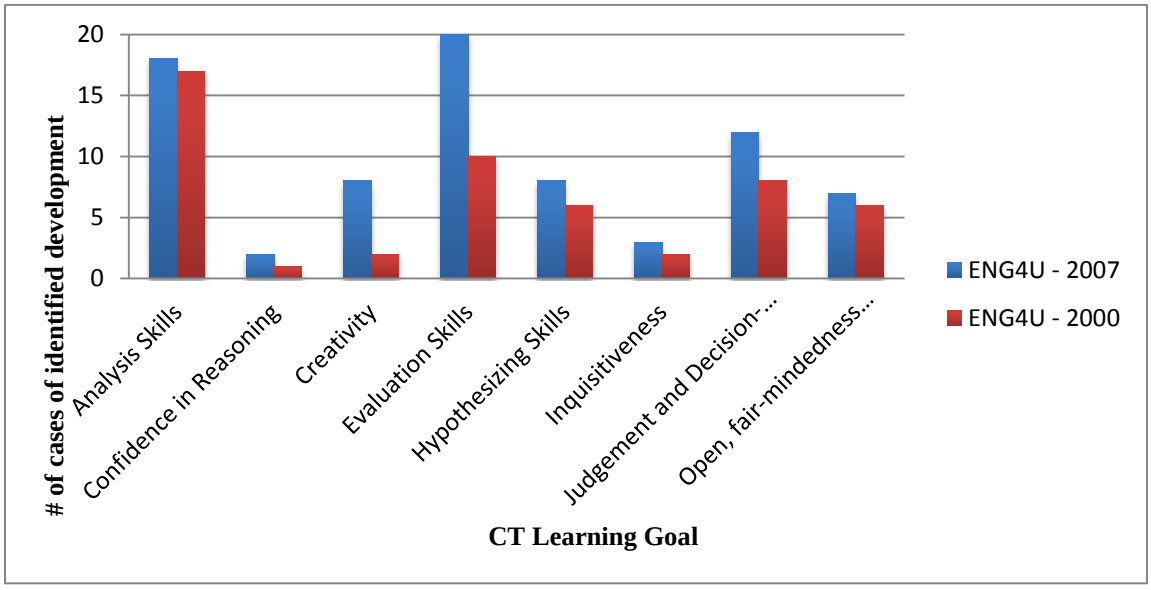

Figure 6: Illustration of the difference between CT learning goal development in two recent version of the ENG4U curriculum document.

University professors' definitions and expectations for CT.

We also examined university professors' views of CT, its value in education, and students' general abilities. Based on the research, most current university professors *strongly agree* that the established CT definition clearly encompasses their idea of CT. CT is held to be of high value in education, and most professors *strongly agree* that CT as defined is necessary for student success at the university level, with English professors usually *completely agreeing* with this concept.

There were two questions where the professors' responses were significantly different based on their disciplines. The first of these items asked respondents to state their level of agreement or disagreement with the statement "Critical thinking can be developed before students begin university/college." Closer inspection and consideration of this question has allowed us to realize that the term "developed" may be ambiguous in this context: it could easily be taken to mean either *advanced to a certain degree (adj.)* or to mean *taught (verb).* This ambiguity may have influenced the perceptions of the professors surveyed: professors might have adopted whichever meaning is more common to their field, leading to the discrepancy between responses.

All of the identified factors of CT were identified as important to fostering student academic success; specific CT components identified as having the highest importance by the entire group of professors included:

- Analysis and evaluation
- Problem-solving and decision making
- Ability to rationalize information and draw hypotheses
- Inquisitiveness and motivation to seek evidence and to be well informed

- Ability to avoid biased/prejudiced thinking
- Ability to communicate clearly and effectively

Several CT learning goals were identified with various emphases in the curriculum documents as well. There are some comparisons that can be made between the curriculum documents and the faculty members' ranked values of CT components.

Physics faculty members placed the highest importance on analysis, evaluation, problem-solving and decision making, and the ability to avoid biased/prejudice thinking. Analysis of the Physics curriculum did not consider the course's development of the ability to avoid biased/prejudice thinking. The document was identified as having a strong emphasis on analysis skills, and a moderate emphasis on evaluation and judgment and decision-making abilities. In many ways, the SPH4U document seems to align with the perceptions of the surveyed Physics faculty members. English and Math faculty members generally ranked all the given CT components at the highest level, except for creativity and problem-solving and decision making. However, the ENG4U curriculum document placed a significantly stronger emphasis on skills in analysis and evaluation compared to the other CT learning goals. The English curriculum also indicated a moderately strong emphasis on creativity and on judgement and decision making. The MHF4U curriculum did not seem to emphasize creativity and judgement and decision making compared to other CT components, and, other than evaluation skills, each of the other CT learning goals was identified several times in the MHF4U curriculum document.

It is clear from this study that university professors do place a strong value and emphasis on CT, as related to students' potential for academic success. This finding is supported by the literature about CT, which emphasized the value of CT and the link between CT and post-secondary academic achievement. Additionally, most professors seemed confident that CT *can*

be developed before students enter university. Responses did vary: one professor expressed scepticism regarding whether CT skills can be developed before university, while another stated belief that even children can learn CT habits. Overall, the professors surveyed expressed agreement with the idea that CT can be developed before students began university/college, and *strongly disagreed* that only adults can be good critical thinkers. Indeed, one professor noted that "Critical thinking is in fact a matter of survival, and can and should be fostered from an early age." Our literature review supports the idea that CT *can* be developed at an early age, and suggests that adolescence may be a crucial stage for the formal development of CT as adolescence is marked by the development of metacognitive and deductive reasoning abilities.

University professors' perceptions of students' CT abilities.

The completed literature review suggested that CT is often not sufficiently developed before students begin post-secondary studies; this original research thus aimed to gain insight into professors' perception of the CT abilities of incoming undergraduate students. Responses varied across professors, though the large majority expressed some extent of dissatisfaction with the CT skill levels of incoming first-year students, and did not think that students began university with sufficiently developed CT abilities, as illustrated in Figure 7.

One professor, who indicated some dissatisfaction with the CT abilities of incoming students, did not think that the lack of skills is necessarily a problem, stating that university instructors would always "want them to have more than what they actually have" and noting that CT needs to develop "over time, including through high school and on through each year of university study." The professor did believe that earlier, more substantial development of CT is tied to greater student success and achievement. Similarly, another professor expressed the

opinion that it is a key part of his job to teach CT in university, musing that "if they had this down I'd be out of a job." This professor noted that a few (10%) of students usually enter his class with CT capacities that could get them an "A" in his course. As he taught, he would try to move other students up to that "A" level of CT through the course.

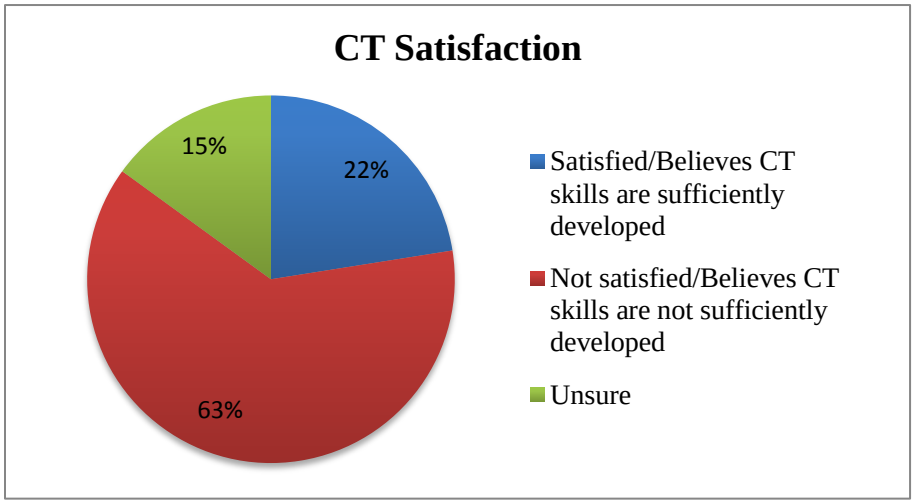

Figure 7: Professors' stated satisfaction with incoming students' CT abilities.

On the other hand, while taking care not to generalize, several university professors expressed the belief that, in one individual's words, "Too many students come to university either indifferent to much of the knowledge and ideas available to them, or, which may even be worse, ready to accept authority's presentation of such things at face value." It was suggested that first-year students are more comfortable with rote learning than CT, or do not know how to exercise CT skills even if they possess them. A professor involved in teaching literature thought that "many students do not consider the possibility of multiple meanings, and have a hard time arguing for an interpretation while also allowing the possibility that others exist." Overall, this study suggests that professors do not think CT skills are sufficiently developed before students begin post-secondary study.

Implications for further research and for practice.

Teachers, curriculum designers, and others involved in education must have a good understanding of CT in order to foster student success in CT development and to encourage subsequent academic achievement. C21 Canada and Ontario's Ministry of Education have taken steps towards defining CT, for example, but an accepted, understandable definition needs to be uniformly promoted. Teachers, especially those involved in secondary education, should understand not only how CT is defined, but how it can be taught and developed in the classroom setting. Accordingly, teacher education and training programs should research good methods for developing CT, and should examine their own programs to ensure that participants have a strong understanding of these methods and of their purpose upon completion of formal training. Education in Ontario can benefit from the addition of specific, explicit curriculum expectations for CT development. Further research could examine other secondary school curriculum documents and lesson plans in Ontario or in other provinces and countries to evaluate how and where CT is developed. In Ontario, the curriculum focuses on objectives: it does not outline the processes involved in ensuring students meet the given expectations. Accordingly, direct classroom observation can support the applicability of future potential research. The practices and activities used by teachers each day have a significant, direct impact on how well students develop critical thinking abilities.

We attempted to research perceptions of secondary school principals as well for this study, and unfortunately did not receive enough response to include the data in this paper. Further research could consider how higher education perceptions and expectations of CT align with the ideas of individuals involved in secondary education, including principals, teachers, and course or curriculum developers, for example. Developing a similar study with a wider scope

may reveal very different perspectives of CT, or of which components should be emphasized in education. This supplemental information can contribute to understanding of the observed discrepancy between post-secondary expectations and high school development of CT and would also begin to indicate areas most in need of intervention.

Our literature review clarified that CT can be developed before adulthood. Additional research may consider how developmental stages impact the ability to think critically. This type of research can help support instruction and educational planning. By understanding more clearly how CT is developed, and how psychology might inhibit or promote CT development at different stages, educational planners can tailor instruction to make the most of students' abilities and to allow them to better achieve their potential in regards to CT ability. Research may also consider the extent to which students' individual aptitudes and environment can enhance or inhibit development of CT abilities.

Summary.

Our literature review suggests that the definition of CT, while it contains elements that are universally accepted, is still dynamic; no one publication currently seems to offer a definition that has been adopted by all stakeholders. Certainly, as educators and those invested in education seem to agree on the paramount importance of CT, establishing and promoting a working definition of CT is an important first step. Hopefully, our work in considering various definitions and ideas of CT to develop a unified, encompassing definition can contribute to this end.

CT skills are clearly valued in education, and university professors view CT as an important contributor to student achievement and academic success. However, while students *can* develop CT skills during adolescence, there is an apparent gap between post-secondary

expectations and the actual CT abilities of first-year undergraduate students. Our examination of Ontario's curriculum documents in particular suggests that direct, explicit development of CT is not clearly evident in this province's secondary school curriculum. There is a dichotomy between what is expected of students pursuing higher education, and what is taught during secondary school to prepare students for further studies; it is important for educators in Ontario to understand and to begin to lessen this gap in order to best support our students' success.

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APPENDICES:

Appendix A.

Screen shots of the question pages from the survey used for original research.

An Analysis of Critical Thinking Expectations

1. What university do you currently teach at? (Please select the institution you most recently taught at if you are not currently teaching).

- ◯ Algoma University
- ◯ Brock University
- ◯ Carleton University
- ◯ McMaster University
- ◯ Queen's University
- ◯ Ryerson University
- ◯ University of Guelph
- ◯ University of Toronto
- ◯ University of Waterloo
- ◯ Western University
- ◯ Wilfrid Laurier University
- ◯ Other (please specify)

2. How many introductory first-year courses do you currently teach?

- ◯ 1 or none
- ◯ 2-3
- ◯ 4 or more

3. On average, how many first year undergraduate university students do you teach each year?

4. How long have you been involved in teaching first year university students?

- ◯ Less than 1 year
- ◯ 1-2 years
- ◯ 3-5 years
- ◯ 6 or more years

An Analysis of Critical Thinking Expectations

Definition:

For the purposes of this study, please consider "Critical Thinking" according to the following definition:

Critical thinking: An important tool of inquiry and an esteemed educational goal. Critical thinking encompasses skills in analysis, evaluation, creativity, rationalization, hypothesizing, judgement, problem-solving, and decision-making – enabling the individual to form logical personal stances when considering complex issues. Critical thinking relates to a character that is fair-minded, inquisitive, flexible, confident in reasoning, and open to entertaining diverse viewpoints.

