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Critical Thinking to Creative Problem-Solving in Engineering and Management

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Walden University
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Abstract

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MS, Islamic Azad University, 1991

BS, Iranian Institute of Advanced Accounting, 1976

Dissertation Submitted in Partial Fulfillment

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Abstract

Organizations advance and grow by solving problems one at a time, and management graduates should possess critical thinking and problem-solving capacities to be effective business managers and creative engineers. The problem was that critical thinking and creative problem solving are operationally ill-defined in engineering and management education. The purpose of this grounded theory study was to discover how, if at all, the engineering and management scholar-practitioner community in British Columbia, Canada, perceives the concepts of critical thinking and creative problem-solving. A three-prong critical thinking conceptual framework was used as template for defining and relating the two key concepts of the study. Research questions asked about operational definitions of critical thinking and creative problem solving and any relationships between them. Data were collected by interviewing eleven participants, with experience as educators and practitioners, and thematized into concepts for developing a theory that describes the perceived meanings of critical thinking and its relation to problem-solving. Findings included that employer's expectations can be better met through critical thinking employees' contributions to find the right problems and solve, or manage, them effectively. Finally, it was illustrated that positive social change ensued from improving the critical thinking and problem-solving capacity of graduates, as they support to their organizations in delivering products and services of value to elevate the living standards of society at large.

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Chapter 1: Introduction to the Study

Positive social change takes place through active engagement of people planning courses of action and executing those plans. Performing these tasks require a certain degree of preparation at the individual citizen's level. Central to such preparedness is a critical thinking capacity, which forms the central concept of my dissertation. This chapter contains background information about the general role that critical thinking plays in the management and engineering disciplines, followed by identification of the societal problem that this dissertation addressed. The research questions are also outlined. Further, I describe the literature-based conceptual framework, which I adopted for investigating the research questions, and I describe the research methodology that I employed to find answers to the research questions. The chapter ends with highlights of the social, professional, and theory contributions, including some of the literature gaps that are addressed.

Background of the Study

In a post-industrial society, the U.S. economy experienced massive migration of jobs from manufacturing to service (Bell, 1999). This phenomenon gave rise to the significance of human capital at the cost of financial capital. Traditional industrial economies relied on skilled and semiskilled labor, whereas the pressure of innovation contributed to shifting of demand to knowledge workers, who are the primary drivers of innovation (Bell, 1999).The expanding service sector in post-industrial economies generated demand for a special class of workforce that is multiskilled, flexible, and willing to learn and adapt quickly to rapidly changing market conditions (Esping-

Anderson, 2000). Possessing such characteristics is fueled by the ability to tackle wide ranges of problems as they emerge (Abbasi et al., 2018; Baird & Parayitam, 2019), which in turn is empowered by the possession of a critical thinking capacity by individual actors of the post-industrial era (Paul & Elder, 2016).

Creative individuals are the primary enabling force that fuels regional economic prosperity (Florida, 2004). For example, the Canadian Institute of Health Research, Natural Sciences and Engineering Council of Canada, and Social Sciences and Humanities Research Council of Canada recognized creativity as a national asset that is needed to facilitate effective economic recovery and enhance the country's competitive standing in global markets (Government of Canada, 2009). As a human quality, creativity enables challenging complex problems that are characterized by (a) fuzzy representation, (b) multiple decision alternatives, and (c) volatility of their environmental conditions (Bogard et al., 2013). Professional bodies like the American Society for Engineering Management, the Project Management Institute, and the Quality Council of Indiana have also recognized critical thinking and creativity as essential attributes of their members, which makes them invaluable contributors to the value-creation processes of their employing organization's (ASEM, 2015; PMI, 2017; QCI, 2014, QCI 2018).

Nurturing critical thinking and the development of creative problem-solving capacity within individuals is largely considered to be part of educational systems' social responsibility (Bandyopadhyay & Szostek, 2019). University-level engineering and management programs consistently underscore the importance of critical thinking and creative problem-solving in their curricula. In his welcome remarks, the Dean of Applied

Sciences of the University of British Columbia stated that success factors include "qualities like, integrity, curiosity, creativity, open-mindedness and willingness to take informed risks in the name of innovation and progress" (Olson, n.d.). This statement aligns with the directives issued by the Accreditation Board of Engineering and Technology (ABET) as they relate to incorporating critical thinking in the instructional materials of engineering curricular (Aboukinane et al., 2013; Ahern et al., 2019). The emphasis on critical thinking in engineering is supported by the need to reconcile design contradictions or in optimizing tradeoffs among competing utility features that are built into a new product or service. Additionally, utility concerns value and choosing what value to incorporate into the design of a new product or service requires critical thinking. Whether they realize it, engineers engage in value-laden design choices that carry social effects, hence responsibility (Kroes, 2015; Nonis & Hudson, 2019).

The same degree of emphasis is placed on critical thinking by business and management schools. To illustrate, the 2018 Academic Calendar of University Canada West included clear references to critical thinking and problem-solving as invaluable attributes possessed by their MBA graduates (UCW, 2018). The vast field of management is commonplace for the application of critical thinking in areas that have direct implications on human experience and the social landscape in which they live and operate. Critical thinking and creative problem-solving skills are qualities that, as future professionals, management students should use to negotiate decision dilemmas in marketing, leadership, motivational, operational, and project-related decisions. There is evidence that the employers are becoming increasingly aware of the business value that

new hires could offer through the application of such cognitive qualities as critical thinking in solving complex problems of the real world (Bandyopadhyay & Szostek, 2019; Nonis & Hudson, 2019). However, reviewed literature revealed deficits in the practical measures that should be taken to stimulate the student population's critical thinking. This is the case in the engineering discipline where little clarity exists about the meaning of critical thinking and the ways such quality could be measured, assessed, benchmarked, and improved upon (Ahern et al., 2019; Bandyopadhyay & Szostek, 2019; Kroes, 2015). Further, there is a disconnect between academia and the effective use of critical thinking, which hampers the intellectual value chain of education-to-practice (Abbasi et al., 2018; Baird & Parayitam, 2019; Livingstone, 2019). The need to device, and incorporate, critical thinking and creative problem-solving in university curricula has been established by many authors in the field (Elder & Paul, n.d.). Employers are also becoming increasingly aware of such disconnect and the need to enhance critical thinking among employees and associates (Bandyopadhyay & Szostek, 2019; Ramazani & Jergeas, 2015).

The current research contributed to bringing clarity to the perception and meaning of critical thinking and explored the key enabling factors that need to be incorporated in management and engineering curricula so graduates are better prepared to solve real-world problems. As socio-technical systems, modern organizations in the postindustrial era are constantly faced with rapid and often unexpected changes in their eco systems. Such changes force them to rapidly adapt to the new conditions to restore their relevance and compatibility with the newly changed realities on the ground (Andrews et al., 2016;

Nelson & Squires, 2017; Vernon et al., 2016; Yordanove, n.d.). Finding, addressing, and solving today's complex problems require people who are capable of using their cognitive skills to engage and contribute their critical thinking abilities to generate feasible, optimal and ethically-sound solutions (Auger & Mirvis, 2018; Bandyopadhyay & Szostek, 2019; Howard et al., 2019). Such individuals are in short supply, largely because the developmental processes of our educational system lacks an operational definition of critical thinking and a good grasp of what is expected of graduates in real workplace settings (Ahern et al., 2019; Bandyopadhyay & Szostek, 2019; Fayomi et al., 2019; Griggs et al., 2018). Addressing such gaps contributes to better integration of the output quality of the educational system to the input expectations of modern organizations in postindustrial times. Preparing graduates to become more valuable creative actors would put employer organizations in more favorable positions to provides goods and services that are better valued by society and deliver on their social missions.

Problem Statement

The value that critical thinkers provide to support organizational growth, regional economic prosperity, and societal well-being is well established in literature (Adobe, 2016; Auger & Mirvis, 2018, Florida, 2004). But many employers believe that management and engineering graduates are underequipped to effectively deploy their critical thinking skills to solve real-world complex problems (Ahern et al., 2019; Atiba et al., 2019; Bandyopadhyay & Szostek, 2019; Ramazani & Jergeas, 2015). The problem was that management and engineering schools lack an operational definition of critical thinking, particularly in the way the concept is deemed productive and beneficial in

professional and practical work environments (Ahern et al., 2019; Kroes, 2015; Moore, 2013). This absence of an operational definition for critical thinking affects the ability of management and engineering schools to develop and incorporate effective instructional processes and assessment rubrics that would transform their students into critically thinking professionals who are adequately prepared to take on the complex challenges of our postindustrial society (Ahern et al., 2019; Auger & Mirvis, 2018; Bandyopadhyay & Szostek, 2019; Moore, 2013; Ramazani & Jergeas, 2015). The current study provided an opportunity to overcome the challenge of developing effective critical thinking professionals who possess the creative problem-solving skills needed to address the increasingly diverse, complex, and unpredictable societal problems.

Purpose of the Study

The purpose of this qualitative grounded theory study was to discover how, if at all, the engineering and management scholar-practitioner community in British Columbia perceived the concepts of critical thinking and creative problem-solving. An operational definition was derived from such discovery as well as a collective convergence on how critical thinking could be integrated in instructional processes to strengthen the students' preparedness in becoming effective problem solvers in professional environments. Review of pertinent literature indicated that critical thinking is defined as the possession, application, and mastering of cognitive traits that would enhance the reasoning quality of an individual to produce an intellectual output (Elder & Paul, 2010; Nonis & Hudson, 2019b; ŽivkoviĿ, 2016). Problem solving is the process adopted by an individual thinker for reducing a knowledge gap (Dörner & Funke, 2017; Mynott, 2018; Paul & Elder,

2016; Wechsler et al., 2018) that bears a demonstrable benefit to his social environment (Ahern et al., 2019; Dörner & Funke, 2017; Kroes, 2015).

Research Questions

The study was focused on finding answers to the following research questions:

RQ 1: What is the operational definition, if any, of critical thinking as perceived by scholars-practitioners and instructed at management and engineering schools in British Columbia?

RQ 2: What theory and process, if any, describe critical thinking elements that drive the development of effective problem-solving skills among engineering and management students in in British Columbia in preparing them for real-world challenges?

Conceptual Framework

I adopted a utilitarian stance toward critical thinking by viewing it as a human quality for creative solving of real-world problems (Dörner & Funke, 2017; Mynott, 2018; Paul & Elder, 2016; Wechsler et al., 2018), which facilitates positive social change (Ahern et al., 2019; Dörner & Funke, 2017; Kroes, 2015). Such stance means that the scope of the study is focused on attributes of critical thinking that prepare management and engineering students to become effective problem solvers in concrete work environments. Therefore, the two central concepts of the current study are critical thinking and creative problem solving. It is important to note that in grounded theory studies, a researcher is expected to be familiar with the key theoretical perspectives that influenced the shaping of the central concepts of the undertaken study while calibrating

their effect on the design, data acquisition, analysis and the inferred conclusions of the study. However, the intent is to discover and generate new theoretical perspectives rather than test to reinforce, or refute, preexisting ones (Glaser & Strauss, 2017; Patton, 2002).

For critical thinking, Paul and Elder's (2010) conceptual framework provides useful guidance on how the constant use of cognitive traits, as human assets, lead to the habitual development of critical thinking in various reasoning contexts while meeting universally recognized quality attributes of a thinker's intellectual production. Being a loosely applied phrase, in both academic and professional quarters, critical thinking means different things to different people and in different contexts. Such lack of specificity is part of the problem, which this research contributed to addressing. One useful source for considering a variety of perspectives is found in the comprehensive literature review carried out by Moore (2013), which provided a broad collection of critical thinking definitions that enriched the design of my data collection instruments as well as the participant interview process.

For creative problem solving, inspiration was sought from several sources. For example, Jonassen (2000) and Smalley (2018) separately proposed perspectives on problem typologies. In Jonassen's perspective, problems differ in terms of the degree of structuredness, complexity, and level of abstraction. Another differentiating dimension for problems is the form and depth of their representation or modeling. Finally, the problem solver's point of view, or mental models, is found to be another difference-making factor. Jonassen noted that the set of problem-solving skills required to produce effective solutions, efficiently, are a function of problem types, their mode of

representation, and the characteristics of the individual, who is tasked to produce a high-quality solution. Smalley proposed four types of problems with the simplest type labeled as *troubleshooting* and the most complex referred to as *open-ended*. In the quality management discipline, as another example, distinctions between system and worker problems are drawn. Problems have also been classified as chronic and rear-event occurrences (Marquardt, 1998). More about the problem end of the conceptual framework will be outlined in the Chapter 2.