The ideal critical thinker should endorse reason and strive to be well informed, and should be able to communicate ideas clearly and effectively through logical appeals. He or she should demonstrate persistence and motivation in pursuing truth, evidence, and results and should make all attempts to avoid bias and prejudice when considering and accepting ideas.

1. Please indicate how much you agree with the following statements, referring to Critical Thinking as defined above.

	Disagree Completely	Strongly Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Strongly Agree	Agree Completely
Only adults can be good critical thinkers.	○	○	○	○	○	○	○
I am satisfied with the critical thinking abilities of the average student entering my university class.	○	○	○	○	○	○	○
The definition above clearly encompasses my idea of critical thinking.	○	○	○	○	○	○	○
Critical thinking can be developed before students begin university/college.	○	○	○	○	○	○	○
Critical Thinking abilities are necessary for students to be successful in university.	○	○	○	○	○	○	○
Critical thinking, as defined above, is of high value in education.	○	○	○	○	○	○	○
Stronger critical thinking skills should be developed before students begin university.	○	○	○	○	○	○	○

Comments:

An Analysis of Critical Thinking Expectations

Definition:

For the purposes of this study, please consider "Critical Thinking" according to the following definition:

Critical thinking: An important tool of inquiry and an esteemed educational goal. Critical thinking encompasses skills in analysis, evaluation, creativity, rationalization, hypothesizing, judgement, problem-solving, and decision-making – enabling the individual to form logical personal stances when considering complex issues. Critical thinking relates to a character that is fair-minded, inquisitive, flexible, confident in reasoning, and open to entertaining diverse viewpoints.

The ideal critical thinker should endorse reason and strive to be well informed, and should be able to communicate ideas clearly and effectively through logical appeals. He or she should demonstrate persistence and motivation in pursuing truth, evidence, and results and should make all attempts to avoid bias and prejudice when considering and accepting ideas.

An Analysis of Critical Thinking Expectations

1. In your opinion, what is the relative importance of each of the following critical thinking components (in terms of the demands and expectations of higher education):

	Of little to no importance				Of extremly high importance
Ability to avoid biased/prejudiced thinking	○	○	○	○	○
Ability to rationalize information and draw hypotheses	○	○	○	○	○
Skills in problem-solving and decision making	○	○	○	○	○
Open, fair-mindedness and flexibility in reasoning	○	○	○	○	○
Analysis and evaluation skills	○	○	○	○	○
Confidence in reasoning	○	○	○	○	○
Ability to communicate clearly and effectively	○	○	○	○	○
Inquisitiveness and motivation to seek evidence and to be well informed	○	○	○	○	○
Creativity	○	○	○	○	○

Comments:

An Analysis of Critical Thinking Expectations

2. Please state your agreement or disagreement with the following statement:

	Disagree completely	Strongly Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Strongly Agree	Agree Completely
In my opinion, most students begin university with sufficiently developed critical thinking skills, abilities and dispositions (as listed above and described in the included definition of critical thinking).	○	○	○	○	○	○	○

Comments:

An Analysis of Critical Thinking Expectations

1. Do you have any questions or comments about the study or any of the questions used for this research?

2. Would you like to receive a copy of the study's results? If so, please enter your email here:

- ○ No
- ○ Yes:

Appendix B.

Inclusion/Exclusion Criteria Applied to Results of Initial Search of Scopus and ERIC Databases and Google Scholar, Question #1.

Inclusion/Exclusion Criteria - Abstracts and Titles (November 19, 2012)						
Citation	**P**	**I**	**M**	**O**	**Y/N/P**	**Retrieved?**
Butler, H. A. (2012). Halpern critical thinking assessment predicts real-world outcomes of critical thinking. *Applied Cognitive Psychology, 26*(5), 721-729.	Y	Y	Y	N	N	Not Applicable
Dhaouadi, R., Al-Assaf, Y., & Rehman, H. -. (2012). Introducing the guided design experience in control engineering education. *International Journal of Engineering Education, 28*(3), 563-571.	Y	Y	Y	N	N	Not Applicable
Flores, K. L., Matkin, G. S., Burbach, M. E., Quinn, C. E., & Harding, H. (2012). Deficient critical thinking skills among college graduates: Implications for leadership. *Educational Philosophy and Theory, 44*(2), 212-230.	Y	Y	Y	P	P	22/11/2012
Stedman, N. L., & Adams, B. L. (2012). Identifying Faculty's Knowledge of Critical Thinking Concepts and Perceptions of Critical Thinking Instruction in Higher Education. *NACTA Journal.*	Y	Y	Y	P	P	22/11/2012
Stirling, J., Nastasi, I., & Symington, J. (2012). Critical social literacy: Empowering young women in a disadvantaged community. *International Journal of Learning, 18*(8), 265-284.	Y	Y	Y	N	N	Not Applicable
Switzer, A. T., & Barclay, L. A. (2012). Book clubs: Best practices in promoting critical thinking in business classes. *Journal of Business and Finance Librarianship, 17*(4), 328-345.	Y	Y	Y	N	N	Not Applicable
Yang Y. -. C. and Wu W. (2012) Digital storytelling for enhancing student academic achievement, critical thinking.; Learning motivation: A year-long experimental study. *Computers and Education, 59*(2), 339-352.	N				N	Not Applicable

Inclusion/Exclusion Criteria - Abstracts and Titles (November 19, 2012)						
Citation	**P**	**I**	**M**	**O**	**Y/N/P**	**Retrieved?**
Yeh, Y. (2012). A co-creation blended KM model for cultivating critical-thinking skills. *Computers and Education, 59*(4), 1317-1327.	Y	Y	Y	P	P	22/11/2012
Brand, L. G., (2011). Evaluating the Effects of Medical Explorers a Case Study Curriculum on Critical Thinking, Attitude toward Life Science, and Motivational Learning Strategies in Rural High School Students. *Ed.D. Dissertation, Ball State University*.	N				N	Not Applicable
Floyd, C. B. (2011). Critical thinking in a second language. *Higher Education Research and Development*, 30(3), 289-302.	P	Y	Y	N	N	Not Applicable
Hatcher, D. L., (2011). Which Test? Whose Scores? Comparing Standardized Critical Thinking Tests. *New Directions for Institutional Research 149*, 29-39.	Y	Y	Y	N	N	Not Applicable
Malik, S. K., & Khurshed, F. (2011). Nature of teacher-students' interaction in electronic learning and traditional courses of higher education- A review. *Turkish Online Journal of Distance Education, 12*(4), 157-166.	Y	Y	Y	N	N	Not Applicable
Saracaloglu, A. S., Aktamis, H., & Delioglu, Y. (2011). The impact of the development of prospective teachers' critical thinking skills on scientific argumentation training and on their ability to construct an argument. *Journal of Baltic Science Education, 10*(4), 243-260.	P	Y	Y	N	N	Not Applicable
Ahern, A., Mac Ruairc, G., McNamara, M., O'Connor, T. (2010). Critical thinking in the university curriculum. Presented at the 3rd International Symposium for Engineering Education (ISEE), *University College Cork, Ireland*.	Y	Y	Y	P	P	22/11/2012
Baysal, Z. N., Arkan, K., & Yildirim, A. (2010). Preservice elementary teachers' perceptions of their self-efficacy in teaching thinking skills. *Paper presented at the Procedia - Social and Behavioral Sciences, 2*(2) 4250-4254.	N				N	Not Applicable

Inclusion/Exclusion Criteria - Abstracts and Titles (November 19, 2012)						
Citation	**P**	**I**	**M**	**O**	**Y/N/P**	**Retrieved?**
Beachboard, M. R., & Beachboard, J. C. (2010). Critical-thinking pedagogy and student perceptions of university contributions to their academic development. *Informing Science, 13*(1), 53-71.	Y	Y	Y	P	P	22/11/2012
Iwaoka, W.T., Li, Y. and Rhee, W.Y., (2010). Measuring Gains in Critical Thinking in Food Science and Human Nutrition Courses: The Cornell Critical Thinking Test, Problem-Based Learning Activities, and Student Journal Entries. *Journal of Food Science Education, 9*(3), 68-75.	Y	Y	Y	N	N	Not Applicable
Van De Vord, R. (2010). Distance students and online research: Promoting information literacy through media literacy. *Internet and Higher Education, 13*(3), 170-175.	Y	Y	Y	Y	Y	22/11/2012
Behar-Horenstein, L. S., Schneider-Mitchell, G., & Graff, R. (2009). Promoting the teaching of critical thinking skills through faculty development. *Journal of Dental Education, 73*(6), 665-675.	Y	Y	Y	N	N	Not Applicable
Fero, L.J., (2009). Comparison of Simulation-Based Performance with Metrics of Critical Thinking Skills in Nursing Students: A Pilot Study. *Ph.D. Dissertation, University of Pittsburg.*	Y	Y	Y	N	N	Not Applicable
Goldberg, L.R. and Coufal, K.L., (2009). Reflections on Service-Learning, Critical Thinking, and Cultural Competence. *Journal of College Teaching & Learning, 6*(6), 39-50.	Y	Y	Y	N	N	Not Applicable
Hand, A. and Winningham, K., (2009), Learning on the Job. *Community College Journal, 79*(3), 10-13.	P	Y	Y	P	P	27/11/2012
Laidlaw, A., Guild, S., & Struthers, J. (2009). Graduate attributes in the disciplines of medicine, dentistry and veterinary medicine: A survey of expert opinions. *BMC Medical Education, 9*(1)	N				N	Not Applicable
Lessons in Learning: Making the Environmental Grade--The Benefits of Going Green in the Classroom. *The Canadian Council on Learning,* 2009.	N				N	Not Applicable

Inclusion/Exclusion Criteria - Abstracts and Titles (November 19, 2012)						
Citation	**P**	**I**	**M**	**O**	**Y/N/P**	**Retrieved?**
Rodriguez, C. M. (2009). The impact of academic self-concept, expectations and the choice of learning strategy on academic achievement: The case of business students. *Higher Education Research and Development, 28*(5), 523-539.	Y	Y	Y	Y	Y	22/11/2012
Sturgess, J., & Locke, T. (2009). Beyond shrek: Fairy tale magic in the multicultural classroom. *Cambridge Journal of Education, 39*(3), 379-402.	N				N	Not Applicable
Piascik, P., & Bird, E. (2008). Creating and sustaining a culture of assessment. *American Journal of Pharmaceutical Education, 72*(5).	N				N	Not Applicable
Yang, Y. -. C. (2008). A catalyst for teaching critical thinking in a large university class in taiwan: Asynchronous online discussions with the facilitation of teaching assistants. *Educational Technology Research and Development, 56*(3), 241-264.	Y	Y	Y	N	N	Not Applicable
Daempfle, P. A. (2006). The effects of instructional approaches on the improvement of reasoning in introductory college biology: A quantitative review of research. *Bioscene, 32*(4), 22-31.	Y	Y	Y	P	P	22/11/2012
Hatcher, D.L. (2006), Stand-Alone versus Integrated Critical Thinking Courses. *Journal of General Education, 55*(3), 26.	Y	Y	Y	N	N	Not Applicable
Priest, T. (2006). Self-evaluation, creativity, and musical achievement. *Psychology of Music, 34*(1), 47-61.	Y	Y	Y	N	N	Not Applicable
Quitadamo, I.J. and Kurtz, M.J., (2007). Learning to Improve: Using Writing to Increase Critical Thinking Performance in General Education Biology. *CBE - Life Sciences Education 6*(2), 140-154.	Y	Y	Y	N	N	Not Applicable
Sharkey, J. (2006). Towards information fluency: Applying a different model to an information literacy credit course. *Reference Services Review, 34*(1), 71-85.	Y	Y	Y	P	P	22/11/2012

Inclusion/Exclusion Criteria - Abstracts and Titles (November 19, 2012)						
Citation	**P**	**I**	**M**	**O**	**Y/N/P**	**Retrieved?**
Azer, S. A. (2005). Challenges facing PBL tutors: 12 tips for successful group facilitation. *Medical Teacher, 27*(8), 676-681.	N				N	Not Applicable
Vandermensbrugghe, J. (2004). The unbearable vagueness of critical thinking in the context of the anglo-saxonisation of education. *International Education Journal, 5*(3), 417-422.	Y	Y	Y	P	P	22/11/2012
Warner, I. M. (2004). Climbing Bloom's ladder. *Journal of Chemical Education, 81*(10), 1413.	Y	Y	Y	P	P	22/11/2012
Williams, R.L. and Stockdale, S.L., (2003). High-Performing Students with Low Critical Thinking Skills. *Journal of General Education 52*(3), 199-225.	Y	Y	Y	P	P	22/11/2012
Williams, R. L., and Worth, S.L., (2001). The Relationship of Critical Thinking to Success in College. *Inquiry: Critical Thinking Across the Disciplines, 21*(1), 5-16	Y	Y	Y	Y	Y	27/11/2012
Olugbemiro J.J, Noordink, P., (1993). The Role of Critical Thinking Skills in Undergraduate Study as Perceived by University Teachers across Academic Disciplines. *Unpublished paper presented at the Fourth Annual Conference on Problem Solving Across the Curriculum at Hobart/William Smith Colleges. Geneva, NY.*	Y	Y	Y	Y	Y	Requested
Totals:					**Y=2, P=11, N=25**	**12 Retrieved**

Appendix C.

Inclusion/Exclusion Criteria Applied to Results From a Secondary Search of Scopus for Question #1.

Inclusion/Exclusion Criteria - Abstracts and Titles. (November 22, 2012)						
Citation	**P**	**I**	**M**	**O**	**Y/N/P**	**Retrieved?**
Kowalczyk, N., Hackworth, R., & Case-Smith, J. (2012). Perceptions of the use of critical thinking teaching methods. *Radiologic Technology, 83*(3), 226-236.	N				N	Not Applicable
Massa, N., Dischino, M., Donnelly, J. F., Hanes, F. D., & DeLaura, J. A. (2012). Problem-based learning in a pre-service technology and engineering education course. *Paper presented at the ASEE Annual Conference and Exposition, Conference Proceedings.*	Y	Y	Y	N	N	Not Applicable
Pierrakos, O., Pappas, E. C., Nagel, R. L., & Nagel, J. K. (2012). A new vision for engineering design instruction: On the innovative six course design sequence of james madison university. *Paper presented at the ASEE Annual Conference and Exposition, Conference Proceedings,*	Y	Y	Y	N	N	Not Applicable
Wald, H. S., Borkan, J. M., Taylor, J. S., Anthony, D., & Reis, S. P. (2012). Fostering and evaluating reflective capacity in medical education: Developing the REFLECT rubric for assessing reflective writing. *Academic Medicine, 87*(1), 41-50.	N				N	Not Applicable
Dukhan, N., & Schumack, M. (2011). Thermal science capstone projects in mechanical engineering. *Paper presented at the ASEE Annual Conference and Exposition, Conference Proceedings.*	N				N	Not Applicable
Simons, L., Jacobucci, R., Houston, H., & Amoroso, K. (2011). Another look at the benefits of disseminating evidence-based practices: A comparative analysis of 2 undergraduate courses. *Addictive Disorders and their Treatment, 10*(2), 60-71.	Y	Y	Y	N	N	Not Applicable
Behar-Horenstein, L. S., Childs, G. S., & Graff, R. A. (2010). Observation and assessment of faculty development learning outcomes. *Journal of Dental Education, 74*(11), 1245-1254.	P	Y	Y	N	N	Not Applicable

Inclusion/Exclusion Criteria - Abstracts and Titles. (November 22, 2012)						
Citation	**P**	**I**	**M**	**O**	**Y/N/P**	**Retrieved?**
Berland, A., Richards, J., & Lund, K. D. (2010). A canada-bangladesh partnership for nurse education: Case study. *International Nursing Review, 57*(3), 352-358.	N				N	Not Applicable
Borchers, A., Park, S. H., Riffe, W., Harris, M., & Tavakoli, M. (2010). Measuring the impact of entrepreneurship across the curriculum. *Paper presented at the ASEE Annual Conference and Exposition, Conference Proceedings.*	Y	Y	Y	N	N	Not Applicable
Hamoudi, N. M., Nagavi, B. G., & Jamil Al-Azzawi, A. M. (2010). Problem based learning and its impact on learning behavior of pharmacy students in RAK medical and health sciences university. *Indian Journal of Pharmaceutical Education and Research, 44*(3), 206-219.	N				N	Not Applicable
Mimica, M. (2010). Implementation of new educational methods: How to overcome obstacles. *Collegium Antropologicum, 34*(SUPPL. 1), 11-14.	N				N	Not Applicable
Behar-Horenstein, L. S., Schneider-Mitchell, G., & Graff, R. (2009). Promoting the teaching of critical thinking skills through faculty development. *Journal of Dental Education, 73*(6), 665-675.	N				N	Not Applicable
Arieli, D., Friedman, V. J., & Hirschfeld, M. J. (2009). The establishment of an academic nursing faculty: Action research in Israel. *International Nursing Review, 56*(3), 299-305.	N				N	Not Applicable
Kumagai, A. K., & Lypson, M. L. (2009). Beyond cultural competence: Critical consciousness, social justice, and multicultural education. *Academic Medicine, 84*(6), 782-787.	N				N	Not Applicable
Neo, M., & Neo, T. -. (2009). Engaging students in multimedia-mediated constructivist learning - students' perceptions. *Educational Technology and Society, 12*(2), 254-266.	Y	Y	Y	N	N	Not Applicable

Inclusion/Exclusion Criteria - Abstracts and Titles. (November 22, 2012)						
Citation	**P**	**I**	**M**	**O**	**Y/N/P**	**Retrieved?**
Wald, H. S., Davis, S. W., Reis, S. P., Monroe, A. D., & Borkan, J. M. (2009). Reflecting on reflections: Enhancement of medical education curriculum with structured field notes and guided feedback. *Academic Medicine, 84*(7), 830-837.	N				N	Not Applicable
Wu, S. -., Chung, M. -., Chen, M. -., Chou, C. -., Liang, S. -., Chen, M. -., & Tsay, S. -. (2009). Nursing student satisfaction in a developed clinical performance examination for medical-surgery nursing: A pilot study. *Journal of Nursing and Healthcare Research, 5*(4), 283-292.	N				N	Not Applicable
Vacek, J. E. (2009). Using a conceptual approach with concept mapping to promote critical thinking. *Journal of Nursing Education, 48*(1), 45-48.	N				N	Not Applicable
Vanaki, Z., & Memarian, R. (2009). Professional ethics: Beyond the clinical competency. *Journal of Professional Nursing, 25*(5), 285-291.	N				N	Not Applicable
Kranov, A. A., Hauser, C., Olsen, R., & Girardeau, L. (2008). AC 2008-2384: A direct method for teaching and assessing professional skills in engineering programs. *Paper presented at the ASEE Annual Conference and Exposition, Conference Proceedings.*	Y	Y	Y	N	N	Not Applicable
Lane, E. A. (2008). Problem-based learning in veterinary education. *Journal of Veterinary Medical Education, 35*(4), 631-636.	N				N	Not Applicable
Sammalisto, K., & Brorson, T. (2008). Training and communication in the implementation of environmental management systems (ISO 14001): A case study at the university of Gävle, Sweden. *Journal of Cleaner Production, 16*(3), 299-309.	N				N	Not Applicable
Burkhart, L., & Sommer, S. (2007). Integrating preventive care and nursing standardized terminologies in nursing education: A case study. *Journal of Professional Nursing, 23*(4), 208-213.	N				N	Not Applicable

Inclusion/Exclusion Criteria - Abstracts and Titles. (November 22, 2012)						
Citation	**P**	**I**	**M**	**O**	**Y/N/P**	**Retrieved?**
Chirema, K. D. (2007). The use of reflective journals in the promotion of reflection and learning in post-registration nursing students. *Nurse Education Today, 27*(3), 192-202.	N				N	Not Applicable
Keselyak, N. T., Simmer-Beck, M., Bray, K. K., & Gadbury-Amyot, C. C. (2007). Evaluation of an academic service-learning course on special needs patients for dental hygiene students: A qualitative study. *Journal of Dental Education, 71*(3), 378-392.	N				N	Not Applicable
Muirhead, R. J. (2007). E-learning: Is this teaching at students or teaching with students? *Nursing Forum, 42*(4), 178-184.	P	Y	Y	N	N	Not Applicable
Papinczak, T., Young, L., Groves, M., & Haynes, M. (2007). An analysis of peer, self, and tutor assessment in problem-based learning tutorials. *Medical Teacher, 29*(5), e122-e132.	P	Y	Y	N	N	Not Applicable
Riddell, T. (2007). Critical assumptions: Thinking critically about critical thinking. *Journal of Nursing Education, 46*(3), 121-126.	N				N	Not Applicable
Ellermann, C. R., Kataoka-Yahiro, M. R., & Wong, L. C. (2006). Logic models used to enhance critical thinking. *Journal of Nursing Education, 45*(6), 220-227.	N				N	Not Applicable
Graber, G. C., & Pionke, C. D. (2006). A team-taught interdisciplinary approach to engineering ethics. *Science and Engineering Ethics, 12*(2), 313-320.	Y	Y	Y	N	N	Not Applicable
Kennison, M. M. (2006). The evaluation of students' reflective writing for evidence of critical thinking. *Nursing Education Perspectives, 27*(5), 269-273.	N				N	Not Applicable
Mpofu, R., & Imalingat, A. (2006). The development of an instrument for assessing community-based education of undergraduate students of community and health sciences at the University of the Western Cape. *Education for Health: Change in Learning and Practice, 19*(2), 166-178.	Y	Y	Y	N	N	Not Applicable

Inclusion/Exclusion Criteria - Abstracts and Titles. (November 22, 2012)						
Citation	**P**	**I**	**M**	**O**	**Y/N/P**	**Retrieved?**
Rao, R. H. (2006). Perspectives in medical education 1. Reflections on the state of medical education in Japan. *Keio Journal of Medicine, 55*(2), 41-51.	N				N	Not Applicable
Waterson, E., Harms, E., Qupe, L., Maritz, J., Manning, M., Makobe, K., & Chabeli, M. (2006). Strategies to improve the performance of learners in a nursing college. Part I: Issues pertaining to nursing education. *Curationis, 29*(2), 56-65.	N				N	Not Applicable
Mikol, C. (2005). Teaching nursing without lecturing: Critical pedagogy as communicative dialogue. *Nursing Education Perspectives, 26*(2), 86-89.	N				N	Not Applicable
Mangena, A., & Chabeli, M. M. (2005). Strategies to overcome obstacles in the facilitation of critical thinking in nursing education. *Nurse Education Today, 25*(4), 291-298.	N				N	Not Applicable
Robinson, N. B., & Sadao, K. C. (2005). Person-focused learning: A collaborative teaching model to prepare future AAC professionals. *AAC: Augmentative and Alternative Communication, 21*(2), 149-163.	P	Y	Y	N	N	Not Applicable
Houlden, R. L., Raja, J. B., Collier, C. P., Clark, A. F., & Waugh, J. M. (2004). Medical students' perceptions of an undergraduate research elective. *Medical Teacher, 26*(7), 659-661.	N				N	Not Applicable
McCurdy, F. A., O'Dell, D. V., Susman, J., Steele, D. J., Paulman, P. M., Harper, J. L., & Lacy, N. L. (2004). From library to discharge: A managing care student project. *Family Medicine, 36*(SUPPL.), S93-S97.	N				N	Not Applicable
Antepohl, W., Domeij, E., Forsberg, P., & Ludvigsson, J. (2003). A follow-up of medical graduates of a problem-based learning curriculum. *Medical Education, 37*(2), 155-162.	N				N	Not Applicable
Christie, C. R., Bowen, D. M., & Paarmann, C. S. (2003). Curriculum evaluation of ethical reasoning and professional responsibility. *Journal of Dental Education,*	N				N	Not Applicable

Inclusion/Exclusion Criteria - Abstracts and Titles. (November 22, 2012)						
Citation	**P**	**I**	**M**	**O**	**Y/N/P**	**Retrieved?**
67(1), 55-63.						
Fullerton, J. T., & Ingle, H. T. (2003). Evaluation strategies for midwifery education linked to digital media and distance delivery technology. Journal of Midwifery and Women's Health, 48(6), 426-436.	N				N	Not Applicable
Lichtman, R., Burst, H. V., Campau, N., Carrington, B., Diegmann, E. K., Hsia, L., & Thompson, J. E. (2003). Pearls of wisdom for clinical teaching: Expert educators reflect. *Journal of Midwifery and Women's Health, 48*(6), 455-463.	N				N	Not Applicable
Tomey, A. M. (2003). Learning with cases. Journal of Continuing Education in Nursing, 34(1), 34-38.	N				N	Not Applicable
Kamin, C., Deterding, R., & Lowry, M. (2002). Student's perceptions of a virtual PBL experience. *Academic Medicine: Journal of the Association of American Medical Colleges, 77*(11), 1161-1162.	P	Y	Y	N	N	Not Applicable
Scanlan, J. M., Care, W. D., & Udod, S. (2002). Unravelling the unknowns of reflection in classroom teaching. *Journal of Advanced Nursing, 38*(2), 136-143.	P	Y	Y	N	N	Not Applicable
Chichester, S. R., Wilder, R. S., Mann, G. B., & Neal, E. (2001). Utilization of evidence-based teaching in U.S. dental hygiene curricula. *Journal of Dental Hygiene/ American Dental Hygienists Association, 75*(2), 156-164.	N				N	Not Applicable
De Robertis, M. M., & Delaney, P. A. (2000). A second survey of the attitudes of university students to astrology and astronomy. J*ournal of the Royal Astronomical Society of Canada, 94(*3), 112-122.	Y	Y	Y	N	N	Not Applicable
Gerrish, K., Ashworth, P. D., & McManus, M. (2000). Some dilemmas of master's level nurse education. *Journal of Advanced Nursing, 32(*4), 834-841.	N				N	Not Applicable

Inclusion/Exclusion Criteria - Abstracts and Titles. (November 22, 2012)						
Citation	**P**	**I**	**M**	**O**	**Y/N/P**	**Retrieved?**
Gordon, J. M. (2000). Congruency in defining critical thinking by nurse educators and non-nurse scholars. *Journal of Nursing Education, 39*(8), 340-351.	N				N	Not Applicable
Pitkälä, K., Mäntyranta, T., Strandberg, T. E., Mäkelä, M., Vanhanen, H., & Varonen, H. (2000). Evidence-based medicine - how to teach critical scientific thinking to medical undergraduates. *Medical Teacher, 22*(1), 22-26.	N				N	Not Applicable
Totals:					**N=51**	**None Retrieved**

Appendix D.