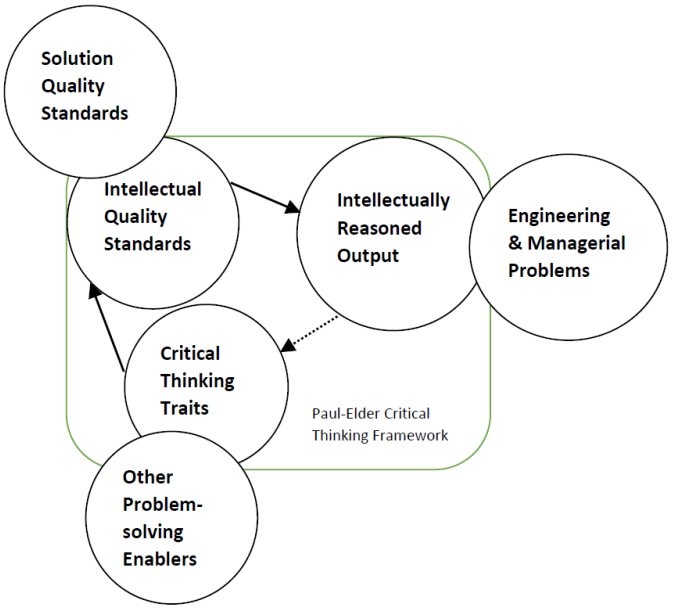
It is also important to consider the vast range of enabling factors, which supplement or overlap the Paul-Elder (2010) critical thinking framework. Such factors are aimed at aiding problem-solving actors in finding high quality solutions faster. These enabling factors include a wide array of personality traits (Andrews et al., 2016; Davila et al., 2004). The psychological mood of the problem-solver is also thought to affect their ability to produce quality outcomes (Chen & Plucker, 2016; Lau, 2016; Raubenolt, 2016). Another cluster of literature focused on the problem-solver's possession of metacognitive awareness, which is thought to be critical in planning, managing and controlling the entire problem-solving process (Bogard et al., 2013). Enabling factors are further elaborated on in Chapter 2.

Figure 1 offers an overall illustration of the conceptual framework that informed the development of the current study. At the core of the framework lies the Paul-Elder critical thinking model, which suggests that certain cognitive traits enable the use of critical thinking process so that well-reasoned outputs, that conform to quality standards, are generated. Consistent repetition of the critical thinking cycle instills, at the

subconscious level, the habitual and automatic use of critical thinking traits, and the production of quality outputs, by an individual. The Paul-Elder model is enriched by (a) augmenting problem-solving enables other than those proposed by the core model, (b) incorporating solution-specific quality metrics, and (c) streamlining the definition of intellectual outputs to underscore creative problem-solving.

Figure 1

Conceptual Framework of the Study



Nature of the Study

The purpose of the study was to discover the current perception, if any, of the concepts of critical thinking and creative problem-solving within the scholar-practitioner engineering and management community of British Columbia. In a way, the study aspired to inform a causal relationship between enhancing the critical thinking property

of the students and their problem-solving capacity in real professional settings. Establishing causality paves the way to the potential development of predictive models. Both causality and prediction are keywords used in describing the typical objectives pursued in theory construction (Reynolds, 1971). Therefore, this study was designed to adopt grounded theory as the method of inquiry. The scope included probing the meaning of critical thinking in the contexts of engineering and management as well as exploring the key enabling factors of that core concept as it relates to creative problem-solving. As an inductive method of inquiry, the grounded theory tradition should be conducted independent of theoretical presuppositions (Charmaz in Gibbs, 2015; Glasser & Strauss, 2017), though the interplay between preexisting theoretical views and grounded theory can take multiple forms (Charmaz in Gibbs, 2015; Glasser & Strauss, 2017; Goulding, 2002). This relationship is expanded on in Chapter 3.

The creation and advancement of grounded theory, as a research method is credited to the initial work of Glaser and Strauss (2017) in the domain of sociology (Goulding, 2002). Other influencers in the field include Charmaz (Gibbs, 2015) and Goulding (2002). The latter contributed to the development of grounded theory by way of mildly tailoring the originally proposed method to fit the research purposes in management fields. Conducting research using grounded theory is not a linear sequence of steps. Although there is a general direction through which the researcher starts with data collection and moves gradually toward generating theory, looping back-and forth is not unusual. Early chunks of collected data may provide feedback that could guide the researcher to reexamine and potentially repeat earlier stages to defocus further data

collection in achieving deeper appreciation of the phenomena under study. Such reexamination often leads to progressively and increasingly more refined versions data themes, categories, and any inherent theoretical causality. The generic technique of constant comparison is at the heart of the grounded theory method and its corresponding processes. Again, further elaboration is provided in Chapter 3.

Definitions

Frequently used words, phrases, and acronyms that may have special meanings are operationally defined within the scope of the current study.

Business or societal problem: An obstacle, which if removed would assist an organization to advance toward achieving its strategic goals and provide tangible benefits to the society. Overcoming such obstacle begins by filling a goal-oriented knowledge gap and obtaining clarity of how an improved state could be achieved (Vernon, 2016).

Complex problem: Problems that (a) involve several parts and relationships, (b) ill-defined, and (c) dynamically influenced by external forces and the influx of new information (Kluwe, 1995; Specter, 2010, as cited in Bogard, 2013).

Concrete setting: Actual business environments with various stakeholder involvements, competing priorities, and conflicting goals where a professional actor is expected to deliver value to organizations and to the public either directly or by extension. Also referred to as the real world.

Critical thinking: The deliberate process of mastering and utilizing cognitive traits by individuals for producing high-quality intellectual outputs (Paul & Elder, 2010) that

reduces a knowledge gap that is recognized as a promising requisite for positive social change.

Positive social change: The generation, planning and implementation of ideas that would elevate the living conditions of individuals, communities, organizations, and society at large (Walden, n.d.).

Postindustrial society: A society that has advanced past economic reliance on heavy industrial production. Among others, post-industrial societies are characterized by (a) a shift from production of standard goods to the provision of tailored services, (b) the recognition of knowledge as valued human capital, (c) the development of information and creativity-based economies (Bell, 1999).

Problem solving: The process adopted by an individual thinker for reducing a knowledge gap (solution) that contributes to that advancement of strategic business goals and bears a demonstrable benefit to the society.

Scholar-practitioner: A practicing educator who has adopted a career path by blending teaching with professional engagement on a part-time basis.

Assumptions

First, I assumed that whether for profit or otherwise, organizations operate with the primary purpose of providing value to a customer segment of the society in which they operate or serve. Some organizations reach of offerings may transcend their immediate societal boundaries, spatially and temporally. Examples include human rights non-governmental organizations, or environmental advocacy groups.

The second assumption made was that professionals are self-motivated, by personal pride and recognition, to create solutions to customer problems by using their cognitive traits that drive critical thinking. Such solutions would be valued by their customers and manifest themselves in products, services, or information. On a related note, it was also assumed that educational institutions are mandated and motivated to equip their students with the knowledge and capacities needed to perform successfully and excel in concrete settings. This assumption implies that a school's reputation is tied to the success of its alumni past their graduation. Public or private, a school's reputation is critical to its sustainable survival in competitive spaces as well as continued business viability.

Third, and last, I assumed that scholar-practitioners are poised ideally to provide insights into the study that comes from their dual experiences in academic environments and real-world settings. As primary participants, these individuals are thought to be familiar with the nature of real-world problems and the employers' expectations of graduates to find high quality solutions. Considering such knowledge, the participating scholar-practitioners would be qualified to offer suggestions on the preparatory measures at school that would support the development of the students into successful socioeconomic actors past graduation.

Scope and Delimitations

Spatially, the scope of the study was limited to the scholar-practitioner community in the Canadian province of British Columbia who operate and specialize in the fields of engineering and management. Flexibility and progressive emergence are

characteristics that are attributed to grounded theory as a method of scientific inquiry (Gibbs, 2015; Glasser & Strauss, 2017; Goulding, 2002). As such, depending on how the front-end process of theoretical sampling unfolds, there might be a need to seek the input of other groups of individuals, on some specific aspects of the research questions, which may require deeper elaboration. For example, informants who are exclusively practitioners or exclusively educators and not necessarily engaged in both occupational strands simultaneously. Such latitude was used in the study, although the reach was confined to the engineering and management disciplines as a delimiting dimension for the contextual scope of the study.

From the temporal perspective, the study's primary focus was on the current perception of the core concepts and their corresponding enabling drivers. In other words, deep historical investigations were excluded from the scope. Of course, the theory that emerges out of the grounded theory study is expected to have a predictive application into the future. Testing and verification of the potential predictive power of the emergent theory falls outside of the scope of the current study. This may be another research study for another time. Another delimiting factor concerns the extent of interest placed in the core concept of critical thinking. In this study, critical thinking was primarily studied in terms of enhancing the creative problem-solving capacity within the engineering and management student population in preparing them to negotiate the complexities of real-world challenges.

Limitations

One general challenge facing the qualitative research tradition is the absence of regimented prescriptive processes, as much is left to the judgement and reflexivity of the researcher. But this challenge allowed the research process to self-adjust and emerge in response to the data (Creswell, 2009; Patton, 2002). The same concern applies to grounded theory as the qualitative research method adopted in the current study. Being fully aware of scope creep as a risk, I used visual reminders to keep my attention focused on the problem statement and the delimited scope of the study.

The outcome of the study was expected to be transferable specially across economic regions, which shared the key characteristics of postindustrial societies such as greater emphasis on knowledge-driven economies and the expansion of service sectors at the cost of traditional manufacturing (Bell, 1999). Transferability into economic region with reliance on mass production and standardized processes would be limited, if appropriate, considering the qualitative differences in the nature of the problems to be solved, or the solution/improvement opportunities available to professional actors in those economies. Although the scope of the study was limited to the disciplines of management and engineering, I anticipated that the outcomes may be transferable to other disciplines within the postindustrial societal space.

Significance of the Study

The effect of critical thinking on an individual's ability generate solutions to problems is well established in psychology, management, and engineering literature (Auger & Mirvis, 2018; Bandyopadhyay & Szostek, 2019; Bogard et al., 2013; Howard

et al., 2019; Paul-Elder, 2016). Nevertheless, the concept of critical thinking lacks the operational clarity required to inform the development of educational processes that would prepare engineering and management students into effective problem-solving actors in concrete settings. Lack of such clarity has led to underprepared graduates joining the workforce, which has raised concerns from employers (Ahern et al., 2019; Auger & Mirvis, 2018; Bandyopadhyay & Szostek, 2019; Moore, 2013; Ramazani & Jergeas, 2015). This study addressed such disconnect by primarily looking at how critical thinking could be integrated into educational processes more effectively so that graduating students would be equipped with the much-needed problem-solving capacities.

Significance to Practice

The practice of engineering and management disciplines in postindustrial economies places special demands on the performance of new graduates. The human capital, in postindustrial societies, is assessed and valued for its ability to create new ideas for solving complex problems or overcoming challenging obstacles to improvement (Lönngren, 2019; Podolskiy & Pogozhina, 2016; Ester van Laar, van Deursen, van Dijk, & de Haan, 2018; Wagy & Bongard, 2015). Regardless of the type or the market space organizations operate in, they are invariably expected to add value to the society at large. As socio-technical systems, organizations rely on the capability of their employees to deliver on their value-adding mandate (Liker & Meier, 2006). This study facilitated better integration of educational systems with concrete work environments so that the knowledge and talents of graduates could add effective value to business processes, thus benefiting both the employer and employees and society by extension.

Significance to Theory

Grounded in the insight and hard experiences of the participating scholar-practitioners, the study explored a contextualized working definition of critical thinking as the primary driving force behind problem solving. Another key contribution of the study was the discovery of acquirable factors, which could be learned through educational processes to develop the students into effective problem-solvers. Scientific discovery is expected to contribute to human knowledge in a few ways, which include (a) showing a way to categorize or things, concept or ideas; (b) generating tools, guidelines and procedures for predicting future events; (c) sledding light on why and how past events occurred; (d) establishing cause-effect relationships; and (e) making events controllable (Reynolds, 1971). I expected the contribution of the current grounded theory study to provide explanation of the perceived meaning of critical thinking as well as to discover enabling factors, which can be incorporated into educational processes to enhance the problem-solving capacity of graduating students.

Significance to Social Change

At the individual level the findings of this study revealed ways to enhance the effectiveness of engineering and management graduates in making positive change by solving one problem at a time and by removing obstacles to improvement. The benefits of such increased empowerment would add value to their employing organizations. The societal benefit will be gained either directly through community service engagements of the graduates or indirectly through the value adding processes of their employing organizations. Organizations populated with critical thinkers are better positioned to

address societal challenges by finding the next problem, or opportunity for improvement, identifying effective and feasible solutions, or strategies to overcome obstacles, and executing such strategies to deliver positive social change.