Inclusion/Exclusion Criteria Applied to Abstracts from Educational Research Complete.

Inclusion/Exclusion Criteria - Abstracts and Titles (December 16, 2012)						
Citation	**P**	**I**	**M**	**O**	**Y/N/P**	**Retrieved?**
Eisen, D.B. (2012). Developing a Critical Lens: Using Photography to Teach Sociology and Create Critical Thinkers. *Teaching Sociology, 40*(4), p. 349-359	Y	Y	Y	N	N	Not Applicable
Pardamean, B. (2012). Measuring Change in Critical Thinking Skills of Dental Students Educated in a PBL Curriculum. *Journal of Dental Education 76*(4), p.443-453	N				N	Not Applicable
Ahuna, K., Tinnesz, C., VanZile-Tamsen, C. (2011). 'Methods of Inquiry': Using Critical Thinking to Retain Students. *Innovative Higher Education, 36*(4), p. 249-259.	Y	Y	Y	P	P	17/12/2012
Anderson, W.L., Sensibaugh, C.A., Osgood, M.P., and Mitchell, S.M. (2011). What Really Matters: Assessing Individual Problem-Solving Performance in the Context of Biological Sciences. *International Journal for the Scholarship of Teaching & Learning, 5*(1) p. 1-20.	Y	Y	Y	N	N	Not Applicable
Floyd, C.B. (2011). Critical Thinking in a Second Language. *Higher Education Research & Development, 30*(3) p. 289-302	Y	Y	Y	N	N	Not Applicable
Malik, S.K. and Khurshed, F., (2011). Nature of teacher-Students' interaction in electronic learning and traditional courses of higher education - a review. *Turkish Online Journal of Distance Education, 12*(4). p. 157-166.	Y	Y	Y	N	N	Not Applicable
Walton, G. and Hepworth, M. (2011). A longitudinal study of changes in learners' cognitive states during and following an information literacy teaching intervention. *Journal of Documentation, 67*(3) p. 449-479.	Y	Y	Y	N	N	Not Applicable
Abdullah, A.G.K., Alzaidiyeen, N.J. and Ng, M.Y. (2010). The Practices of Critical Thinking Component and Its Impact in Malaysian Nurses Health Education.	N				N	Not Applicable

Inclusion/Exclusion Criteria - Abstracts and Titles (December 16, 2012)						
Citation	**P**	**I**	**M**	**O**	**Y/N/P**	**Retrieved?**
International Education Studies, 3(1), p. 73-82.						
Azar, A. (2010). The Effect of Critical Thinking Dispositions on Students Achievement in Selection and Placement Exam for University in Turkey. *Journal of Turkish Science Education (TUSED), 7*(1). p. 61-73.	N				N	Not Applicable
Farrar, F.C. and Suggs, L. (2010). Empowering Critical Thinking Skills With Computerized Patient Simulators. *Journal of College Teaching & Learning, 7*(5), p. 1-4.	P	Y	Y	N	N	Not Applicable
French, E. and Tracey, N. (2010) Critical Thinking and Organisation Theory: Embedding a process to encourage graduate capabilities. *E-Journal of Business Education & Scholarship of Teaching, 4*(1). p. 1-10.	Y	Y	Y	N	N	Not Applicable
James, N., Hughes, C. and Cappa, C. (2010). Conceptualising, developing and assessing critical thinking in law. *Teaching in Higher Education, 15*(3). p. 285-297.	Y	Y	Y	N	N	Not Applicable
Ku, K.Y.L. and Ho, I.T. (2010). Metacognitive strategies that enhance critical thinking. *Metacognition & Learning, 5*(3). p. 251-267.	Y	Y	Y	N	N	Not Applicable
Lloyd, M. and Bahr, N. (2010). Thinking Critically about Critical Thinking in Higher Education. *International Journal for the Scholarship of Teaching and Learning, 4*(2).	Y	Y	Y	P	P	17/12/2012
Mortagy, Y., Boghikian-Whitby, S. (2010). A Longitudinal Comparative Study of Student Perceptions in Online Education. *Interdisciplinary Journal of E-Learning & Learning Objects, 6*, p. 23-44.	Y	Y	Y	N	N	Not Applicable
Tolutienė, G. (2010) Critical thinking self-developmennt opportunities of andragogy speciality students in the university study program. *Teacher Education / Mokytoju Ugdymas, 14*(1), p. 63-76.	Y	Y	Y	N	N	Not Applicable

Inclusion/Exclusion Criteria - Abstracts and Titles (December 16, 2012)						
Citation	**P**	**I**	**M**	**O**	**Y/N/P**	**Retrieved?**
Behar-Horenstein, L.S., Schneider-Mitchell, G. and Graff, R. (2009). Promoting the Teaching of Critical Thinking Skills Through Faculty Development. *Journal of Dental Education, 73*(6). p. 665-675.	P	Y	Y	N	N	Not Applicable
Errington, E.P. (2009). Being There: Closing the Gap between Learners and Contextual Knowledge Using Near-World Scenarios. *International Journal of Learning, 16*(8) p. 584-594.	P	Y	Y	N	N	Not Applicable
Brammer, L. and Wolter, S. (2008) Public Discourse: Experiential Training for Citizenship. *International Journal of Learning, 15*(7), p. 307-314.	Y	Y	Y	N	N	Not Applicable
Shy-Jen G., Chung-Hsien T., Chang, F.M-T. and Hsu-I H. (2007). The Study of Questioning Skills on Teaching Improvement. *International Journal of Learning, 14*(8), p.141-145.	P	Y	Y	N	N	Not Applicable
Ryan, J. and Louie, K. (2007) False Dichotomy? 'Western' and 'Confucian' concepts of scholarship and learning. *Educational Philosophy & Theory, 39*(4), p. 404-417.	Y	Y	Y	N	N	Not Applicable
Suraya, A., Tarmizi, R.A., Nor, S.M., Abu, R., Ismail, H., Wan Z.W.A., Abu B.K. and Hamzah, R. (2007) Necessary Skills For Success in Higher Learning. *International Journal of Learning, 13*(10), p. 41-55.	Y	Y	Y	Y	Y	17/12/2012
Noddings, N. (2007). Education and democracy in the 21st century. *Nordisk Pedagogik, 27*(1), p. 8-17.	N				N	Not Applicable
Daempfle, P.A. (2006). The Effects of Instructional Approaches on the Improvement of Reasoning in Introductory College Biology: A Quantitative Review of Research. *Bioscene, 32*(4), p. 22-31.	Y	Y	Y	N	N	Not Applicable
Tinnesz, C.G., Ahuna, K.H. and Kiener, M. (2006). Toward college success: Internalizing active and dynamic strategies. *College Teaching, 54*(4), p. 302-306.	Y	Y	Y	P	P	17/12/2012

Inclusion/Exclusion Criteria - Abstracts and Titles (December 16, 2012)						
Citation	**P**	**I**	**M**	**O**	**Y/N/P**	**Retrieved?**
Carini, R., Kuh, G. and Klein, S. (2006). Student Engagement and Student Learning: Testing the Linkages. *Research in Higher Education, 47*(1), p. 1-32.	Y	Y	Y	N	N	Not Applicable
Watt, L.A. (2005/2006). Why Linking Content to Teach Writing Skills is a Good Idea. *International Journal of Learning, 12*(7), p. 357-362.	Y	Y	Y	N	N	Not Applicable
Burns, H.K. and Foley, S.M. (2005). Building a Foundation for an Evidence-Based Approach to Practice: Teaching Basic Concepts to Undergraduate Freshman Students. *Journal of Professional Nursing, 21*(6), p. 351-357.	N				N	Not Applicable
Totals:					**Y=1 P=3 N=24**	**4 Retrieved**

Appendix E.

Inclusion/Exclusion Criteria Applied to Full Texts of Documents, Question #1.

Inclusion/Exclusion Criteria - Full Text (November 22-December 17, 2012)					
Citation	**P**	**I**	**M**	**O**	**Y/N/P**
Flores, K. L., Matkin, G. S., Burbach, M. E., Quinn, C. E., & Harding, H. (2012). Deficient critical thinking skills among college graduates: Implications for leadership. *Educational Philosophy and Theory, 44*(2), 212-230.	Y	Y	Y	Y	Y
Stedman, N. L., & Adams, B. L. (2012). Identifying Faculty's Knowledge of Critical Thinking Concepts and Perceptions of Critical Thinking Instruction in Higher Education. *NACTA Journal.*	Y	Y	Y	Y	Y
Yeh, Y. (2012). A co-creation blended KM model for cultivating critical-thinking skills. *Computers and Education, 59*(4), 1317-1327.	Y	Y	Y	N	N
Ahuna, K., Tinnesz, C., VanZile-Tamsen, C. (2011). 'Methods of Inquiry': Using Critical Thinking to Retain Students. *Innovative Higher Education, 36*(4), p. 249-259.	Y	Y	Y	Y	Y
Ahern, A., Mac Ruairc, G., McNamara, M., O'Connor, T. (2010). Critical thinking in the university curriculum. Presented at the 3rd International Symposium for Engineering Education (ISEE), *University College Cork, Ireland*.	Y	Y	Y	N	N
Beachboard, M. R., & Beachboard, J. C. (2010). Critical-thinking pedagogy and student perceptions of university contributions to their academic development. *Informing Science, 13*(1), 53-71.	Y	Y	Y	N	N
Lloyd, M. and Bahr, N. (2010). Thinking Critically about Critical Thinking in Higher Education. *International Journal for the Scholarship of Teaching and Learning, 4*(2).	Y	Y	Y	N	N
Van De Vord, R. (2010). Distance students and online research: Promoting information literacy through media literacy. *Internet and Higher Education, 13*(3), 170-175.	Y	Y	Y	N	N

Inclusion/Exclusion Criteria - Full Text (November 22-December 17, 2012)					
Citation	**P**	**I**	**M**	**O**	**Y/N/P**
Choy, S. C. and Rahman, T.A., (2009) Teacher perceptions of critical thinking among students and its influence on higher education. *International Journal of Teaching and Learning in Higher Education*, 20(2), 198-206.	Y	Y	Y	N	N
Hand, A. and Winningham, K., (2009), Learning on the Job. *Community College Journal, 79*(3), 10-13.	Y	Y	Y	N	N
Rodriguez, C. M. (2009). The impact of academic self-concept, expectations and the choice of learning strategy on academic achievement: The case of business students. *Higher Education Research and Development, 28*(5), 523-539.	Y	Y	Y	N	N
Suraya, A., Tarmizi, R.A., Nor, S.M., Abu, R., Ismail, H., Wan Z.W.A., Abu B.K. and Hamzah, R. (2007) Necessary Skills For Success in Higher Learning. *International Journal of Learning, 13*(10), p. 41-55.	Y	Y	Y	Y	Y
Daempfle, P. A. (2006). The effects of instructional approaches on the improvement of reasoning in introductory college biology: A quantitative review of research. *Bioscene, 32*(4), 22-31.	Y	Y	Y	N	N
Sharkey, J. (2006). Towards information fluency: Applying a different model to an information literacy credit course. *Reference Services Review, 34*(1), 71-85.	Y	Y	Y	N	N
Tinnesz, C.G., Ahuna, K.H. and Kiener, M. (2006). Toward college success: Internalizing active and dynamic strategies. *College Teaching, 54*(4), p. 302-306.	Y	Y	Y	Y	Y
Vandermensbrugghe, J. (2004). The unbearable vagueness of critical thinking in the context of the anglo-saxonisation of education. *International Education Journal, 5*(3), 417-422.	Y	Y	Y	N	N
Warner, I. M. (2004). Climbing Bloom's ladder. *Journal of Chemical Education, 81*(10), 1413.	Y	Y	Y	Y	Y
Williams, R.L. and Stockdale, S.L., (2003). High-Performing Students with Low Critical Thinking Skills. *Journal of General Education 52*(3), 199-225.	Y	Y	Y	N	N

Inclusion/Exclusion Criteria - Full Text (November 22-December 17, 2012)					
Citation	**P**	**I**	**M**	**O**	**Y/N/P**
Williams, R. L., and Worth, S.L., (2001). The Relationship of Critical Thinking to Success in College. *Inquiry: Critical Thinking Across the Disciplines*, 21(1), 5-16	Y	Y	Y	Y	Y
Olugbemiro J.J, Noordink, P., (1993). The Role of Critical Thinking Skills in Undergraduate Study as Perceived by University Teachers across Academic Disciplines. *Unpublished paper presented at the Fourth Annual Conference on Problem Solving Across the Curriculum at Hobart/William Smith Colleges.* Geneva, NY.	**Inapplicable: Not Retrieved**				
Totals					**Y = 7** **N = 12** **N/a = 1**

Appendix F.