Summary and Transition

The purpose of this qualitative study was to discover the working definition of critical thinking as perceived by the scholar-practitioner community in the Canadian province of British Columbia. The study probed into the experiences of the participants on factors of the educational processes that would enhance critical thinking among graduating students in the engineering and management disciplines, thus enhancing their effective capacity in solving real-world problems and overcoming obstacles to advancement. Grounded theory was adopted because my primary source of data was the working experiences of scholar-practitioners. The outcome of the study is expected to contribute to the betterment of the practices of management and engineering, create new knowledge by explaining the contextualized meaning of critical thinking and its enabling factors, and enable positive social change. Chapter 2 covers a more elaborate review of literature to further explain the conceptual framework, followed by a comprehensive review of literature on the topic of the study, the problem and the concepts investigated.

Chapter 2: Literature Review

This study concerns the discovery of how critical thinking is understood and defined by the scholar-practitioner community of British Columbia in the fields of management and engineering. Lack of adequate preparedness of engineering and management students for solving problems is an established concern that has been voiced out by several employing communities as it is evident in literature. As such, this study contributed to narrowing the operational gap by offering greater clarity on the how engineering and management schools could develop the critical thinking skills of their students to better meet the creative problem-solving needs of concrete profession environments in which their graduates are expected to function effectively and efficiently. This chapter contains an explanation of the search strategy that was adopted to locate and identify pertinent literature for the study. Next, a summary of the core conceptual construct that guided the logical development of the current project is presented including its key elements, which in turn were reviewed with further depth in a comprehensive essay and conclusion.

Literature Search Strategy

I accumulated the literature for the current dissertation primarily from the following sources:

- Retrieved references from previously reviewed literature.
- Books and articles, which I used in previous PhD modules.
- Recommended sources by Walden faculty.
- Filtered search through the mobile application Researcher.

- Academic databases accessed through Walden University's library.

For the last two sources, I used *critical thinking* and *problem solving* as primary key phrases with the AND logical operator. The Researcher application's search filter does not offer much in terms of delimiting factors such as date of publication and language. Therefore, I sifted through the hits manually and selected those articles which matched the date currency and language criteria. From Walden library, I conducted similar searches into two databases namely, Complete Academic Research and Science Direct. The date, language, and other delimiters offered by these databases were much more helpful than those of the Researcher applications in returning a short list of more appropriate suggestions of literature.

After the short lists were generated, I examined the articles starting with the titles, then the abstracts, and by skimming through the contents of some of the shortlisted articles, if necessary. About 50% of the Complete Academic Research hits and about one third of the Science Direct hits advanced to the abstract reviewing stage of my search. Between the two databases, Science Direct resulted in a higher yield rate in terms of relevancy and richness of articles. My interest in an article excluded those that (a) are discipline-specific outside of the engineering, management, and business domains; (b) discussed critical thinking and creative problem-solving with no demonstrated connection to real-world practice; and (c) concerned studies conducted outside of postindustrial economic regions. I considered articles that were not region-neutral where the source contained transferable information of value to the purpose of the current study. The

Researcher mobile application pointed to nine potentially useful articles, which I retrieved from Walden University's library separately.

It could not be excluded that in the process of reviewing the selected literature there would be a possibility that new and relevant information emerge, thus calling for pointed searches to fill any newfound knowledge gap. Such need for searching for new literature was expected as a natural outcome of the theoretical sampling stage in grounded theory studies, which I elaborate on in Chapter 3. I was aware of the risk of scope creep and had limited such potential expansion of reviewed literature to what added value to the purpose of the study and with respect to its delimited scope and research questions.

Conceptual Framework

The Paul-Elder critical thinking model was the conceptual framework adopted for this study. The Paul-Elder model comprises three key elements, which are logically interconnected to explain the interplay among the traits that are activated in the mind of an individual critical thinker for the creation of critically thought-out outputs that possess certain quality standards. The core concept of Paul-Elder's model was augmented with extended concepts to serve the purpose of the current study, as specified in Chapter 1. The extended augmentations to the Paul-Elder model are summarized in Table 1.

Table 1

Paul-Elder's Key Elements and Corresponding Augmentation

Paul-Elder key elements	Extended augmentations
Intellectually reasoned output	Solutions to problems that are typically found in the engineering and management work environments.

Solution quality standards	Rubrics used in prior studies to assess the value and utility of produced solutions to problems.
Critical thinking traits	A broader range of enabling factors identified in prior studies that promote critical thinking within problem solvers and contribute to their production on higher value solutions.

Next, an overview of the three extended augmentations, to the core critical thinking model will be provided. Later, the discussion is expanded on by reviewing literature on the key concepts of the theoretical framework adopted for this study to include problem characteristics, various definitions of critical thinking and problem solving, as well as quality attributes of good solutions to engineering and managerial problems, and lastly the contributing factors to the generation of feasible, optimal, and ethically-sound solutions to complex problems.

Engineering and Managerial Problems

There are engineering-specific problems and management-specific problems. These two strands of profession also overlap in some areas such as the disciplines of quality management, operations management, and project management. The conceptual framework of this study was influenced by problem typologies and definitions relevant to engineering, management as well as any overlapping fields of practice, such as project management.

Engineering Problems

In the theory of inventive problem solving (TRIZ), Altshuller (2004) described technical problems as the presence of some form of contradiction between two competing features of the design subject, where improving one feature could come at the cost of compromising the other. TRIZ offers a typology of design (or improvement)

contradictions as well as resolution strategies that are deemed to be more promising in guiding the designer through a problem-solving process.

The concept of *wicked problem*s offers another perspective on engineering problems. In their seminal article, Rittel and Webber (1973) defined wicked problems by 10 characteristics, which among others include open ended, ill-defined, unique and complex. Wicked problems were initially used as a term to define planning level problems in the engineering and architectural disciplines. Later, the idea spread out to describe problems in policy planning in social sciences domains. If TRIZ illustrates micro-level design problems, the concept of wicked problems could be found useful in tackling macro-level planning problems of greater complexity and fluidity of their corresponding decision environments.

General Managerial Problems

The field of management is broad and diverse, and so is the range of managerial problems. The diversity of the field of management could be described vertically and horizontally. Horizontal diversity concerns the functions of management such as finance, operations, human resources, marketing, and product development. The vertical diversity ranges from the high and abstract strategic level to the operational process level of any given organization. Few scholars have attempted to compile and categorize the overwhelmingly diverse landscape of managerial problems. Szarucki (2015) was one of the few who took the challenge of grouping managerial problems into 16 categories, which among others included efficiency, administrative, behavioral, operational control and optimization, system, cybernetic and process problems. Szarucki's classification

covers a comprehensive range of managerial problems but also problems in areas overlapping engineering fields. For example, efficiency-related problems apply to engineering as they relate to reducing production waste and eventually raising process productivity. The same could be stated about operational control and optimization. In real-world settings, the distinguishing lines between disciplines seem to blur and multi-disciplinary collaborative efforts are often mobilized to solve the problem at hand. Such overlap between engineering and managerial problems manifests itself in a few strands of professional knowledge areas. For further exploration, two obvious areas of concern to both managers and engineers have been considered: quality and project management.

Quality and Operational Problems

As early thinkers and contributors, quality gurus occupy a predominant space in the global quality movement and its tradition. Philip Crosby is recognized as one of the most influential gurus known for his short and impactful quotes in the professional field of quality. His rudimentary definition of quality was conformance to requirement ("Philip Crosby: The guru of quality management," n.d.). Crosby's definition is abstract enough to be applicable to a wide range of contexts, including those in management and engineering. After all, the keyword *requirement* is as applicable to engineering as it is to management, and lack of conformance amounts to a problem.

Moving the discussion away from the abstractness of definition to more applied levels, quality observers offered several classifications of quality and operational problems. For example, quality problems could be described at the system or macro level,

or at the process or micro level (Marquardt, 1998). Another perspective concerns the degree of problem recurrence: chronic or occasional (Marquardt, 1998).

From the social responsibility point of view, consumerism has led to the emergence of clusters customer-centric problems (Juran, 1998). Solving such problems are perceived as an essential element of enhancing customer satisfaction and expanding market share in competitive spaces. Although paying attention to customer problems makes business sense, organizations are mandated to be compliant with mandatory government legislation as they enact and become enforceable. Primary among others are safety standards as they relate not only to production process but also to fitness for use of the end-products and services by their ultimate consumers. Another cluster of legislation concern environmental and public health problems, which often manifest themselves as gaps between some current state and a future target state (Juran, 1998). Closing such gaps often amount to the definition of complex problems for managers and engineers to solve.

Project Management Problems

The Project Management Institute (2017) defined a project as "a temporary endeavor undertaken to create a unique product, service or result" (p. 13). Much like quality, the definition of project is generic in nature, which allows for the inclusion of a wide range of projects in various domains, including in management and engineering. Problems in project management are also frequent and diverse. The Project Management Institute recognized four phases in the lifespan of a project: initiation, planning, executing, and closing (PMI, 2017). Initiation problems include defining a viable project that could close a strategic gap for the organization. Planning problems often involve

negotiating tradeoffs between competing project priorities such as time, quality, or cost. Execution problems concern deviations from the project plan that amount to undesirable effects. Left unresolved, such problems could compromise the success of a project by causing budget overruns, schedule delays, or failure to meet the quality targets as outlined in the produce, service, or result's specifications. Closing problems occur when there is daylight between the project's outcome and the customers' perception. Perceived nonconformances could cause problematic disputes, which should be resolved to prevent financial or reputational damages to the performing organization.

Solution Quality Attributes

Once a solution to a given problem has been produced by a critical thinker, the quality of that solution would be subject to scrutiny based on some assessment criteria. Paul and Elder (2016) referred to such criteria as universal intellectual standards. They posited that good quality intellectual production should possess attributes as clarity, accuracy, precision, relevance, depth, breadth, logic, significance and fairness (Paul & Elder, 2016). Scholarly literature on creative problem solving frequently pointed to a narrower range of assessment criteria, some of which are associated with rubrics to allow for consistency in assessing the utility of comparable solutions, such as usefulness (Bogard et al., 2013; Hargrove & Nietfeld, 2015; Lau, 2016; Medeiros et al., 2014; Olsen et al., 2017; Peterson et al., 2013; Zuber & Moody, 2018), originality or novelty (Chen et al., 2016; Davila et al., 2004; Figl & Recker, 2016; Ghosh, 2015; Hargrove & Nietfeld, 2015; Lau, 2016; Medeiros et al., 2014; Peterson et al., 2013), fluency or divergence (Bogard et al., 2013; Chen et al., 2016; Davila et al., 2004; Figl & Recker, 2016; Ghosh,

2015), elegance and delimitation (Medeiros et al., 2014; Olsen et al., 2017; Peterson et al., 2013; Zuber & Moody, 2018), and impact (Figl & Recker, 2016; Olsen et al., 2017; Zuber & Moody, 2018).

Enabling Factors

In their critical thinking model, Paul and Elder (2016) identified a set of intellectual traits that describe the characteristics of a critical thinker: humility, courage, empathy, autonomy, integrity, perseverance, evidence-oriented, and fair. Possessing such traits enables critical thinkers to be effective in intellectual outputs. In their stage theory of critical thinking development, Paul and Elder associated a set of prerequisite traits with each stage of development. This discussion is worth expanding on by considering alternative views and contemporary definitions of the core concept of critical thinking as explored by Moore (2013).

Prior literature points to other factors than personal traits that are thought to contribute to the creative problem-solving performances of individuals such as talkativeness, agreeableness, and openness may be named (Andrews et al., 2016; Davila et al., 2004). The effect of mood on problem-solving performance was also examined by some scholars in recognition of the emotional conditions, which problem solvers experience while engaged in intellectual production activities (Chen et al., 2016; Lau, 2016). Other researchers identified several external enablers that are thought to help critical thinkers in their problem-solving challenges. These external enablers include how the problem is framed and presented (Figl & Recker, 2016), as well as insight into a problem-solver's mind by virtue of the association theory and the theory of spreading

activation (Bogard et al., 2013; Chen et al., 2016; Davila et al., 2004; Figl & Recker, 2016). Lastly, the ability of a critical thinker, who routinely engage in creative problem-solving may be enhanced through the orderly execution of a process, or an integrated series of steps (Aboukinane et al., 2013; Andrews et al., 2016; Bogard et al., 2013; Hargrove & Nietfeld, 2015; Lau, 2016; Nelson & Squires, 2017; Thompson, 2018; Vernon, Hocking, & Tyler, 2016; Zuber & Moody, 2018).