Inclusion/Exclusion Criteria applied to abstracts and titles; Question #2a

Inclusion/Exclusion Criteria - Abstracts and Titles. (November 30, 2012)						
Citation	**P**	**I**	**M**	**O**	**Y/N/P**	**Retrieved?**
Dias, D. and José Sá, M. (2012) From high school to university: Students' competences recycled. *Research in Post-Compulsory Education, 17*(3)	Y	Y	Y	Y	Y	30/11/2012
Ford, R. W. (2012). Industry based leadership development. *Paper presented at the ASEE Annual Conference and Exposition, Conference Proceedings.*	P	Y	Y	N	N	Not Applicable
Maguire, C., Donovan, C., Mishook, J., de Gaillande, G., & Garcia, I. (2012). Choosing a life one has reason to value: The role of the arts in fostering capability development in four small urban high schools. *Cambridge Journal of Education, 42*(3), 367-390.	Y	Y	Y	N	N	Not Applicable
McCoy, L. P. (2012).Studies in Teaching: 2012 Research Digest. Action Research Projects Presented at Annual Research Forum. *Wake Forest University, Department of Education*	Y	Y	Y	N	N	Not Applicable
Pritchard, J. W., & Mina, M. (2012). Hands-on, discovery, critical thinking, and freshman engineering: A systems level approach to learning and discovery. *Paper presented at the ASEE Annual Conference and Exposition, Conference Proceedings.*	Y	Y	Y	N	N	Not Applicable
Project SEED. What Works Clearinghouse intervention report. (2012). *What Works Clearinghouse.*	N				N	Not Applicable
Saxton, E., Belanger, S., & Becker, W. (2012). The critical thinking analytic rubric (CTAR): Investigating intra-rater and inter-rater reliability of a scoring mechanism for critical thinking performance assessments. *Assessing Writing, 17*(4), 251-270.	Y	Y	Y	N	N	Not Applicable
Sherwin, P.R. (2012). The disconnection between high school and college: A study of retention of students who are at risk of leaving college before completing a	Y	Y	Y	Y	Y	30/11/2012

Inclusion/Exclusion Criteria - Abstracts and Titles. (November 30, 2012)						
Citation	**P**	**I**	**M**	**O**	**Y/N/P**	**Retrieved?**
degree. *Ed.D Dissertation, Lindenwood University.*						
Willing but not yet ready: A glimpse of California teachers' preparedness for the common core state standards. (2012). C*enter for the Future of Teaching and Learning at WestEd.*	N				N	Not Applicable
Framework for success in postsecondary writing. (2011). *National Writing Project. University of California.*	Y	Y	Y	P	N	Not Applicable
Griggs, R. A., & Jackson, S. L. (2011). Teaching introductory psychology: Tips from "ToP" Society for the Teaching of Psychology.	Y	Y	N		N	Not Applicable
Lo, T.M.H., (2011) From high school to higher education: Processes, changes, and ways to succeed. *Doctoral thesis, Durham University.*	P	Y	Y	P	P	30/11/2012
Matthews, M. L. (2011). Connecting creativity and critical thinking to the campaign planning process. *Communication Teacher, 25*(1), 61-67.	P	Y	Y	N	N	Not Applicable
Sam, S. (2011). High school principals' rating of success in implementation of 21st century skills.	P	Y	Y	N	N	Not Applicable
Skelton, G. W., Pang, Q., Zheng, W., & Shih, H. R. (2011). Using robotics for teaching critical thinking, problems solving and self-regulated learning for freshmen engineering students. *Paper presented at the ASEE Annual Conference and Exposition, Conference Proceedings.*	P	Y	Y	N	N	Not Applicable
Zulu, C. (2011). Empowering first year (post-matric) students in basic research skills: A strategy for: For social justice. *South African Journal of Education, 31*(3), 447-457.	Y	Y	Y	N	N	Not Applicable
Dison, L. (2010) Higher order thinking in transition: A case study of first year university students. *Collection of Electronic Theses and Dissertations*	P	Y	Y	P	P	30/11/2012

Inclusion/Exclusion Criteria - Abstracts and Titles. (November 30, 2012)						
Citation	**P**	**I**	**M**	**O**	**Y/N/P**	**Retrieved?**
Finkel, E. (2010). Gearing up for the new assessment. *District Administration, 46*(7), 78-82.	Y	Y	Y	N	N	Not Applicable
Finnegan, R. J.(2010). Writing expectations beyond high school: A study of the alignment of the New Jersey high school proficiency assessment in writing and college-level expectations. 201-201.	Y	Y	Y	Y	Y	30/11/2012
Green, C. C. (2010) The effectiveness of a first-year learning strategies seminar. 114-114.	N				N	Not Applicable
Peak, D. J. (2010) A correlational study of the advancement via individual determination (AVID) program with middle school student achievement in mathematics.	N				N	Not Applicable
Pittman, K. J. (2010). College and career readiness. *School Administrator, 67*(6), 10-14.	P	Y	Y	P	P	30/11/2012
Walker, H. E. (2010). 'All Work and No Play?' The Transition to University. *Thesis, Master of Arts: University of Otago.*	Y	Y	Y	Y	Y	30/11/2012
Zelkowski, J. (2010). Secondary mathematics: Four credits, block schedules, continuous enrolment? What maximizes college readiness. *Mathematics Educator, 20*(1), 8-21.	Y	Y	Y	P	P	30/11/2012
Adolescent literacy. Fact sheet. (2009). *Alliance for Excellent Education. Washington, DC.*	P	Y	Y	P	P	30/11/2012
Brownlee, J., Walker, S., Lennox, S., Exley, B., and Pearce, S. (2009). The first year university experience: Using personal epistemology to understand effective learning and teaching in higher education. *Higher Education, 58*(5) p. 599-618.	Y	Y	Y	N	N	Not Applicable
Jerman, J. (2009). Unlocking the transformational power of continuing education. Proceedings of the annual meeting of the Association for Continuing Higher Education.	N				N	Not Applicable

Inclusion/Exclusion Criteria - Abstracts and Titles. (November 30, 2012)						
Citation	**P**	**I**	**M**	**O**	**Y/N/P**	**Retrieved?**
Kimmins, L. and Stagg, A. (2009) Creating confidence: Developing academic skills and information literacy behaviours to support the precepts of tertiary academic performance. *4APCEI: Educational Integrity: Creating an Inclusive Approach*, 28-30	N				N	Not Applicable
Lewis, B. (2009). Inquiry-based instruction in geometry: The impact on end of course geometry test scores.	P	Y	Y	N	N	Not Applicable
Todd, V., Mcilroy, D., and Bunting, B., (2009). Individual differences in education: What do we know beyond ability? *The Irish Journal of Psychology, 30*(3-4), p. 147-160	P	Y	Y	N	N	Not Applicable
Sovic, S. (2008) Lost in Transition? The International Students' Experience Project. *University of the Arts, London: CLIP-CETL*	P	Y	Y	N	N	Not Applicable
Bellomo, C., & Strapp, R. (2008). A survey of advanced mathematics topics: A new high school mathematics class. *International Journal of Mathematical Education in Science and Technology, 39*(1), 13-22.	Y	Y	Y	N	N	Not Applicable
Magno, C. (2008). Self-regulation, self-efficacy, metacognition and achievement goals of high school and college adolescents. *Philippine Journal of Psychology, 41*(1-2)	Y	Y	Y	N	N	Not Applicable
Quint, J., Thompson, S. L., & Bald, M. (2008). Relationships, rigor and readiness. Strategies for improving high schools. *MDRC: New York, NY.*	Y	Y	Y	P	P	30/11/2012
Stern, B. S., & Kysilka, M. L. (2008). Contemporary readings in curriculum. *SAGE Publications: Thousand Oaks, CA.*	P	Y	N		N	Not Applicable
Stupnisky, R. H., Renaud, R. D., Daniels, L. M., Haynes, T. L., & Perry, R. P. (2008). The interrelation of first-year college students' critical thinking disposition, perceived academic control, and academic achievement. *Research in Higher Education, 49*(6), 513-530.	P	Y	Y	P	P	30/11/2012

Inclusion/Exclusion Criteria - Abstracts and Titles. (November 30, 2012)						
Citation	**P**	**I**	**M**	**O**	**Y/N/P**	**Retrieved?**
Conley, D.T. (2007). Redefining College Readiness, vol. 3. *Eugene, OR: Educational Policy Improvement Center.*	Y	Y	Y	Y	Y	30/11/2012
DiMartino, J., & Castaneda, A. (2007). Assessing applied skills. *Educational Leadership, 64*(7), 38-42.	Y	Y	Y	N	N	Not Applicable
Giuliano, B., & Sullivan, J. (2007). Academic wholism: Bridging the gap between high school and college. *American Secondary Education, 35*(3), 7-18.	Y	Y	Y	P	P	17/12/2012
Risley, R. A. (2007). Today's "Neglected Majority". *Community College Journal, 78*(1), 36-38.	Y	Y	Y	N	N	Not Applicable
School's back in session. (2007). *American Printer, (NOV.)*	Y	Y	Y	N	N	Not Applicable
Steele, M. (2007). Teaching science to students with learning differences. *Science Teacher, 74*(3), 24-27.	N				N	Not Applicable
Marchant, G. J., & Paulson, S. E. (2005). The relationship of high school graduation exams to graduation rates and SAT scores. *Education Policy Analysis Archives, 13*(6), 17-17.	Y	Y	Y	N	N	Not Applicable
Poudel, D. D., Vincent, L. M., Anzalone, C., Huner, J., Wollard, D., Clement, T., Blakewood, G. (2005). Hands-on activities and challenge tests in agricultural and environmental education. *Journal of Environmental Education, 36*(4), 10-22.	N				N	Not Applicable
Laird, L., & Ward, R. (2004). Camp gems (A success story). *Paper presented at the ASEE Annual Conference Proceedings, 1469-1478.*	N				N	Not Applicable
Trevino, R. E. (2004). Against all odds: Lessons from parents of migrant high-achievers.	P	Y	Y	N	N	Not Applicable
Arnold, J. C., & Keller, J. L. (2002). Cultures of medicine: A technology based learning environment to enhance critical thinking skills.	Y	Y	Y	N	N	Not Applicable

Inclusion/Exclusion Criteria - Abstracts and Titles. (November 30, 2012)						
Citation	**P**	**I**	**M**	**O**	**Y/N/P**	**Retrieved?**
Thompson, G. L., & Joshua-Shearer, M. (2002). In retrospect: What college undergraduates say about their high school education. *High School Journal, 85(4), 1-15.*	P	Y	Y	P	P	30/11/2012
Martorana, J., Curtis, S., DeDecker, S., Edgerton, S., Gibbens, C., & Lueck, L. (2001). Bridging the gap: Information literacy workshops for high school teachers. *Research Strategies, 18*(2), 113-120.	N				N	Not Applicable
Totals:					**Y=5 P=9 N=35**	**14 Retrieved**

Appendix G.