Literature Review

In the remaining part of this chapter, current literature as it relates to the extended elements of the Paul-Elder model is further discussed. Prior scholarly findings, with respect to the types of problems, which engineering, and management students should anticipate challenging in their professional career lives, is drawn upon. Criteria that are likely used by business managers and customers to assess the desirability of the solutions will also be reviewed. Finally, a discussion of divergent perspectives on internal and external enabling factors, which are deemed to facilitate and enhance critical thinking performance, follows. Realizing the tradition pursued in grounded theory studies, I exercised care to prevent anchoring effects while probing experts' opinions in the process of collecting field data. I used the findings from literature review to (a) articulate my survey and interview questions with clarity and in line with the current trends in the topic under discovery through this project, (b) better understand the contribution of research participants, and (c) be able to thematize data into logical categories that are consistent with the research questions as well as the ongoing scholarly discourse on the central concepts of critical thinking and complex problem solving.

Problem Characteristics

The range of problems encountered by managers and engineers is broad and diverse. One would be hard-pressed to make an all-embracing statement about what constitutes a problem. At a high level of abstraction, one common thread to describe almost every problem faced by engineers and managers is the challenges to closing a gap (Baird & Parayitam, 2019; Dörner & Funke, 2017; Rittel & Webber, 1973; Mejía, Mariño, & Molina, 2019; Rhodes, Danaher, & Ater Kranov, 2018; Szarucki, 2015). That gap may take different forms and shaped, such as the difference between the current state and a desired future state, or mending issues of noncompliance with a requirement or a mandatory standard. A problem could involve a tension that needs a resolution, a barrier to overcome, or a contradiction to find a trade-off solution for (Altshuller, 2004). Finding and defining a problem is considered an integral part of the entire problem-solving process (van Laar et al. , 2017). Failing to identify and frame the right problem leads to ineffective outcomes and waste of resources.

Problem Contexts

The managerial and engineering contexts in which those gaps, which amount to problems, are present are also wide ranging and disparate. Projects are vehicles for creating results which fill gaps between organizational current states and their visions (PMI, 2017). They are also commonplace for the emergence of problems of conformance kind due to discrepancies between planned targets and actual results (Rittel & Webber, 1973; Ramazani & Jergeas, 2015). The frequency of such occurrences is due to the uniqueness and temporary nature of projects, which makes them more vulnerable to

deviations from plans. Projects are frequently used in problem-prone fields such as information systems and information technology (Aldave et al., 2019; Kitchin, 2017; Termeer, Dewulf, & Biesbroek, 2019), infrastructure and sustainability (Chester & Allenby, 2019; Lönngren, 2019; Metz, 2014), setting up a new business (Carriger, 2015), manufacturing and multi-disciplinary settings in general (A. Rhodes et al., 2018; Termeer et al., 2019).

Problems are also found in abundance where knowledge gaps are present, such as in research projects (E. van Laar, van Deursen, van Dijk, & de Haan, 2019; van Laar et al., 2017), overcoming berries to attaining strategic goals (Wright et al., 2019), socio-technical systems where conflicts emerge continually as the result of competing priorities (Aldave et al., 2019), design (Altshuller, 2004; Lönngren, 2019; Metz, 2014), and more critical matters such as in healthcare, security (Metz, 2014), as well as global crises including global warming, mass migration, water shortage, and the list goes on (Metz, 2014; Peters & Tarpey, 2019; Termeer et al., 2019).

Problem Types

Several scholars developed and proposed typologies for the different types of problems, faced by engineers, managers, and business leaders, with the intent to suggest solution-finding approaches to match each type. More frequently, literature pointed to a spectrum of problem types that ranges from tame problems to complex or wicked problems. Rittel and Webber (1973) were widely credited to be the first to introduce the concept of wicked problems. In their description, they contrasted wicked problems with tame problems in that the latter type of problems may be readily solved using known

models from operations research or similar quantitative domains. What's more, evaluating the solutions obtained for tamed problems are relatively straightforward compared to the wicked end of the spectrum (Rittel & Webber, 1973). Traditionally, it is believed that the wicked and tame distinction of problem types are attributed to the social and natural sciences strands, respectively. This way of thinking has been adjusted over time as problems in the natural sciences are being augmented by their social dimensions, moving them closer to the wicked end of the spectrum (Lönngren, 2019). As such the division between tame and wicked problems is becoming less pronounced considering that many wicked problems include elements of tameness and vice versa (Peters & Tarpey, 2019). This implies that one strategy for addressing wicked problem could involve isolating the tamed part(s) from the problem scenario, thus making the wicked portion better manageable (Lönngren, 2019; Termeer et al., 2019). Tamed problems are those that place lighter demand on the critical thinking skills of their problem-solver. This contrasts the more challenging end of the spectrum which consists of complex and wicked problems. Tame problems are well defined with a relatively clear path of solving. They typically have one or few best solutions, which the problem-solver can find, given reasonable time and resources (Peters & Tarpey, 2019).

Other problem classifications include problems that occur in hard versus soft systems. Hard system problems are well organized, isolated from environmental turbulences and may be studied and solved in controlled settings, such as a laboratory. On the other hand, soft systems are conditions that are characterized by an ever changing environment, confusion and excessive complexities (Wright et al., 2019). Another

typology considers the clarity and precision of the paradigm used in the field of study from which the problem is drawn. High paradigmatic and low paradigmatic fields parallel hard and soft systems, respectively (Lönngren, 2019). Problems defined in soft systems using low paradigmatic languages are considered more complex than the alternative.

Finally, Szarucki (2015), offered another classification of problems: puzzles, problems, and messes. Table 2 contains a summary contrasting the main characteristic of the three classes.

Table 2

Szarucki's Problem Classification

Attribute	Puzzle	Problem	Mess
Problem definition	Structured	Structurable	Ill-structured or unstructurable
Solution method	Known	To be found	Illusive or non-existent
Level of analysis	Process	Operational or functional	Strategic

Problem Complexity and Wickedness

With one exception, all reviewed literature used wickedness and complexity, either interchangeably, or as one as a partial descriptor of the other. Peters and Tarpey (2019) parted ways with the others in positing that the two concepts differ in terms of linearity. They considered complex problem as non-linear, while wicked problems as linear. Linear is described as the causal traceability of the solutions' implications more so than the way problems are defined or their structurability. The authors further introduced another category of problems: super-wicked. Super-wicked problems are characterized by (a) extreme time pressure, (b) lack of decisive managerial authority, (c) problem-solvers

are the same as those who caused it, (d) little extrapolation is possible as future conditions are expected to be substantially different from past or current conditions (Peters & Tarpey, 2019).

In conformance with the consensus inferred from the reviewed literature, this study drew no distinction between wicked and complex problems here and shall refer to them as complex for simplicity and writing consistency. Grounded in the reviewed literature, Table 3 offers a summary of the key characteristics that are attributed to complex problems, using Rittel and Webber's widely cited ten characteristics of wicked problems as a baseline. Table 4 contains other complexity characteristics referenced by other cited scholars.

Table 3

Characteristics of Wicked Problems Based on Rittel and Webber's Definition

Article	Rittel & Webber's (1973) Characteristics										
	Ill-defined and ill-structured	**Ongoing with no stopping rules**	**Outcomes assessed or judged qualitatively**	**Testing of a solution result is unavailable**	**Non-repetitive problem conditions**	**Unlimited solution alternatives**	**Uniqueness of the problem/context**	**Interconnectedness of a network of problems**	**Multiplicity of value perspectives**	**Low tolerance for errors and omissions**
Ahern et al., 2019			X				X		X	
Aldave et al., 2019	X					X	X			
Baird & Parayitam, 2019		X								
Bowman, 2019	X	X				X		X		
Carriger, 2016	X		X				X		X	
Carvalho, 2016	X			X			X			
Chester & Allenby, 2019		X	X			X		X	X	
Dodd, 2019	X								X	
Dörner & Funke, 2017	X	X			X	X			X	
E. van Laar et al., 2019		X			X		X		X	
Kroes, 2015									X	
Lönngren, 2019	X		X	X					X	
Mejía et al., 2019			X	X					X	
Peters & Tarpey, 2019	X	X	X	X				X		X
Rhodes et al., 2018			X			X			X	
Wright et al., 2019	X	X	X						X	

Table 4

Problem Complexity Characteristics Extracted from Reviewed Literature

Article	Has vague or non-controllable variables	Has social dimensions and implications	Involves several stakeholders	Requires cross-disciplinary approaches	No ready-made methods available	Involve conflicting and competing goals
Ahern et al., 2019	X	X		X		X
Aldave et al., 2019	X	X	X		X	
Baird & Parayitam, 2019		X	X			
Bowman, 2019	X					
Carriger, 2016		X		X		
Carvalho, 2016			X		X	
Chester & Allenby, 2019		X	X			X
Dodd, 2019		X	X			X
Dörner & Funke, 2017	X	X		X	X	X
E. van Laar et al., 2019		X				
Kitchin, 2017	X	X		X		
Kroes, 2015		X				
Lincoln & Kearney, 2019					X	
Lönngren, 2019	X		X	X		X
Mejía et al., 2019		X	X			X
Peters & Tarpey, 2019	X	X	X			X
Ramazani & Jergeas, 2015		X		X		
Rhodes et al., 2018		X	X	X		X
Rittel & Webber, 1973		X	X		X	X
(Wright et al., 2019)	X	X	X		X	X

There is disagreement among observers on whether it makes sense to isolate the tamed part of a complex problem to lessen the challenges involved in dealing with

complexity. Termeer et al. (2019) surveyed literature and identified scholars who thought of wicked problems as a distinct category that differ from traditional problems in several ways, including the path to a definitive solution (Termeer et al., 2019). This group of observers, spearheaded by Rittel and Webber (1973), believed that wicked problems were so enormously complex that one could only hope to manage them rather than arrive at an ultimate solution Observers such as Lönngren (2017) expressed opposition to attempts aiming to *tame* wicked problems, arguing that such oversimplification distorts the nature of a problem, which leads to disconnects between the problem and the solution. In the process of the current grounded theory study, the opinions of participants will be probed to find out where engineering and management problems stood in the tame-to-wicked spectrum.

Reviewed literature pointed to a consensus among the scholars, who studied wicked and complex problems, in that such problems are difficult to manage or solve, in part due to the presence of a social dimension (Ahern et al., 2019; Auger & Mirvis, 2018; Carvalho, 2016; Kroes, 2015; Ramazani & Jergeas, 2015; Termeer et al., 2019; Wright et al., 2019). The social connection section is dedicated to further exploring such social connections, which contributed to the complexities of a problem as well as the process leading to its solution or management.

The Social Connection

Thinking past riddles and tame problems, one enters the challenging domain of dealing with complex or wicked problems (Lönngren, 2019; Peters & Tarpey, 2019; Rittel & Webber, 1973; Termeer et al., 2019), which are of interest to the study. Social

problems are highly complex in nature and very challenging to solve (Dörner & Funke, 2017; Termeer et al., 2019). Being large and complex systems, societies are commonplace for broad ranging types of problems (Mejía et al., 2019). Open social systems are characterized by complexities that breed ill-defined and challenging problems, which involve large numbers of stakeholders and interest groups. For example, Western societies are made up of diverse groups of citizens with heterogeneous, and often divergent, goals. Inevitably, such differences of goals translate into conflicting priorities, which develop into complex problems that needs to be solved (Rittel & Webber, 1973). Resolving social conflicts amounts to solving high-complexity problems (Mejía et al., 2019). To emphasize the difficulty in dealing with social problems, many of them are labeled as wicked (Termeer et al., 2019). Due to their uniqueness, there is hardly any ready-made method available to solve any given social problems. As such devising a solution approach is considered an essential part of the problem-solving process (Aldave et al., 2019).

Once implemented, solutions to social problems will affect groups of stakeholders (Ahern et al., 2019). In fact, stakeholders' involvement and concerns transcend multiple phases of implementation. Solutions often begin with projects for setting up processes, followed by a longer-term operation, which is responsible for delivering the results. Stakeholders are potentially affected by the project, on a short term basis, and by the results with a longer lasting effect (Aldave et al., 2019; Dodd, 2019; Lönngren, 2019; Wright et al., 2019). Therefore, any approach adopted to manage wicked problems, or

attempts to solving complex social problems, must consider the short-and-long-term implications on stakeholder groups (Wright et al., 2019).

Societal problems require committed and capable individuals to tackle. Such individuals need to be trained and motivated to challenge the continuous emergence of societal problems. Training is largely the responsibility of education systems, which must aim at developing individuals who are capable of providing utility to their societies (Mejía et al., 2019). To be effective social actors, students must be trained to appreciate social responsibility as much as they need to be equipped with the required technical knowledge. Motivation, on the other hand is achieved through the transactional interaction that forms between individuals and societies (Baird & Parayitam, 2019).