Inclusion/Exclusion criteria applied to abstracts and titles; Question #2b

Inclusion/Exclusion Criteria - Abstracts and Titles. (December 17, 2012)						
Citation	**P**	**I**	**M**	**O**	**Y/N/P**	**Retrieved?**
Önen, S.A. and Koçak, C. (2010) Determining the Critical Thinking Levels of Student Teachers and Evaluating Through Some Variables. *International Online Journal of Educational Sciences, 2*(3), p. 865-867.	N				N	Not Applicable
Paulson, E.J. and Armstrong, S.L. (2010). From the Editors: Expanding Access to JCLL. Journal of College Literacy & Learning, 36. p. 1-2.	P	Y	Y	P	P	17/12/2012
Chong, M.C. and Wing, S.C. (2008). Online discussion and critical thinking skills: A case study in a Singapore secondary school. *Australasian Journal of Educational Technology, 24*(5), p. 556-574.	N				N	Not Applicable
Bellomo, C. and Strapp, R. (2008). A survey of advanced mathematics topics: a new high school mathematics class. *International Journal of Mathematical Education in Science & Technology, 39*(1) p. 13-22.	Y	Y	Y	P	P	17/12/2012
Mendelman, L. (2007/2008). Critical thinking and reading. *Journal of Adolescent & Adult Literacy, 51(4), p. 300-302.*	Y	Y	Y	N	N	Not Applicable
Fletcher, J. (2007). Reaching Higher with Rhetoric: The CSU Expository Reading and Writing Course. *California English, 12*(3), p. 17-19.	Y	Y	Y	P	P	17/12/2012
Data on Student Preparation, College Readiness, and Achievement in College. (2007). Peer Review, 9(1) p. 24-25.	Y	Y	Y	P	P	17/12/2012
Wagie, D. and Fox, W. (2005/2006). Transforming Higher Education in the United Arab Emirates (UAE). *International Journal of Learning, 12*(7), p. 277-286.	Y	Y	Y	N	N	Not Applicable
Banks, J. (2005). African American College Students' Perceptions Of Their High School Literacy Preparation. *Journal of College Reading & Learning, 35*(2), p. 22-37.	P	Y	Y	P	P	17/12/2012

Warren, W.J., Memory, D.M. and Bolinger, K. (2004). Improving Critical Thinking Skills in the United States Survey Course: An Activity for Teaching the Vietnam War. *History Teacher*, *37*(2), p. 193-209.	N				N	Not Applicable
Whitaker, A.K. (2002/2003). Critical Thinking in the Tower Ivory. *Academic Questions*, *16*(1), p. 50.	P	Y	Y	N	N	Not Applicable
Totals:					**Y=0 P=5 N=6**	**5 Retrieved**

Appendix H.

Inclusion/exclusion criteria applied to full texts of retrieved documents, Question #2.

Inclusion/Exclusion Criteria - Full Text. (December 1 and 17, 2012)					
Citation	**P**	**I**	**M**	**O**	**Y/N/P**
Dias, D. and José Sá, M. (2012) From high school to university: Students' competences recycled. *Research in Post-Compulsory Education, 17*(3)	Y	Y	Y	Y	Y
Sherwin, P.R. (2012). The disconnection between high school and college: A study of retention of students who are at risk of leaving college before completing a degree. *Ed.D Dissertation, Lindenwood University.*	N				N
Lo, T.M.H., (2011) From high school to higher education: Processes, changes, and ways to succeed. *Doctoral thesis, Durham University.*	Y	Y	Y	Y	Y
Dison, L. (2010) Higher order thinking in transition: A case study of first year university students. *Collection of Electronic Theses and Dissertations*	N				N
Finnegan, R. J.(2010). Writing expectations beyond high school: A study of the alignment of the New Jersey high school proficiency assessment in writing and college-level expectations. 201-201.	Y	Y	Y	Y	Y
Paulson, E.J. and Armstrong, S.L. (2010). From the Editors: Expanding Access to JCLL. Journal of College Literacy & Learning, 36. p. 1-2.	N				N
Pittman, K. J. (2010). College and career readiness. *School Administrator, 67*(6), 10-14.	Y	Y	Y	Y	Y
Walker, H. E. (2010). 'All Work and No Play?' The Transition to University. *Thesis, Master of Arts: University of Otago.*	P	Y	Y	N	N
Zelkowski, J. (2010). Secondary mathematics: Four credits, block schedules, continuous enrollment? What maximizes college readiness. *Mathematics Educator, 20*(1), 8-21.	Y	Y	Y	N	N
Adolescent literacy. Fact sheet. (2009). *Alliance for Excellent Education. Washington, DC.*	Y	Y	Y	N	N

Inclusion/Exclusion Criteria - Full Text. (December 1 and 17, 2012)					
Citation	**P**	**I**	**M**	**O**	**Y/N/P**
Bellomo, C. and Strapp, R. (2008). A survey of advanced mathematics topics: a new high school mathematics class. *International Journal of Mathematical Education in Science & Technology, 39*(1) p. 13-22.	Y	Y	Y	N	N
Quint, J., Thompson, S. L., & Bald, M. (2008). Relationships, rigor and readiness. Strategies for improving high schools. *MDRC: New York, NY.*	Y	Y	Y	N	N
Stupnisky, R. H., Renaud, R. D., Daniels, L. M., Haynes, T. L., & Perry, R. P. (2008). The interrelation of first-year college students' critical thinking disposition, perceived academic control, and academic achievement. *Research in Higher Education, 49*(6), 513-530.	Y	Y	Y	Y	Y
Conley, D.T. (2007). Redefining College Readiness, vol. 3. *Eugene, OR: Educational Policy Improvement Center.*	Y	Y	Y	Y	Y
Data on Student Preparation, College Readiness, and Achievement in College. (2007). Peer Review, 9(1) p. 24-25.	Y	Y	Y	Y	Y
Fletcher, J. (2007). Reaching Higher with Rhetoric: The CSU Expository Reading and Writing Course. *California English, 12*(3), p. 17-19.	Y	Y	Y	Y	Y
Giuliano, B., & Sullivan, J. (2007). Academic wholism: Bridging the gap between high school and college. *American Secondary Education, 35*(3), 7-18.	Y	Y	Y	N	N
Banks, J. (2005). African American College Students' Perceptions Of Their High School Literacy Preparation. *Journal of College Reading & Learning, 35*(2), p. 22-37.	Y	Y	Y	N	N
Thompson, G. L., & Joshua-Shearer, M. (2002). In retrospect: What college undergraduates say about their high school education. *High School Journal, 85(4), 1-15.*	Y	Y	Y	N	N
Totals:					**Y=8** **N=11**

Appendix I.

Preliminary inspection of the ENG4U curriculum document.

ENG4U		
Factor of CT	**Example:**	**Description**
Analysis skills Evaluation skills Creativity Hypothesizing skills Judgement and decision-making abilities Confidence in reasoning Inquisitiveness Open, fair-mindedness and flexibility in reasoning	*"emphasizes the consolidation of the literacy, communication, and critical and creative thinking skills necessary for success in academic and daily life" (p.91)*	The curriculum describes an overall objective to focus on development of CT as necessary for academic and daily success. This implies development of each of the identified components of CT, though only creativity is mentioned directly in this case.
Analysis skills Evaluation skills Creativity	*"Students will analyse a range of challenging literary texts…interpret and evaluate informational and graphic texts… create oral, written, and media texts in a variety of forms." (p.91)*	This overall goal explicitly relates to practice of analysis and evaluation. Creativity may also be implicitly developed, through practice of creating a variety of literature and media.
Evaluation skills Judgement and decision-making abilities Confidence in reasoning	*"An important focus will be on using academic language coherently and confidently, selecting the reading strategies best suited to particular texts and particular purposes for reading" (p.91)*	Here, the curriculum describes an overall focus on developing student confidence and the selection of learning strategies, which is related to the development of both evaluation skills and judgement and decision-making abilities.
Overall CT development	*"reflect on and identify their strengths as listeners and speakers, areas for improvement, and the strategies they found most helpful in oral communication situations" (p.92)*	The described expectation of reflection can be related to the development of metacognition, which can promote overall CT abilities.

ENG4U		
Factor of CT	**Example:**	**Description**
Evaluation skills Judgement and decision-making abilities Open, fair-mindedness and flexibility in reasoning	*"identify the purpose of a wide range of listening tasks and set goals for specific tasks… e.g., prepare counterarguments during a debate;"* *"**Teacher prompt:** 'Which strategy works best for you? How does this change in different situations?'" (p.92)*	Here, the curriculum encourages students to use judgement and decision making abilities, evaluation skills, and to become more flexible in their reasoning methods. Development of the CT components is considered implicit in this case, and examples and possible teacher prompts are included to support classroom instruction.
Evaluation skills Judgement and decision-making abilities	*"select and use the most appropriate active listening strategies… select and use the most appropriate listening comprehension strategies" (p.92)*	These activities imply development of judgement and decision-making abilities and evaluation skills. Instruction is supported with a few examples.
Analysis skills Evaluation skills	*"identify the important information and ideas in oral texts… What was the main evidence" (p.92)*	To complete the described activity, students may practice analysis and evaluation skills. Development is implicit here, and instruction is supported with examples of teacher prompts.
Hypothesizing skills	*"develop and explain interpretations of oral texts" (p.92)*	Here, the text implies practice of hypothesizing skills.
Analysis skills Inquisitiveness Open, fair-mindedness and flexibility in reasoning	*"making insightful connections between the ideas in them and personal knowledge, experience, and insights; other texts; and the world" (p.93)*	The described activity may implicitly develop analysis skills, inquisitiveness, and open, fair-mindedness and flexibility in reasoning.
Analysis skills	*"analyse oral texts, including complex and challenging texts" (p.93)*	Here, the document explicitly promotes practice of analysis skills.

ENG4U		
Factor of CT	**Example:**	**Description**
Analysis skills	*"identify and analyse in detail the perspectives and/or biases evident in oral texts" (p.93)*	Here, the document explicitly promotes practice of analysis skills.
Evaluation skills Judgement and decision-making abilities	*evaluate the effectiveness of a wide variety of presentation strategies used in oral texts… suggest other strategies (p.93)*	Here, the document explicitly promotes practice of evaluation skills. To suggest other strategies, students may also practice judgement and decision making, though development of this component is implicit.
Open, fair-mindedness and flexibility in reasoning	*"Adapt them to suit the purpose, situation, and audience, exhibiting sensitivity to cultural differences" (p.93)*	The described practice implies promotion of open, fair-mindedness and flexibility in reasoning.
Creativity	*"use a variety of audio-visual aids effectively to support and enhance oral presentations" (p.93)*	Students may be encouraged to develop creativity to come up with effective audio-visual aids. Here, CT development is implicit.
Overall CT development	*"demonstrate insight into their strengths and weaknesses as listeners and speakers, and practise the strategies they found most helpful…identify a range of their skills" (p.94-95)*	The described expectation of reflection can be related to the development of metacognition, which can promote overall CT abilities.
Evaluation skills.	*"identifying specific purposes for reading" (p.96)*	Here, students' evaluation skills may be developed implicitly through practice.
Analysis skills Evaluation skills Judgement and decision-making abilities	*"select and use, with increasing facility, the most appropriate reading comprehension strategies" (p.96)*	When selecting effective strategies, students may have to analyze and evaluate possible options, and then use judgement to make a decision. CT development is implicit here.

ENG4U		
Factor of CT	**Example:**	**Description**
Evaluation skills.	*"identify the most important ideas and supporting details in texts"(p.96)*	Here, students will need to use evaluation skills to identify comparative importance of various ideas/details.
Analysis skills Hypothesizing skills	*"make and explain inferences of increasing subtlety and insight about texts… supporting their explanations with well-chosen stated and implied ideas (p.96)*	This practice implies development of analysis skills and hypothesizing skills.
Analysis skills Creativity Hypothesizing skills	*"extend understanding of texts…making rich and increasingly insightful connections..* ***Teacher prompt****…What possibilities can you imagine now" (p.97)*	This example shows implicit development of student creativity, analysis skills, and hypothesizing skills.
Analysis skills	*"analyse texts in terms of the information, ideas, issues, or themes" (p.97)*	Here, the curriculum clearly notes a focus on the practice of analysis skills.
Evaluation skills	*"evaluate the effectiveness of texts" (p.97)*	This is an example of an explicit focus on the practice of evaluation.
Analysis skills Open, fair-mindedness and flexibility in reasoning	*"identify and analyse the perspectives and/or biases evident in texts… insight on any questions they may raise about beliefs, values, identity, and power" (p.97)*	Here, there is an explicit focus on the practice of analysis skills. Students may also develop (implicitly) open, fair-mindedness and flexibility in reasoning.
Analysis skills Evaluation skills	*"identify a variety of characteristics… text features.. elements of style… and explain how they help communicate meaning" (p.97-98)*	Determine how different characteristics might communicate meaning can implicitly promote the development of analysis and evaluation skills.
Judgement and decision-making abilities	*"use decoding strategies effectively to read and understand unfamiliar words" (p.98)*	Here, judgement and decision making abilities may be implicitly developed.