The social connection between engineering and societies is less obvious than the case for management. Public image of the engineering community at large precludes close engagement with societal concerns (Lönngren, 2019). Such view juxtaposes the reality that, invariably, engineers engage in solving problems that has lasting social implications. Such implications manifest themselves in making crucial decisions about the priority of the societal problems to work on as well as allocation of resources to those priorities (Ahern et al., 2019; Kroes, 2015; Lönngren, 2019). It can be argued that possession of social skills and awareness of social responsibility are critical prerequisites to solving engineering problems with wide reaching social implications (Ahern et al., 2019). Understanding the social context of engineering problems is much more of a challenge than deciding on the technical approach to a solution (Aldave et al., 2019).

Managers are aware of the social implications of the decision they make within the purview of their organizational authority. Thanks in part to the propagation of the socio-technical systems' (STS) perspective of organizations (Liker & Meier, 2006). Due to the social dimension, STS problems are inherently complex (Aldave et al., 2019). The social impact of solving managerial problems transcends the borders of the organization in which the solutions result in managerial decisions. Almost with every managerial decision, there are stakeholders external to the organization, which will be affected in some ways (Lincoln & Kearney, 2019). By inference, like engineers, managers should be trained to exercise social skills and social responsibility in solving organizational problems in view of the dual implications of their decisions internally and within the society at large.

Discussion

The reviewed literature lacks consistency on whether problem-finding is part of the problem-solving process. Some scholars argued that a viable problem-solving endeavor should entail a careful search for a problem that is worth the efforts put into solving it (Podolskiy & Pogozhina, 2016; Ester van Laar et al., 2017, 2018). Other scholars implied that problems finding does not require much efforts if one thinks of closing a gap between a current state and a desired future state as a problem (Mejía et al., 2019; Szarucki, 2015). It is conceivable that the skills and information required to find a problem may differ from those used in solving the problem. Such gap in the literature calls for clarification, bearing in mind the potential confusion between defining a symptom and a problem or the issue to be resolved.

Knowing and identifying the sources of problem complexity have an implication on the selection of an approach to finding a solution or solution alternatives. Literature lacks agreement on what constitutes complexity. Some observers referred to problem complexity in terms of the multitude of parts and actors, and the relationships involved in the problem setting (Ahern et al., 2019; Auger & Mirvis, 2018; Bandyopadhyay & Szostek, 2019; Kroes, 2015). Another group found complexity in uncertainty, volatility, and the ambiguities of the problem environment. Yet, another cluster or scholars used the term complexity to indicate sharp conflicting perspectives and goal among the key stakeholders in a problem scenario (Chester & Allenby, 2019; Dodd, 2019; Dörner & Funke, 2017; Lönngren, 2019; A. Rhodes et al., 2018). What is worth noting is that a considerable number of the reviewed literature included the word complex or complexity -some frequently- but with not much elaboration, mostly to imply difficulty of the problem (Aldave et al., 2019; Bowman, 2019; Carriger, 2015; Dörner & Funke, 2017; Frank et al., 2018; Ramazani & Jergeas, 2015; Ester van Laar et al., 2018; Wilkin, 2017; ŽivkoviĿ, 2016). Although it is imaginable that a problem may be subject to multiple kinds of complexity, it is imperative to add specificity to the discourse to prevent uncalled for ambiguities in the upcoming round of interviews with subject matter experts.

Problem-Solving

The Relationship with Critical Thinking

The relationship between problem-solving and critical thinking is explored in this section. Almost all reviewed literature either set the two concepts in the same category or presumed that critical thinking powers the problem-solving capacity of individuals. The

latter relation seems to be more consistent with the Paul-Elder position (Elder & Paul, 2010; Paul & Elder, 2016) which has been adopted as a centerpiece of the theoretical framework of the current research. An overview of the literature where problem-solving and critical thinking were combined in a single category will be presented first, followed by those which posited that critical thinking enhances and drives problem-solving skills within individuals.

Both critical thinking and problem solving are considered essential employability skills that are widely sought by employers' community at large (Abbasi et al., 2018; Awange et al., 2017; Lincoln & Kearney, 2019). Awange et al. (2017) considered both skills as drivers and enablers that empower young graduates entering the professional world to support transformation into a better world. This is why some observers included critical thinking and problem-solving in the one single category labeled professional skills (Ahern et al., 2019; Fayomi, Fayomi, Atiba, & Ayuba, 2019; Feijoo, Crujeiras, & Moreira, 2018; Jang, 2018; Luo & Wu, 2015; Metz, 2014; Simpson, Williams, & Hripko, 2017). For example, particularly in engineering, design tasks are thought to be influenced by the performing professional's possession of both critical thinking and problem-solving skills (Feijoo et al., 2018; Metz, 2014).

Another cluster of scholars used more generic and abstract labeling to characterize problem-solving and critical thinking. Such higher-level characterizations suggest that the two skills may be applied to a wide range of contexts, which are independent of the educational background or discipline of the actor, or of the nature of the problem to be addressed. Lönngren (2019) posited that both critical thinking and-

problem-solving are capacities that are greatly enhanced by metacognitive training. Among other labels, soft skills (Osman, Abu, Mohammad, & Mokhtar, 2015; Podolskiy & Pogozhina, 2016; Ruder, Stanford, & Gandhi, 2018), transferable skills (Carvalho, 2016; Díaz Martínez, 2019; A. Rhodes et al., 2018), and essential skills (Cohen, Renken, & Calandra, 2017; E. van Laar et al., 2019) have been used to characterize and categorize critical thinking and problem-solving. With emphasis on learning ability, yet another perspective emphasized the connection between critical thinking and problem-solving with filtering the overwhelming amount of digital information, which professionals are typically exposed to, for the purpose of determining credibility and telling facts from rhetoric and opinions (Kavanagh & Rich, 2018; Ester van Laar et al., 2017, 2018).

In another vein, a considerable number of scholars subscribed to the thought that causality existed between the two key concepts of problem-solving and critical thinking. In other words, it is believed that critical thinking is an individual's skill that is largely responsible for enhancing their capacity to solve complex problems effectively and efficiently. Such conviction is consistent with the Paul-Elder model (Elder & Paul, 2010; Paul & Elder, 2016) referenced earlier as central to the conceptual framework adopted for the current study. The purported effect of critical thinking on problem-solving tends to manifest itself in various ways. Table 5 offers a summary of the perspectives presented by various scholars with respect to the nature of the causal relationship between the two concepts, with critical thinking as the enabling factor of problem-solving skills.

Table 5

Types of Causal Effects of Critical Thinking on Problem Solving

Reference	Description of the relationship
Ahern et al., 2019	Used in effective framing of assumptions, hypothesizing, designing appropriate experiments, and enhancing interpersonal skills and emotional intelligence.
Kitchin, 2017	Solving design problems of increasingly intelligent algorithms that include the complexities of socio-political elements and implications.
Bandyopadhyay & Szostek 2019	Basis for decision making. Informs solving unemployment problems of college graduates.
Mejía et al., 2019	Critical thinking is shaped by the problem-solver's world view, which in turn influences their unique approach to finding solutions.
ŽivkoviĿ, 2016	Critical thinking is an umbrella concept which includes problem-solving.
Dwyer, Hogan, & Stewart, 2014	The relationship is moderated by (a) informational literacy, and (b) interpersonal skills or emotional intelligence.
Wechsler et al., 2018	Critical thinking augmented by creative thinking informs problem-solving.
Cooper & Ramey, 2014	While critical thinking affects problem-solving, yet they belong to the same category of personal skills.
Carriger, 2015	Critical thinking is required in team-based problem-solving challenges. Therefore, it is important to include members with such quality.
Mynott, 2018	Critical thinking informs finding creative solutions and making informed decisions.
Dörner & Funke, 2017	Moderated by reasoning power, creative thinking enhances problem-solving.
(Awange et al., 2017)	Enhances problem-finding and problem-solving.
Podolskiy & Pogozhina, 2016	Critical thinking, augmented by informational literacy, enhances problem-solving.
Dwyer, Hogan, Harney, & O'Reilly, 2014	Increased the chance of finding viable solutions to complex problems.

Categorizing the two key concepts of critical thinking and problem-solving assisted in putting them into context, particularly during the data collection and analysis stages of the current research project. Different problem-solving strategies identified the reviewed literature will be discussed next.

Problem-Solving Strategies

Investigation into the various approaches, which are typically adopted by problem-solvers led to some interesting results. Reviewed literature revealed categories of such approaches, which include breaking down of the problem, being stakeholder-centric in finding solutions, design thinking, reflective versus structured thinking, managing a complex problem rather than solving it, taking a proactive stance, closing the vision gap, and staged processes. These strategies are briefly discussed, next.

Breaking Down Strategy. The breaking down strategy involves subdividing a large, complex and overwhelming problem into sub-problems that can be solved using known and available techniques (Lönngren, 2019). Upon solving of the sub-problems, the solutions could be assembled to construct the solution to the original grand problem. Another form of breaking down involves an algorithmic approach to finding solutions to problems with higher degrees of complexity, risk, and uncertainty. Problem-solving using the algorithmic approach design solutions approaches, or paths, using logical operators such as IF, AND, and OR to chart multiple possible paths to finding a solution. Taken to applied levels, algorithms are programmed through coding to become accessible as

problem-solving applications that inform decision making process (Bandyopadhyay & Szostek, 2019).

Stakeholder-Centric Strategy. An outward-looking approach to problem-solving, takes the views and perspectives of the stakeholders into consideration. Stakeholders become essential participants of problem-solving process, which includes identification and definition of the problem itself (Chester & Allenby, 2019; Wright et al., 2019). Part of problem complexity is attributed to the divergent and often conflicting views of the key stakeholders (Chester & Allenby, 2019), often due to the unique perspective or worldview of each stakeholder, which shapes there unique perception of the problem and characterization of a plausible solution (Mejía et al., 2019). A stakeholder-centric solution to a complex problem, therefore, would be influenced by the problem-solver's understanding of stakeholder's expectations, attempting to meet the, but also trying to reconcile the differences in perspectives with the least resort to inevitable compromises (Chester & Allenby, 2019; Wright et al., 2019).

Design Thinking Strategy. Another interesting perspective of problem solving involves considering designing a product or a process as a problem-like challenge to be overcome. Design problems are often reduced to a contradiction, or a conflict, between two features where improving one comes at the cost of the other. In other words, design projects entail resolving such contradictions by adopting the least compromising approach to accommodate the two conflicting features (Altshuller, 2004). Aldave et al. (2019) broke down the design problem solving process into two stages, which involved exploring (a) the problem space and (b) the solution space. The problem space

exploration begins with investigating the issue from the main stakeholders' perspective with the purpose of summarizing it into a problem statement. The solution space exploration starts with ideation, and moves into generation of alternative prototypes and winds down with evaluation and selecting of the most desirable design solution (Aldave et al., 2019).

Reflective Versus Structured Thinking Strategy. Problems with high degrees of social complexity are dubbed as wicked by many observers. Socially complex problems are hard to structure after archetypal models. This is due to the uniqueness of the problems as well as the large number of players and stakeholders involved, which result in such levels of network complexity that is almost impossible to tame into a stable structure that lends itself to rational deliberate solving processes. The alternative approach to unstructurable problems is reflection (Dodd, 2019). Dodd (2019) advocated adopting a non-structured strategy called staged appreciation for solving socially complex problems. Stage appreciation is a stakeholder-centered approach which suggests that the problem-solver should imagine assuming the position of the people affected by the problem environment to be guided into viable solutions by reflection.

Managing Versus Solving Strategy. In view of their vagueness, enormity, and multiplicity of goals, wicked and complex problems may not have definitive and final best solutions. Scholars with insight into such problems suggested that perhaps one should abandon the search for the non-existent best solution and shift attention to *managing* the problem, instead (Lönngren, 2019; Rittel & Webber, 1973; Wilkin, 2017). In other words, the disposition of critical thinking is deployed by the problem-solver to

alleviate tensions among stakeholders and their conflicting and contradicting goals, which are grounded in their social positions toward the issue at hand (Wilkin, 2017). Wilkin (2017) called such process "resolving dissonance", which has a striking resemblance to the focus of resolving contradictions as advocated by proponents of the TRIZ theory (Altshuller, 2004). Based on the *problem management* perspective, solving entails negotiating the barriers for approaching a goal state rather than fully attaining it (Dörner & Funke, 2017). Approaching a goal amounts to finding compromises with the intention of reducing the gaps among stakeholder positions rather than eliminating those gaps (Lönngren, 2019) and the adoption of "multiplism and relativism" attitudes to managing complex problems rather than dualistic and binary approaches (Wilkin, 2017).