ENG4U		
Factor of CT	**Example:**	**Description**
Overall CT development	*demonstrate insight into their strengths and weaknesses as readers, and practise the strategies they found most helpful… identify a variety of their skills" (p.98-99)*	The described expectation of reflection can be related to the development of metacognition, which can promote overall CT abilities.
Creativity Hypothesizing skills Judgement and decision-making abilities Inquisitiveness Open, fair-mindedness and flexibility in reasoning	*"generate, expand, explore, and focus ideas for potential writing tasks" (p.100)*	This curriculum expectation may involve the use of several CT components, as listed.
Evaluation skills Judgement and decision-making abilities	"locate and select information to fully and effectively support ideas for writing" (p.100)	To select appropriate supportive information, students may practice evaluation skills and judgement and decision making abilities.
Evaluation skills Judgement and decision-making abilities	*"selecting the organizational pattern best suited to the content and the purpose" (p.101)*	Practice selecting the best organizational pattern may implicitly support development of evaluation skills and judgement and decision making abilities.
Analysis skills Evaluation skills Open, fair-mindedness and flexibility in reasoning	*explain, with increasing insight, how their own beliefs, values, and experiences are revealed in their writing… e.g., examine their writing to check for bias" (p.102)*	This practice can implicitly develop student analysis and evaluation skills, as well as open, fair-mindedness and flexibility in reasoning.
Evaluation skills	*"revise drafts to improve the content, organization, clarity, and style of their written work" (p.102)*	Here, students will need to evaluate their own work before beginning revisions. This practice includes implicit skill development.

ENG4U		
Factor of CT	**Example:**	**Description**
Judgement and decision-making abilities	*"use a variety of presentation features, including print and script, fonts, graphics, and layout, to improve the clarity and coherence of their written work and to heighten its appeal" (p.103)*	Judgement and decision making abilities should be practiced, and implicitly developed, as students determine which presentation features to use.
Overall CT development	*"demonstrate insight into their strengths and weaknesses as writers, and practise the strategies they found most helpful… identify a variety of skills they have" (p.103-104)*	The described expectation of reflection can be related to the development of metacognition, which can promote overall CT abilities.
Evaluation skills Judgement and decision-making abilities	*"select a variety of types of writing that they think most clearly reflect their growth" (p.104)*	Here, students will need to evaluate their own writing and then use judgement and decision making abilities to select examples for a portfolio.
Evaluation skills	*"evaluate how effectively information, ideas, themes, issues, and opinions are communicated in media texts" (p.105)*	This is an example of an explicit focus on the practice of evaluation skills.
Analysis skills	*"identifying and explaining with increasing insight the overt and implied messages" (p.105)*	This practice may implicitly promote the development of analysis skills.
Analysis skills Creativity Hypothesizing skills	*"explain, with increasing insight, why the same media text might prompt different responses" (p.106)*	Students may need to use creativity, analysis skills, and hypothesizing skills for this curriculum objective.
Analysis skills	*"identify and analyse the perspectives and/or biases evident in texts" (p.106)*	In this case, the practice of analysis skills is an explicit focus of the curriculum
Creativity Hypothesizing skills	"explain, with increasing understanding and insight, how production, marketing, financing, distribution, and legal/regulatory factors influence the media industry" *(p.106)*	Here, students may need to develop hypotheses and use creative thinking to come up with ideas. Development of both CT components is considered implicit in this example.

ENG4U		
Factor of CT	**Example:**	**Description**
Analysis skills Evaluation skills	*"identify conventions and/or techniques used… demonstrate insight into the way they convey meaning and influence" (p.106)*	This is a case of implicit CT development, and may involve evaluation of factors' meaning and influence, and analysis of the media to determine what techniques are used.
Creativity Hypothesizing skills	*"identify practical, interpretive, and/or creative challenges they may face" (p.106)*	Here, students may develop creativity as they think about different challenges. They also may practice hypothesizing skills.
Analysis skills Evaluation skills	*"explain why these will help communicate a specific aspect of their intended meaning most effectively" (p.107)*	This curriculum objective implies practice of evaluation skills and analysis.
Creativity	*"produce media texts, including complex texts, for a variety of purposes and audiences" (p.107)*	Creation of various media texts may encourage student creativity.
Overall CT development	*"demonstrate insight into their strengths and weaknesses as media interpreters and producers, and practise the strategies they found most helpful"(p.107)*	The described expectation of reflection can be related to the development of metacognition, which can promote overall CT abilities.

Appendix J.

Preliminary inspection of the MHF4U curriculum document.

MHF4U		
Factor of CT:	**Example:**	**Description:**
Analysis skills Evaluation skills Hypothesizing skills Judgement and decision-making abilities Open, fair-mindedness and flexibility in reasoning Confidence in reasoning	*"The mathematical processes are to be integrated into student learning in all areas of this course… develop and apply reasoning skills… demonstrate that they are reflecting on and monitoring their thinking" (p. 86)*	The math curriculum begins with descriptions of seven mathematical processes that relate strongly to principle of CT. These learning goals are supported by reflection, and practice of monitored thinking, which is likely to improve students' metacognitive abilities and to benefit overall CT progress. Development is considered to be explicit in this case for each learning goal *except* for open, fair-mindedness and flexibility in reasoning.
Hypothesizing skills Judgement and decision-making abilities Open, fair-mindedness and flexibility in reasoning	*"including those in problems arising from real-world applications" (p.87)*	In this instance, the curriculum connects equation solving in the classroom to real-world problem solving, implying development of judgement, flexibility in reasoning, and hypothesizing skills. This practice may also promote transfer of the CT components.
Analysis skills Evaluation skills Hypothesizing skills Judgement and decision-making abilities Open, fair-mindedness and flexibility in reasoning	*"make connections between related logarithmic and exponential equations… between the laws of exponents and the laws of logarithms… with or without technology" (p.87)*	To make connections as described, students may be required to practice analysis skills, evaluation skills, hypothesizing skills and judgement and decision making abilities. Requiring the students to develop reasonable connections with or without technological assistance can help them to practice flexibility in reasoning. Here, CT development is considered implicit.

MHF4U		
Factor of CT:	**Example:**	**Description:**
Analysis skills Evaluation skills Hypothesizing skills Judgement and decision-making abilities Open, fair-mindedness and flexibility in reasoning	*"Sample problem: Give examples to show that the inverse of a function is not necessarily a function… pose problems based on real-world applications of exponential and logarithmic functions" (p.88)*	The described activities implicitly require students to practice several CT skills, as listed.
Analysis skills Hypothesizing skills Judgement and decision-making abilities Open, fair-mindedness and flexibility in reasoning	*"solve problems involving exponential and logarithmic equations algebraically, including problems arising from real-world applications" (p.88)*	This practice will again implicitly promote the development of several CT learning goals. Connection with real world applications can promote successful transfer of the CT components. An example is provided of a student activity, encouraging students to think about how variables might affect their findings.
Analysis skills Hypothesizing skills Judgement and decision-making abilities	*"make connections between trigonometric ratios and the graphical and algebraic representations … use these connections to solve problems" (p.89)*	Here, the curriculum supports implicit development of several identified CT goals. Finding connections between ratios and representations – and then applying the connections – can help to support advanced reasoning techniques.
Creativity Hypothesizing skills Open, fair-mindedness and flexibility in reasoning	*"pose problems based on applications… (e.g., seasonal changes in temperature, heights of tides… and solve these and other such problems" (p.90)*	Forming their own problems can encourage students to be flexible in reasoning, and can promote creativity and hypothesizing skills. CT component development is implicit in this case.

MHF4U		
Factor of CT:	**Example:**	**Description:**
Analysis skills Creativity Hypothesizing skills Judgement and decision-making abilities Open, fair-mindedness and flexibility in reasoning	*"prove trigonometric identities through the application of reasoning skills, using a variety of relationships" (p.90)*	Reasoning skills involved in the task described here will likely include analysis, hypothesizing, and judgement and decision making. Students may also be encouraged to be open and flexible in their reasoning, as they are asked to use a variety of relationships to support their conclusions.
Analysis skills Hypothesizing skills Inquisitiveness Open, fair-mindedness and flexibility in reasoning	*"compare, through investigation using graphing technology, the numeric, graphical, and algebraic representations… make connections, through investigation" (p.91)*	The investigations and comparisons described may involve implicit promotion of analysis skills, hypothesizing skills, inquisitiveness, and flexibility in reasoning.
Analysis skills Evaluation skills Hypothesizing skills Judgement and decision-making abilities Open, fair-mindedness and flexibility in reasoning	*"determine an equation of a polynomial function that satisfies a given set of conditions… using methods appropriate to the situation… recognize that there may be more than one polynomial function that can satisfy a given set of conditions" (p.92)*	The practices included in this curriculum objective involve use of analysis skills, evaluation skills, hypothesizing skills, judgement and decision-making, and flexibility in reasoning. The development of each of these CT components is considered implicit in this case.
Analysis skills Evaluation skills Hypothesizing skills Judgement and decision-making abilities Open, fair-mindedness and flexibility in reasoning	*"Sample problem: Investigate numerically, graphically, and algebraically, with and without technology, the conditions under which an even function has an even number of x-intercepts." (p.92)*	The problem described implies practice of several CT components, as listed.
Analysis skills Hypothesizing skills Open, fair-mindedness and flexibility in reasoning	*"make connections, through investigation using technology (e.g., computer algebra systems)" (p.93)*	Again, the curriculum asks students to make connections, specifically supported by technology. Here, the students can be expected to develop several (listed) CT learning goals; development is considered implicit in this case.

MHF4U		
Factor of CT:	**Example:**	**Description:**
Creativity Judgement and decision-making abilities Open, fair-mindedness and flexibility in reasoning	*"by selecting and applying strategies" (p.93)*	Requiring students to select and apply strategies to solve problems can encourage implicit development of creativity, judgement and decision making abilities and flexibility in reasoning. This practice may also promote metacognition, which can benefit overall CT ability and application.
Evaluation skills Hypothesizing skills	*"make a conjecture about the relationship between the given function and the polynomial function for very large positive and negative x-values, and verify your conjecture" (p.93)*	Here, students are asked to develop a hypothesis and to support it through verification. This practice involves explicit promotion of hypothesizing skills, and implicit promotion of evaluation skills.
Analysis skills Evaluation skills Hypothesizing skills Judgement and decision-making abilities Open, fair-mindedness and flexibility in reasoning	*"solve problems by modelling and reasoning with functions, including problems with solutions that are not accessible by standard algebraic techniques"(p.95)*	Advance problem solving and reasoning involves the use of several CT learning goals. CT development in this part of the curriculum is implicit.
Analysis skills Evaluation skills Creativity Hypothesizing skills Judgement and decision-making abilities Open, fair-mindedness and flexibility in reasoning	*"gather, interpret, and describe information about real-world applications… examining applications, including those arising from real-world situations… make connections" (p.95)*	Once again, the Mathematics curriculum is supported by real world application, promoting CT transfer and implicit development of several identified CT learning goals.
Analysis skills Judgement and decision-making abilities Open, fair-mindedness and flexibility in reasoning	*"determine, through investigation using various representations of relationships… make connections, through investigation"(p.96)*	Requiring students to make connections and determinations through investigation may implicitly promote development of analysis skills, judgement and decision making abilities, and flexibility in reasoning.

MHF4U		
Factor of CT:	**Example:**	**Description:**
Analysis skills Hypothesizing skills Judgement and decision-making abilities	*"solve problems involving average and instantaneous rates of change, including problems arising from real-world applications" (p.96).*	The curriculum again involves connection of real world application with course problem solving, implying practice of analysis and hypothesizing skills, and judgement and decision making abilities.
Analysis skills Judgement and decision-making abilities Open, fair-mindedness and flexibility in reasoning	*"recognize real-world applications of combinations of functions" (p.96)*	Supports implicit development of several CT abilities, as previously described.
Analysis skills Judgement and decision-making abilities	*"solve problems involving the composition of two functions, including problems arising from real-world applications" (p.97)*	This involves implicit promotion of the listed CT learning goals (for more information, see previous descriptions).
Analysis skills Evaluation skills Creativity Hypothesizing skills Judgement and decision-making abilities Open, fair-mindedness and flexibility in reasoning	*"compare, through investigation using a variety of tools and strategies… solve problems, using a variety of tools and strategies, including problems arising from real-world applications, by reasoning"(p.97)*	This involves implicit promotion of the listed CT learning goals (for more information, see previous descriptions).

Appendix K.

Preliminary inspection of the SPH4U curriculum document.

SPH4U		
Factor of CT:	**Example:**	**Description:**
Analysis skills	*"They will further develop their scientific investigation skills, learning, for example, how to analyse" (p.194)*	Here, the course introduction mentions a learning goal explicitly related to the development of analysis skills.
Analysis skills Evaluation skills Hypothesizing skills Judgement and decision-making abilities	*"demonstrate scientific investigation skills… initiating and planning, performing and recording, analysing and interpreting, and communicating" (p.196)*	The scientific investigation skills described include mention of analysis. They may also involve practice of judgement and decision-making abilities to facilitate planning, and evaluation or hypothesizing skills to interpret data.
Analysis skills Evaluation skills Creativity Hypothesizing skills Inquisitiveness	*"formulate relevant scientific questions… make informed predictions, and/or formulate educated hypotheses to focus inquiries" (p.196)*	This curriculum goal may involve practice of analysis skills and/or evaluation skills in order for students to make predictions. Hypothesizing skills are mentioned directly. Students may implicitly develop inquisitiveness and creativity as well when formulating questions.
Judgement and decision-making abilities	*"apply knowledge and understanding… when planning investigations" (p.196)*	To correctly apply knowledge and understanding in planning, as described, students may need to practice good judgement and decision-making abilities.