Proactive Strategy. Engineers are known to adopt reactive approaches to problem-solving. As a high-paradigmic domain, engineering culture values objectivity, and often intentionally ignores predominant considerations such as the political debates on the social value, which lead to the choice of the very problems to be solved. In fact, engineers attempt to shield their thoughts from political influences, or subjective judgements, from their surrounding environments so that they could guarantee utmost technical objectivity in finding solutions. While technical objectivity is respected, other views advocate the involvement of engineers in the proactive determination of working with strategic and political groups to engage in defining the next problems while developing proforma solutions, concurrently. For example, a design engineer should seek proactive involvement with organizational leadership and the marketing function to

define characteristics of the next product design or improvement to work on, rather than waiting to be told about the next problem they are expected to solve (Lönngren, 2019).

Closing-the-Gap Strategy. From the closing-the-gap perspective, a problem is identified when there is disparity, discrepancy, or non-conformity, between a current state and a desired state. A solution as such, constitutes focusing on the gap as the perceived cause of the problem (Rittel & Webber, 1973).Reviewed literature pointed to two types of gaps, closing of which amounts to solving a given problem totally, or partially. One type of the gaps speaks putting in place what is missing between *now* and *a goal state* (Rittel & Webber, 1973; Szarucki, 2015). Developing components of a strategic plan for an organization constitutes solving problems by overcoming obstacles that appear in the way to attaining strategic goals. The second type of gaps concern resolving dysfunctional disagreements of divergent stakeholder perspectives and social positions (Lönngren, 2019; Mejía et al., 2019; Rittel & Webber, 1973). Perspective-related gaps are seldom solved once and for all. That is why Rittel and Webber (1973) preferred to use the term re-solve to convey the need for solving wicked problems, as they describe them over and over and over (Rittel & Webber, 1973).

Staged Process Strategy. The task of solving a problem could be carried out in logically ordered consecutive steps leading to a solution or a set of alternative solutions. For example a four-stage problem-solving process was suggested to unfold as "preparation, incubation, illumination, and verification" (Wallas, 1926/2014 in Wechsler et al., 2018, p. 115). Another example is a five-stage model proposed by Osborn-Parnes

which involves “fact-finding, problem clarification, idea finding, solution generation, and acceptance finding” (Wechsler et al., 2018, p.115).

The Association of American Colleges and Universities (AACU) advocated the use of VALUE (Valid Assessment of Learning in Undergraduate Education) rubrics that are tailored to assess the learning outcomes of engineering and technology students. The rubrics are outlined in a sequence that mimics sequenced stages of problem-solving: Problem definition, identification of strategies, generating alternative solutions or hypotheses, evaluating alternatives, implementation, post-implementation tracking and evaluation (Cooney, 2014). Another rubric-inspired sequence of stages could be derived from the McKinsey Problem Solving Test (PST) in which the problem-solving capacity of an individual is assessed on the basis of “problem identification, structuring of the problem, prioritization of the tasks, analysis of the problem elements, development of a solution plan, finding a solution, and formulation of conclusion” (Podolskiy & Pogozhina, 2016). The processes mentioned thus far seem to miss one important step which concerns evaluating the credibility of the body of information used in the problem identification and the problem-solving stages. van Laar et al. (2018) named such step as an activity that requires the problem-solving individual to be able to tell apart facts from fictions so that only reliable data would be introduced into the progression of stages leading up to viable solutions.

Influencing Factors

This section delves into factors that tend to shape and influence the problem-solving process. These factors are a combination of external and internal influencers to

the problem solver. They include, the problem-solver's own perspective or world-view, the perspectives or worldviews of the key stakeholders involved and affected by the problem and its solution, the extent to which the problem-solver uses their metacognitive capacity, the body of knowledge applied in arriving at a solution, the effect of collaboration, determinants, and some other factors identified in the reviewed literature.

The Problem-Solver's World View. The mindset of the problem-solver is believed to have an influence on the entire problem-solving process, from identification of the problem, to the adoption of problem-solving strategies, and selecting the preferred course of action leading to a solution (Lönngren, 2019; Mejía et al., 2019). The problem-solver's perception of their societal role and responsibility tend to shape their value system, and on the nature an ideal state which defines what to expect of a good solution. Often times such perspectives are domain-specific, but are also influenced by the level of system analysis where the problem and the problem-solver are situated (Mejía et al., 2019). The individual's training and developmental background functions as a mental lens through which they see the world in a specific way. For example, the problem-solver's educational background exposes them to a series of discipline-specific theories, or theoretical frameworks, which informs their perspective and worldview and how they envision realistic and achievable outcomes as solutions to a given problem (Lönngren, 2019; Mejía et al., 2019).

Stakeholders' Perspectives. Another influencing perspective comes from the key stakeholders whose concerns constitute the problem, or are temporarily affected by the problem-solving process, or will be permanently affected by implementing the solution.

The complexity of problems has multiple dimensions, which include social complexity (Chester & Allenby, 2019; Dodd, 2019). Complex and wicked problem environments are characterized by the presence of multiple stakeholders, and for the solutions to be effective, they must be crafted with the wide range of stakeholders' goals in mind. This makes it necessary for the problem-solver to take the time to gain a deeper appreciation of the stakeholders' concerns and perceptions of value to be found in the outcome of the problem-solving process (Baird & Parayitam, 2019; Chester & Allenby, 2019; Lönngren, 2019). Stakeholders' expectations may be expressed or implied. Being a professional actor, the problem-solver is expected to find solutions that adhere to ethical standards, which are informed and inspired by a sense of social responsibility (Baird & Parayitam, 2019). Two points to infer: (a) ethical solutions are expected even if such expectation is not contractually affirmed, and (b) working toward developing ethically sound solutions constrains the feasible space in which the problem-solver can operate.

Metacognitive Training. Metacognition concerns the individual's "thinking about thinking" (Dwyer, Hogan, Harney, et al., 2014, p. 691). It consists of two components namely, the person's awareness and control of how they engage in addressing a given problem, and their ability to apply their cognitive processes in solving problems (Dwyer, Hogan, & Stewart, 2014). In other words, an individual using their metacognitive skills, constantly engages in critically evaluating the problem-solving process at hand, and questioning the effectiveness of the solution-seeking steps they undergo, including assessing the validity and usefulness of the input information used in the process (Wilkin, 2017). Metacognitive skills refers to the objective self-organization

of the problem-solving process, whereas metacognitive experience relates to use of the intuition and subjective judgements in making decisions during the problem-solving process (Lönngren, 2019). Many observers believed that metacognitive training improves critical thinking skills, which in turn enhances the individual's problem-solving capacity (Carriger, 2015, 2016; Dwyer, Hogan, Harney, et al., 2014; Dwyer, Hogan, & Stewart, 2014; Lönngren, 2019; Morin, Robert, & Gabora, 2018). Anecdotal evidence also points to the promising positive effect of adopting problem-based-leaning pedagogy to develop and enhance metacognitive abilities within individuals who engage in creative problem-solving processes (Carriger, 2015, 2016).

Prior Knowledge. The fast pace of innovations in post-industrial economies placed high demand on all strands of knowledge, particularly in the science and engineering disciplines (Lönngren, 2019). Knowledge-based economies are fueled by knowledge *acquisition*, which informs knowledge *application*. It is through the purposive application of knowledge that complex problems are solved (Ester van Laar et al., 2018). Hence, the translation of acquired knowledge into active use should be emphasized in training competent problem-solving professionals to tackle complex challenges (Lönngren, 2019), for it is through the active application of knowledge that problems are solved (Ester van Laar et al., 2018).

Collaboration. Managing the overwhelming complexities of wicked problems requires concerted contribution from multiple knowledge disciplines and lines of experience. Wicked problems are commonplace for interdisciplinary collaboration. In engineering, for example, problems are often unique and complex on the one hand and

knowledge is distributed among organizational actors on the other. Hence, problem-solving teams are assembled to address a specific challenge. Apart from discipline-specific knowledge, such cross-disciplinary teams must possess the skills of effective collaboration for the efforts to fruition (Carriger, 2015; Lönngren, 2019).

Determinants of Problem-Solving Skills. In a quantitative study van Laar et al. (2019) identified essential digital skills that drove successful employment of professionals. Among others the authors named problem-solving as an essential skill. The study hypothesized fifteen factors that affected the development of problem-solving skills, within professionals. Table 6 contains a summary of the top five of these factors.

Table 6

Top Five Determinants of Problem-Solving Skills Among Employed Professionals

Determinant	Description
Perceived ease of use	The degree to which a person feels comfortable and at ease in using information and communication technologies.
Personal initiative	Whether the person is proactive and self-starter, capable of developing and implementing new ideas with little external support.
Learning goal orientation	An attribute assigned to individuals who are keen at exploiting opportunities to develop and diversify their skills.
Self-directed learning	Refers to a person who identifies a knowledge gap in attaining a specific goal and is capable of planning and acquiring that missing piece of knowledge.
Avoidance goal orientation	A characteristic given to a person who seeks to avoid mistakes which would inhibit their task performance.

Other Influencing Factors. Table 7 contains other factors, extracted from the reviewed literature, which are believed to affect the nature and quality of the problem-solving process.

Table 7

Other Factors Influencing the Problem-Solving Process

Factor	Description	Source
Gamestorming	A set of tools and techniques meant to facilitate interactive exchange of thoughts and ideas among goal-oriented members of a team. It is an engaging method that uses graphics and props to stimulate finding creative solutions to problems in a collective team configuration.	Feijoo et al. (2018)
Digital literacy and life skills	The ability to locate and validate information from various digital sources that are useful to the problem-solving process.	van Laar et al. (2017)
Reasoning capacity	Problem-solvers will benefit from possessing the ability to deduce, or infer, new meanings form an existing body of information.	Dörner & Funke (2017)
Deployment of cognitive and emotional processes	Being calm and in control of the dynamic process of solving complex problems.	Dörner & Funke (2017)
Motivation	An interest in facing new challenges and eagerness in turning an unknown into a known.	Wilkin (2017)
Active learning strategies	Involve facilitated processes that guide problem-solving trainers into developing their own knowledge and applying it in the problem-solving process.	Ruder et al. (2018)
Problem or project-based learning guided by field experts	A training approach to developing problem-solving skills that uses a problem or a project, in a real-life context as a central challenge. Learners are coached and guided by a field expert, who stimulates the thinking process toward finding plausible solutions.	Carvalh (2016)

Discussion

The relationship, or lack of, between critical thinking and problem-solving forms a central question of the current study. Literature lacks consensus on the direction and nature of such relationship. The majority of the reviewed literature point to the influencing effect possession of critical thinking by an actor has on their ability to perform problem-solving tasks (Ahern et al., 2019; Awange et al., 2017; Bandyopadhyay & Szostek, 2019; Carriger, 2015; Dörner & Funke, 2017; Dwyer, Hogan, Harney, et al., 2014; Mynott, 2018; Podolskiy & Pogozhina, 2016; T. Rhodes, 2010; Wechsler et al., 2018). Conversely, Yet, another group of scholars believed that the two concepts belonged to the same category and presumed to have reciprocal relationship on one another (Cooper & Ramey, 2014; Dwyer, Hogan, & Stewart, 2014; Mejía et al., 2019; Morin, Robert, & Gabora, 2015). Although both concepts were discussed, the balance of the reviewed literature was silent on causality between critical thinking and problem-solving (Aldave et al., 2019; Auger & Mirvis, 2018; Baird & Parayitam, 2019; Bowman, 2019; Carriger, 2016; Chester & Allenby, 2019; Cooney, 2014; Dodd, 2019; Fayomi et al., 2019; Griggs et al., 2018; Howard et al., 2015; Lönngren, 2019; Murillo & Vallentin, 2016; Nonis & Hudson, 2019b; Ong & Djajadikerta, 2019; Peters & Tarpey, 2019; Ramazani & Jergeas, 2015; Sauli, Ishak, Mustapha, Yidris, & Hamat, 2019; Szarucki, 2015; Termeer et al., 2019; Varvara, Tikhonova, & Backwaters, 2018; Wright et al., 2019; Zimmerman, 2015). Only one scholar assumed that critical thinking was an overarching set of skills that included problem-solving as a component (ŽivkoviĿ, 2016).

It is evident that past literature is inconclusive with respect to the nature of the causality between critical thinking and problem solving. Filling such knowledge gap was a purpose of the current study.

Invariably, complex problems have obvious social connections and implications represented by multiple stakeholders, often with divergent views or conflicting goals. Expecting a perfect and overarching solution in such complex problem environments is beyond reasonable expectations, as achieving full consent among stakeholders would be impossible (Chester & Allenby, 2019; Rittel & Webber, 1973; Wright et al., 2019). Differing views were expressed and advocated by scholars with respect to approaches to arriving at a partial resolution among stakeholders' positions, which amount to compromises. Simon (as cited in Chester & Allenby, 2019) coined an alternative term to solving a complex or wicked problem: "Satisficing". As a made-up word, satisficing is a hybrid of satisfying and sufficiently, which translates to good enough. One approach to addressing complex problems is giving up on the ambitions of finding a perfect solution, and looking, instead, to satisfice the stakeholders involved as a more realistic outcome of the problem-solving process. Satisficing could be achieved by bringing stakeholders together to obtain a shared understanding of the issues rather than full consensus (Chester & Allenby, 2019). Another perspective suggests that facilitating active engagement of the key stakeholders would be an effective strategy to reach workable compromises (Wright et al., 2019). Finally, consensus may be obtained if the problem-solver emphasizes the importance of maintaining the stakeholders' bilateral relationships unharmed, in developing a satisficing solution (Dodd, 2019).

Solutions Quality

Table 2 included cursory references to come the more frequently used criteria to evaluate the desirability of a solution to a given problem. This section expands on that brief discussion in three ways. First, the idea solution quality will be explored at a deeper level, by borrowing operational definitions from the professional language used to describe quality. Second, solution criteria used in summative assessment of solution will be expanded upon, and lastly, formative assessment criteria will be discussed.

Contextualized Meaning of "Quality"

The term quality has been defined from a variety of perspectives by various authors and professional authorities. In the context of the current project, the meaning of quality was adopted from the writings of Joseph Juran (1904-2008); a prominent figure and well-recognized guru in the field of quality. Quality has a dual meaning, namely (a) the description of a *product* by its features, characteristics and functions, and (b) the manner in which the product-making *process* has been conducted or carried out (Juran, 1998). The product-oriented definition of quality is stated by listing its *dimensions*, whereas the process-oriented definition of quality is expressed by listing its *determinants*. Determinants are those enabling processes, which are responsible for the creation of a product that carries the desired dimensions (Stevenson, Hojati, & Cao, 2015). To establish a parallel in the context of problem-solving, quality may be assessed in two ways. First, a product-oriented perspective which is focused on the desirability of the solution and is referred to as *summative assessment*. Second, a process-oriented perspective which is focused on the care put into the execution steps, leading up to the

solution, and is referred to as *formative assessment* (Dörner & Funke, 2017). Summative and formative solution quality criteria, as they relate to problem-solving, will be discussed next.

Summative Solution Quality Criteria

What makes a solution to a problem, a good solution? Starting with the summative criteria included in Table 2, operational definitions will be provided. These criteria will be enriched by more concepts that were extracted from reviewing literature pertinent to characteristics of good solutions, particularly as they relate to complex or wicked problems.

Usefulness. A solution is considered useful if it carries the promise of addressing the problem or concern effectively. Usefulness could transcend the problem's boundaries and prove beneficial to the field or profession, by generalization (Morin et al., 2018). In complex or wicked problems, a single solution may not be available for the issue at hand. In such cases, usefulness would be measured in the degree to which solution measures are believed to result in positive effects (Dörner & Funke, 2017; Rittel & Webber, 1973).

Originality. The uniqueness of a solution is another criterion of a desirable solution (Aboukinane et al., 2013). Further, originality seem to correlate with the richness of the solution description (Medeiros, Partlow, & Mumford, 2014). Originality has also been described in terms of novelty or unexpectedness or surprise element of the solution (Figl & Recker, 2016).

Fluency. Fluency is measured by the number of ideas used in developing a solution or the number of alternative solutions developed for a given problem (Chen et

al., 2016; Hargrove & Nietfeld, 2015; Wechsler et al., 2018). A problem solver is expected to consider and explore a wide range of possibilities, by activating divergent thinking, which in turn results in fluency of ideas and alternative solutions (Davila, A., Lubart, T., Myszkowski, N., & Storme, 2004). Fluency is an important criterion used in assessing solutions in process improvement (Figl & Recker, 2016), science and engineering (Aboukinane et al., 2013), and management (Medeiros et al., 2014).

Elegance. How coherent the solution elements fit into each other is considered a property of a good solution. Elegance is about the internal consistency of the solution. The solution is expected to be articulated as a sensible package of interrelated actions. Elegance is assessed subjectively by the use of scaled rubrics with anchor point descriptions (Medeiros et al., 2014; Peterson et al., 2013).

Impact. Implementing a solution is expected to cause positive change with respect to the problem being addresses. The magnitude of that positive change is used as a criterion. For example, some solutions are better than the others because they are believed to have a permanent or lasting effect, rather than being quick fixes with limited longevity (Figl & Recker, 2016). A problem-solver is expected to recognize, evaluate and present the consequences of implementing a solution (Mejía et al., 2019). The Accreditation Board of Engineering and Technology (ABET) recognized the importance of evaluating implications and incorporated such criterion into the rubrics of their VALUE (Valid Assessment of Learning in Undergraduate Education) instrument (Cooney, 2014).

Flexibility. While some authors used flexibility and fluency criteria interchangeably (Morin et al., 2018), other drew a distinction between the two. For solution alternatives to be flexible, they need to belong to different categories. In other words, they should not be slightly modified versions of one another. Rather, they should be drawn from unique high-level ideas or theoretical perspectives (Morin et al., 2015; E. van Laar et al., 2019).

Feasibility. A good solution should be associated with a feasible execution plan. Execution plans should take context and resources into consideration (Cooney, 2014). Evaluating the feasibility of implementing a given solution includes risk assessment and prediction of the palatability of the outcomes from various stakeholders' perspectives (Wechsler et al., 2018; Wright et al., 2019).

Stakeholder Satisfaction. Solutions are generated with beneficiaries in mind, but consideration should also be given to those groups who will be affected, temporarily, by the solution implementation process or permanently by the outcome (Chester & Allenby, 2019; Wright et al., 2019). In complex or wicked problem scenarios. the perspectives and expectations of various stakeholder groups are so diverse, and often conflicting, that makes it virtually impossible to arrive at a perfect solution. As such, desirability of a solution would entail the degree to which stakeholder expectations are met (Rittel & Webber, 1973) or harmful consequences are minimized.

Complex problems are characterized by attributes that makes them unique and challenging. Looking at the characteristics listed in Table 3 and Table 4, one would agree with the subscribers of Rittle and Webber's perspective of wicked problems that there is

no way to be able to tell that a best solution exited, and if it did what would it entail (Rittel & Webber, 1973). The alternative if to place our faith in the process leading up to the solution and assure that it was conducted with care and diligence. The next discussion will be about obtaining a deeper appreciation of formative assessment of the contributing actions taken to enhance the quality of the outcome, the solution.

Formative Solution Quality Criteria

What steps should be taken with care to generate a good solution? It is great to have a great solution; however, it is important to recognize that a great solution is the outcome of a process, performed by a problem solver. The quality of a solution may be judged by how well and diligently the process of generation it was performed (Dörner & Funke, 2017; Lönngren, 2019; Luo & Wu, 2015). With increased problem complexity, the desirability of solution outcomes moves away from adopting traditional criteria, such as efficiency, into the assessment of the appropriateness of the approach adopted in finding a solution, or in managing a problematic situation (Rittel & Webber, 1973).

Several scholars and observers suggested proposed or cited stepwise processes that guide a problem-solver into a structured path to finding plausible solution alternatives to a given problem. Select problem-solving processes are presented in Table 8.

Table 8

Stepwise Creative Problem-Solving Processes Identified in the Literature

Referenced source	Process identifier	Steps
Aboukinane (2013)	Theoretical perspectives promoted by several scholars, including Young and Kirton	Divergent-Convergent thinking
	The Osborn-Parness Process Model (OPPM); a five-step model initially proposed by Osborn and advanced by Parnes, Torrance, and Safter.	1. Sensing 2. Definition 3. Alternative generation 4. Comparison 5. Deployment planning
	Treffinger's three-level model	1. Foundation 2. Critical thinking 3. Changing
Andrews et al. (2016)	The I-P-O model for creative teams. Focused on enabling factors	1. Input 2. Process 3. Output
Bogard et al. (n.d.)	Steps within the thresholds of knowledge development	1. Identify 2. Define 3. Explore 4. Act 5. Look
OECD (2017)	PISA 2015 framework for assessing collaborative problem solving	1. Exploring and understanding 2. Representing and formulating 3. Planning and executing 4. Monitoring and reflecting
Hargrove & Nietfeld (2015)	The continuum of creativity development by Beghetto and Kaufman	1. mini-c 2. little-c 3. Pro-c 4. Big-C
Lau (2016)	Partridge and Rowe view of creative process	1. Input Creativity Model 2. Output Creativity Model
	Kneller's five-step process	1. First insight 2. Preparation 3. Incubation 4. Illumination 5. Verification
	Lauer and Pentak simplified process	1. Thinking 2. Looking 3. Doing
Nelson& Squire (2017)	Problem-solving processes should begin by separating two components, each of which requiring its own approach.	The first step should always be about breaking down into (a) technical, and (b) adaptive components. Creative thinking mostly applies to the adaptive component.

Referenced source	Process identifier	Steps
Thompson (2018)	Wallas' four-stage model	1. Preparation 2. Incubation 3. Illumination 4. Verification
	The Romantic Imagination process	1. Sensing 2. Memory retrieval 3. Primary imagination 4. Secondary imagination 5. Image development 6. Creative expression
Vernon et al. (2016)	Creative problem-solving (CPS) process	1. Definition 2. Ideation 3. Solution evaluation
	The Amusement Park theory	1. Requirement identification 2. Theme selection 3. Domain (park) selection 4. Enabler tool selection
Zuber & Moody (2018)	Human-centered design (HCD)	1. Finding 2. Ideation 3. Testing

Note. Table reprinted from Knowledge Area Module 7 by B. Amouzgar, Walden University, 2019.

Evaluating how well each step of the adopted problem-solving process has been executed amounts to formative assessment of the quality of the generated solution alternatives (Luo & Wu, 2015). At a deeper level, the problem-solver is expected to have exercised care in considering aspects of the solution process which determine the quality of the outcome, or the solution alternatives. These enabling aspects are discussed next.

Information Quality. As the adage goes: "garbage in, garbage out". It is important that the problem-solver takes the time and exerts efforts to ascertain that the information they used in all the problem-solving steps are corroborated. This is seen to be an essential measure to be taken in the problem-solving process (Cooney, 2014; Manalo & Sheppard, 2016; Mejía et al., 2019).

Engagement. Particularly in complex situations, the problem-solver will benefit from exercising openness with their surrounding environment. For example, some scholars found it critical to engage with the key stakeholders of the problematic situation throughout the problem-solving process (Wright et al., 2019). Stakeholder engagement not helps the problem-solver in understanding their unique positions and preferences (Chester & Allenby, 2019), it is also helpful in making sure that all concerned parties have been accounted for (Dörner & Funke, 2017; Howard et al., 2015), and that solution alternatives are designed that are deemed feasible by those stakeholders (Wright et al., 2019).

Risk Analysis. Another aspect of a solution concerns the likelihood of its successful implementation. The problem-solver is expected to have assessed the

uncertainties surrounding the execution of the plan of action that brings the solution to life (Wright et al., 2019). Part of the risk analysis process involves evaluating any assumptions made in the process of generating solution alternatives and assuring that these assumptions are realistic enough to be relied on (Cooney, 2014). It is also critical to identify and assess any potential challenges that may be faced in the process of implementation (Wright et al., 2019). The degree to which the problem-solver has conducted risk analysis is considered a formative criteria for judging the quality of a solution alternative (Lönngren, 2019).

Contextual Assessment. Another argument in support of using formative solution quality criteria, is the uniqueness of context in complex problem scenarios. In other words, summative criteria are hardly transferable from problem to problem in light of contextual uniqueness (Dörner & Funke, 2017). A good solution should be supported by evidence that adequate contextual and environmental assessment has been performed and considered in the problem-solving process (Cooney, 2014; T. Rhodes, 2010).

Research. There is an implicit expectation that the problem-solver has made an effort to conduct research on the problematic situation, including learning from narratives of historical case with partial resemblance to the one being addressed (Díaz Martínez, 2019). Included in such background research are theoretical perspectives pertinent to the domain in which the core issue lies (Wright et al., 2019). Perhaps in high complexity situations, adopting the classical research method, including intensive literature review, would be beneficial to making sure that a comprehensive problem-solving proves has

been executed, thus providing evidence-based support for the quality of the of the resultant solution alternatives (Kavanagh & Rich, 2018).

Performing the steps of the problem-solving processes, outlined in Table 9, well as well as delivering on the ensuing criterion for formative assessment, require an intellectual capacity referred to as critical thinking. Critical thinking, for example, becomes an essential driver in problem-solving steps and task such as problem definition, informational assessment, validation assumptions, recognizing context, just to name a few (Cooney, 2014). The extent to which critical thinking was activated and applied by a problem-solver becomes an umbrella criterion for formative assessment of solution alternatives (Carriger, 2015; van Laar et al., 2018). A more extensive discussion of the key concept of critical thinking will follow.