SPH4U		
Factor of CT:	**Example:**	**Description:**
Analysis skills Evaluation skills Hypothesizing skills Judgement and decision-making abilities Open, fair-mindedness and flexibility in reasoning	*"synthesize, analyse, interpret, and evaluate qualitative and quantitative data; solve problems involving quantitative data; determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements" (p.196)*	Here, the curriculum develops skills in analysis, evaluation and hypothesizing. Students may implicitly develop open, fair-mindedness and flexibility in reasoning through this practice, as they are asked to identify sources of bias and to discover ways to improve evidence and reduce error. Additionally, students may practice judgement and decision making abilities to suggest improvement and to judge given evidence.
Analysis skills	*"analyse the information gathered from research sources" (p.196)*	The example clearly shows practice of analysis skills.
Hypothesizing skills	*"draw conclusions based on inquiry results and research findings, and justify their conclusions" (p.197)*	Students may practice hypothesizing skills to think about and form potential justifiable conclusions
Analysis skills Inquisitiveness	*"identify and describe a variety of careers related to the fields of science under study" (p.197)*	This practice may encourage students to draw connections between the Physics course and real world application, and implicitly promote student inquisitiveness. Students may also use analysis skills to understand how various careers are related to particular fields of science.
Analysis skills Hypothesizing skills	*"analyse a technological device **Sample questions**: What aspects of the principles of motion are applied in archery?" (p.198)*	Here, the curriculum specifically mentions practice of analysis skills. Some sample questions are given that connect scientific principals with real world examples and application, which may implicitly promote student hypothesizing skills and inquisitiveness.

SPH4U		
Factor of CT:	**Example:**	**Description:**
Analysis skills Hypothesizing skills Judgement and decision making abilities	*"assess the impact on society and the environment of technological devices" (p.198)*	This objective may involve the practice of analysis skills, hypothesizing skills, and judgement and decision-making abilities. A sample issue is provided, as well as some example questions students might be asked.
Analysis skills	*"analyse, in qualitative and quantitative terms, the relationships" (p.198)*	Practice of analysis skills is explicitly mentioned.
Analysis skills Hypothesizing skills	*"predict, in qualitative and quantitative terms, the forces acting on systems of objects" (p.198)*	To form logical predictions, students may need to practice analysis skills and hypothesizing skills.
Analysis skills	*"analyse, in qualitative and quantitative terms, the relationships between the motion of a system and the forces" (p.198)*	Here, the curriculum clearly mentions practice of analysis skills.
Analysis skills	*"analyse, …forces acting on and the acceleration experienced by an object in uniform circular motion" (p.199)*	This is an example of an explicit focus on the practice of analysis skills.
Analysis skills Hypothesizing skills Judgement and decision-making abilities Inquisitiveness	*"conduct inquiries into the uniform circular motion of an object… analyse, …relationships between centripetal acceleration, centripetal force, radius of orbit, period, frequency, mass, and speed" (p.199)*	In order to conduct inquiries as described here, students may need to use hypothesizing skills and judgement and decision making abilities. They might develop inquisitiveness as well through exploration. The part of the curriculum also explicitly mentions practice in analysis.
Analysis skills Evaluation skills Hypothesizing skills	*"explain the advantages and disadvantages of static and kinetic friction in situations" (p.199)*	Developing explanations might involve the use of analysis, hypothesizing and evaluation skills.

SPH4U		
Factor of CT:	**Example:**	**Description:**
Analysis skills Hypothesizing skills	*"analyse, and propose ways to improve, technologies or procedures that apply principles related to energy and momentum, and assess the social and environmental impact" (p.200)*	Analysis skills are explicitly mentioned in this case. This overall objective might also involve the use of hypothesizing skills to propose methods of improvement, and evaluation skills in determining technologies' impact.
Analysis skills Hypothesizing skills	*"analyse, with reference to the principles of energy and momentum, and propose practical ways to improve, a technology or procedure" (p.200)*	Analysis skills are explicitly mentioned in this objective, and hypothesizing skills might be used in order to propose practical methods of improvement.
Analysis skills Evaluation skills	*"assess the impact on society and the environment of technologies or procedures that apply the principles of energy and momentum" (p.200)*	The assessment described here should involve practice of analysis and evaluation skills.
Analysis skills	*"analyse, in qualitative and quantitative terms, the relationship between work and energy, using the work–energy theorem" (p.201)*	Here, analysis skills are used and applied to specific cases and theories.
Analysis skills	*"use an inquiry process to analyse" (p.201)*	Analysis skills are again the explicit focus of the curriculum here.
Creativity Hypothesizing skills Judgement and decision-making abilities Inquisitiveness	*"conduct a laboratory inquiry or computer simulation to test the law of conservation of energy" (p.201)*	In this case, students might develop creativity and inquisitiveness as they try to come up with ideas for inquiry, depending on related instruction. They may also practice hypothesizing skills and judgement and decision making abilities.
Analysis skills	*"analyse… relationships between mass, velocity, kinetic energy, momentum, and impulse for a system of objects (p.201)*	In this case, the practice of analysis skills is explicitly mentioned.

SPH4U		
Factor of CT:	**Example:**	**Description:**
Analysis skills	*"analyse, …elastic and inelastic collisions in one and two dimensions" (p.201)*	In this case, the practice of analysis skills is explicitly mentioned.
Creativity Hypothesizing skills Judgement and decision-making abilities Inquisitiveness	*"conduct laboratory inquiries or computer simulations involving collisions and explosions in one and two dimensions" (p.201)*	Here, creativity and inquisitiveness may be developed as students create ideas for inquiry, depending on the accompanying instruction. Students may also practice hypothesizing skills and judgement and decision making abilities through the described activities.
Analysis skills Evaluation skills Hypothesizing skills	*"analyse the operation of technologies that use gravitational, electric, or magnetic fields, and assess the technologies' social and environmental impact" (p.202)*	Analysis skills are explicitly mentioned in this overall objective. Evaluation and hypothesizing skills may also be used, to assess the technologies' impact.
Analysis skills Evaluation skills Hypothesizing skills	*"analyse the operation… assess the impact on society and the environment of technologies that use gravitational, electric, or magnetic fields of a technological system" (p.202)*	Here, the practice of analysis skills is again mentioned clearly, and students may also use skills in evaluation and hypothesizing to assess impact.
Analysis skills	*"analyse, and solve problems relating to, Newton's law of universal gravitation and circular motion" (p.202)*	Analysis skills are the explicit focus of this curriculum objective
Analysis skills	*"analyse, and solve problems involving, electric force, field strength, potential energy, and potential" (p.202)*	Here, the curriculum clearly mentioned practice of skills in analysis.
Analysis skills	*"analyse, and solve problems involving, the force on charges moving in a uniform magnetic field" (p.203)*	This is another example of the development through practice of analysis skills in the Physics' curriculum.

SPH4U		
Factor of CT:	**Example:**	**Description:**
Evaluation skills Hypothesizing skills	*"conduct a laboratory inquiry or computer simulation to examine the behaviour of a particle in a field" (p.203)*	Students may use evaluation skills to examine the completed inquiry, and may use the information they gained to form hypotheses. This potential CT development would be implicit.
Analysis skills Evaluation skills Hypothesizing skills	*"analyse technologies that use the wave nature of light, and assess their impact on society and the environment" (p.204)*	This overall curriculum objective clearly mentions practice of analysis skills. Students may also use evaluation and hypothesizing skills to assess the technologies' impact.
Analysis skills Evaluation skills Hypothesizing skills	*"analyse, with reference to the principles related to the wave nature of light… assess the impact on society and the environment of technologies that use the wave nature of light" (p.204)*	Analysis skills are mentioned clearly, and to assess technologies' impact, students may also practice evaluation and hypothesizing skills.
Analysis skills	*"analyse diffraction and interference of water waves and light waves" (p.204)*	This curriculum expectation is explicitly linked to the practice of analysis skills.
Analysis skills	*"analyse, with reference to quantum mechanics and relativity" (p.205)*	Here, analysis skills are explicitly mentioned.
Analysis skills	*"analyse the development of the two major revolutions in modern physics" (p.206)*	Here, analysis skills would be practiced to meet the curriculum's expectation.
Analysis skills Evaluation skills Hypothesizing skills	*"assess the importance of relativity and quantum mechanics to the development of various technologies" (p.206)*	The described assessment may involve the use of several CT components, including analysis, evaluation, and hypothesizing skills.
Analysis skills	*"conduct a laboratory inquiry or computer simulation to analyse data" (p.207)*	This example includes a way for students to use and practice analysis skills.

Appendix L.

Sample of Kruskal-Wallis test calculations for survey response data.

Using the Kruskal-Wallis test on responses from Sections 1 and 2 of the survey, we tested the following hypotheses:

- H_0: responses are equivalently distributed in the different groups.
- H_1: responses are systematically higher or lower in some groups than in others.

The statistic H can be used with chi-square approximations to find a value for the probability (P) of obtaining results like or less extreme than those observed when the null hypothesis is assumed. A *sample calculation* is shown here, using the data from Question 1: "The definition above clearly encompasses my idea of critical thinking."

Raw and ranked data:

Count	**Raw Data for Sample**			**Ranks for Sample**		
	English	Math	Physics	English	Math	Physics
1	5	3	6	3	1	12.5
2	5	6	6	3	12.5	12.5
3	5	6	6	3	12.5	12.5
4	6	6		12.5	12.5	
5	6	6		12.5	12.5	
6	6	6		12.5	12.5	
7	6	6		12.5	12.5	
8	6			12.5		
9	6			12.5		
10	6			12.5		

Let R_i represent the sum of the ranks for the *i*th sample. Calculate the statistic *H* using the Kruskal-Wallis equation.

$$H = \frac{12}{N(N+1)} \sum \frac{R_i^2}{n_i} - 3(N+1)$$

$$H = \frac{12}{20(20+1)} \left(\frac{76^2}{7} + \frac{37.5^2}{3} + \frac{96.5^2}{10} \right) - 3(20+1)$$

$$H = 0.574795918$$

Using the chi-square table for probability, with **df = 2** we find a probability of approximately **0.75**, convincingly supporting the null hypothesis. The calculations shown above were also applied to all other questions from Section 1 and Section 2 of the survey.

Appendix M.

Sample of Mann-Whitney test calculations for survey response data.

The Mann-Whitney test statistic *U* can be used to determine if a responses are significant compared to another real or randomly generated dataset. Here, a sample of the calculations completed is provided for Question 1: "The definition above clearly encompasses my idea of critical thinking."

- H_0: responses are randomly distributed across the provided options.
- H_1: responses are systematically higher or lower than random.

Count	**Raw Data for Sample**		**Ranks for Sample**	
	Actual	Random	Actual	Random
1	6	1	28	2
2	6	2	28	5
3	6	3	28	8.5
4	5	4	15.5	11.5
5	5	5	15.5	15.5
6	6	6	28	28
7	6	7	28	39
8	6	1	28	2
9	6	2	28	5
10	5	3	15.5	8.5
11	6	4	28	11.5
12	6	5	28	15.5
13	6	6	28	28
14	6	7	28	39
15	6	1	28	2
16	6	2	28	5
17	3	3	8.5	8.5
18	6	5	28	15.5
19	6	6	28	28
20	6	7	28	39
Total			**503**	**317**

Find the Mann-Whitney test statistic *U*.

Substitute the values $T_X = 503$, $N_1 = 20$, $N_2 = 20$ and $N_X = 20$ into the equation:

$$U = N_1 \times N_2 + N_x \times \frac{N_x + 1}{2} - T_x$$

$$U = 20 \times 20 + 20 \times \frac{20 + 1}{2} - 503$$

$$U = 400 + 210 - 503$$

$$U = 107$$

Compare the value for *U* to the critical values for U at a 0.05 significance level. For $N_1 = 20$ and $N_2 = 20$, the critical value for *U* has a lower limit of 127, and an upper limit of 273. Statistical significance depends on the obtained *U* value being either equal to or less than the lower limit of the critical value, *or* equal to or higher than the upper limit of the critical value (Lowry, 2013).

Therefore, **the null hypothesis is rejected,** since 107 < 127**.** Inspection of the medians suggests that the actual responses are **significantly higher** than random. The Mann-Whitney test was likewise applied to the other applicable survey questions, using a combined dataset.