Discussion

How could the problem-solver's problem-solving performance be evaluated? The preceding review explains two approaches which various scholars adopted in performing solution quality evaluations. The reviewed literature, however, is muted on the conditions that makes one of the two approaches more relevant than the other.

Critical Thinking

As noted in the previous section, it is evident from the reviewed literature that critical thinking is that human property required to challenge complex problems (Carriger, 2015; Cooney, 2014; Ramazani & Jergeas, 2015; van Laar et al., 2018). There is a suggestion that critical thinking is applied in all stages throughout the problem-solving process (Wechsler et al., 2018), and that it is instrumental in situations where

existing methods, tools techniques and knowledge bases are not fully fit to support the development of effective solutions (Lincoln & Kearney, 2019). From the current research's perspective, critical thinking is considered an enabling factor deployed for solving complex problems. As depicted in Figure 1, the Paul-Elder critical thinking construct is adopted as a key element of the theoretical framework which guides the thought development of this study. The Paul-Elder construct defines critical thinking as "the art of analyzing and evaluating thinking with a view to improving it." (Paul & Elder, 2016, p. 4). The construct is broken down into three components, namely intellectually reasoned output, intellectual quality standards, and critical thinking traits. These three components will be discussed, next.

Intellectually Reasoned Output

Critical thinking is applied in to serve a variety of purposes, including articulating the purpose of producing solutions, asking good questions, analyzing and expressing points of views, evaluating information, making inferences using an existing body of data, predicting the implications of adopting a certain course of action, and making valid and safe assumption (Paul & Elder, 2016). Moore (2013) conducted a research, through scanning pertinent literature, with the aim to find variations of critical thinking definitions, and arrived at a thematic categorization of the concept which involved keywords such as judgement, skepticism, originality, sensitive reading, activism and self-reflection. Lincoln and Kearney (2019) posited that the ability to evaluate implications, by way of extrapolation, was a critical output of a critically thought-out process. Table 9

is a consolidation of the verbs used to describe the various outputs of critical thinking as identified in the reviewed literature.

Table 9

Descriptive Verbs Used for Outputs of Critical Thinking

All the outlined keywords seem to support empowering the critically thinking problem-solver to device plans of action -or solutions- meant to adapt to changes -including rapid and sudden changes- in the problem's environment (Baird & Parayitam, 2019; Dwyer, Hogan, & Stewart, 2014; ŽivkoviĿ, 2016).

Intellectual Quality Standards

Critical thinking could be disposed of at different quality levels. The Paul-Elder construct named nine quality criteria, which are briefly described in Table 10. It is worth noting that the quality criteria presented for critical thinking resemble those presented earlier for problem-solving. This is likely due to the fact that, unlike the perspective adopted in the current research, a number of scholars considered problem-solving and critical thinking to belong to the same category without much distinction (Carvalho, 2016; Devedzic et al., 2018; Díaz Martínez, 2019; Feijoo et al., 2018; Jang, 2018; Lincoln & Kearney, 2019; Osman et al., 2015; Ruder et al., 2018; E. van Laar et al., 2019).

Table 10

Intellectual Standards as Criteria for Quality of Critical Thinking

Standard	Description
Clarity	How elaborately described is the output statement? Does it convey the meaning with no ambiguity? Are key terms operationally defined with respect to context?
Accuracy	Is the output and conclusion presented without reasonable doubt? Could the claims be validated as true?
Precision	Are the statements presented with adequate detail and specificity? Are implications predicted within a limited range of possible outcomes?
Relevance	Are the solutions related to the problem? Have all critical concerns been addressed?
Depth	Have the complexities of the problem been recognized and addressed? Has the problem been traced down to its root-causes?
Breadth	Have all perspectives been considered and examined? This is particularly critical where multiple stakeholders are involved in a problem setting.

Logic	Does the output statement pass a common sensibility test? Are the conclusions grounded in the presented evidence?
Significance	How important the issue or the problem is? Is it worth the efforts?
Fairness	Has the conclusion or solution been generated in a bias-free environment? Have third party perspectives and sensitivities been accounted for?

Intellectual quality is subject to development and improvement over a spectrum-like scale with lack of reflective ability at the lower end and full accomplishment of critical thinking capacity at the other (Elder & Paul, 2010).

Critical Thinking Traits

What are the personality characteristics of a critical thinker? First, it is important to recognize that critical thinking is an individual person's property, which means that it is not applicable to collective or team-based problem-solving endeavors (Mejía et al., 2019; Mynott, 2018; van Laar et al., 2019). In describing critical thinking as an individual property, Paul and Elder (2010) used the prefix "*self"* four times in eleven words: "self-directed, self-disciplined, self-monitored, and self-corrective" (Paul & Elder, 2016, p. 4). Of course teams would benefit from the membership of critical thinkers who will contribute to enhancing the team's problem-solving abilities (Carriger, 2015). It is worth noting that, empowered by a set of traits, critical thinking is considered a habit that is performed consistently by an individual rather than on a part-time basis (Elder & Paul, 2010; Rhodes, 2010). In other words, once a critical thinker, always a critical thinker.

Paul and Elder (201) identified eight intellectual traits to describe the personality characteristics of an ideal critical thinker. For clarity, they presented contrasting words and phrases for each trait, which are listed in Table 11.

Table 11

Intellectual Traits that Drive Critical Thinking

Trait: Description	Contrast
Humility: Acknowledgement of one's resource limitations.	Arrogance
Courage: No reservations in facing challenging realities.	Cowardice
Empathy: Understanding and being helpful to others' positions	Narrow-mindedness
Autonomy: Stability of forming unique opinions, independently.	Conformity
Integrity: Upholding ethical standards and the common good.	Hypocrisy
Perseverance: Determination and commitment to the cause.	Laziness
Reason: Being forthcoming in sharing the pursued rationale.	No evidence
Fairmindedness: Impartiality and keeping clear of self-interest.	Unfairness

Other words used in describing critical thinking traits include prudence, objectivity, and curiosity (Lincoln & Kearney, 2019), and in characterizing a critical thinker include reason-driven, purposeful and evidence-based reflector, sound judge and thinker (Abbasi et al., 2018; Dwyer, Hogan, & Stewart, 2014; Mejía et al., 2019; Nonis & Hudson, 2019a; van Laar et al., 2019; van Laar et al., 2017, 2018; Wilkin, 2017; ŽivkoviĿ, 2016). Critical thinking traits are considered generic and transferable from one problematic situation to another. In other words they are generic and not discipline-specific (Carvalho, 2016; Díaz Martínez, 2019; Frank et al., 2018; A. Rhodes et al., 2018).

The activation of critical thinking traits is stimulated by intrinsic motivation. The critical thinker should be driven by the burning desire for contributing to positive change and in finding effective solutions to complex problems (Dwyer, Hogan, Harney, et al., 2014; Dwyer, Hogan, & Stewart, 2014; van Laar et al., 2019; Wechsler et al., 2018). The traits seem to evolve and improve over time and through consistent engagement in

critical thinking and they require a strong short-term memory for maximum effect (Dwyer, Hogan, & Stewart, 2014; Manalo & Sheppard, 2016; Mejía et al., 2019).

Discussion

The preceding review of literature on the key concept of critical thinking points to a strong consensus among observers that critical thinking is an individual's quality which is available for disposition by one person. Today's problem-solving endeavors, however, are largely carried out by multi-disciplinary configurations of teams. With the exception of tangential references to teamwork and critical thinking (Carriger, 2015, 2016), the reviewed literature is silent on ways to inject critical thinking into problem-solving teams. Such knowledge gap was explored in probing the insight and experiences of the participants of the current study.

Summary and Conclusions

A deeper investigation into the elements of the conceptual framework adopted in this study revealed that the concepts of problem-solving, and critical thinking had received notable attention from scholars and observers over the past decade. The problems to be solved can be classified in various ways. This research is concerned with solving complex problems, which are characterized by attributed listed in Tables 4 and 5. Complex problems, typically have wide-reached social implications, and the problem-solver must not only be aware of, but makes sure to address them in the process of generating viable solution alternatives. The process of problem-solving may be pursued by adopting specific strategies and influenced by factors that are both intrinsic and extrinsic to the problem-solver.

Solution quality could vary, and it is important to use criteria to assess the desirability level of a solution alternative as an output of a problem-solving process. Two views were presented for assessment criteria. Summative criteria help in evaluating the solution. Formative criteria shift the evaluation to the steps and measures taken to arrive at a solution or a solution alternative. Considering uniqueness of complex problems, formative criteria appears to provide a better scale for assessing the quality of the output.

Sporadic anecdotal and implied consensus exists among scholars that critical thinking drives good problem-solving. However, there seem to be lack of clarity with respect to the causal relationship between the two key concepts of the current study. Grounded theory was adopted to research that relationship and fill the corresponding knowledge gap. Once causal clarity is established, action could be planned to reinforce those factors that are believed to enhance the problem-solving capacity among professionals in the engineering and management disciplines, who operate in British Columbia.

Chapter 3: Research Method

This study aimed for exploring the meaning of critical thinking and problem-solving as they are perceived by the community of scholar-practitioners of British Columbia in engineering and management. In the exploratory process of the study, particular interest was placed in discovering the relationships between critical thinking and problem-solving. Additionally, the enabling factors for both were explored. The outcome of this project may yield multiple social benefits, including offering suggestions on how the current educational processes could be rethought and redesigned to result in better alignment with the problem-solving needs that are expected of management and engineering graduates as they launch their serious professional careers. Such better alignment would increase the value-creation capacity of the economy at large, elevating the living standard of host societies.

Research Design and Rationale

Research Questions

The development of this research was directed by two research questions:

RQ 1: What is the operational definition, if any, of critical thinking as perceived by scholars-practitioners and instructed at management and engineering schools in British Columbia?

RQ 2: What theory and process, if any, describe critical thinking elements that drive the development of effective problem-solving skills among engineering and management students in in British Columbia in preparing them for real-world challenges?

Central Concepts

Two concepts are central to the study: critical thinking and problem-solving. Critical thinking is a purposeful cognitive process that mobilizes an individual thinker's traits aimed at producing a pre-defined output (Elder & Paul, 2010), which carries a recognized social value. Problem-solving is the process executed by an actor or actors for producing new knowledge that is believed to be critical to solving a given problem. To be meaningful, the study was focused on solving problems that exhibit a certain degree of complexity. A complex problem is one that involves multiple parts and stakeholders as well as relationships among them. It is ill-defined, contextually unique, and is positioned in a constantly changing environment. Complex problems are juxtaposed with simple and routine everyday type of problems.

Research Tradition and Design

The qualitative research tradition was adopted as it fit the general intent and purpose of the current research. Qualitative methods are best suited when further exploration of complex issues are sought and where there is a need to uncover and explain causalities in conjunction with preceding of ensuing quantitative studies (Creswell, 2007). The study, in part, sought to obtain a contextualized understanding of past quantitative research findings but also to construct a theory that could be used in future quantitative studies for enumeration and verification purposes. Another characteristic of qualitative studies present in this research is the creation of new knowledge as contrasted with verification of previously discovered knowledge (Patton, 2002). The qualitative tradition is also applicable in situations where the personal insight

and intimate experience of the participants is sought for deeper appreciation of concepts and relations in a given context (Strauss & Corbin, 2008). Drawing on the contextualized knowledge, experience, and perceptions of the participants formed the basis for data collection in this study.

Design Rationale

Of the several thematic designs of the qualitative tradition, the grounded theory approach was implemented in the current project. Grounded theory is based on the social constructivist and interpretive philosophical persuasion, which is juxtaposed by the positivism (Gibbs, 2015). Positivism begins with logically deduced theories, followed by a verification process meant to test the validity of the knowledge claimed through theory (Patton, 2002). Conversely, grounded theory research is primarily based in concrete data, which are collected for constructing a fact-based theory rather than a logically deduced alternative (Gibbs, n.d.; Glaser & Strauss, 2017; Patton, 2002). Grounded theory is an appropriate approach to addressing the inquiries at hand, because I sought firsthand qualitative data from participants who have direct contextual experience with the main concepts of the study. As an outcome, a context-specific theory was drawn to illustrate conceptual perceptions as well as any induced relationships among the concepts.

Since its original design and introduction by Glaser and Straus in 1999, grounded theory has been subject to modifications and adaptations by scholars and researchers. Three particular variations of the method have gathered followers, which are compared and contrasted by Rupsiene and Pranskuniene (2010) and Sebastian (2019). The three variations differ in several ways, including the role of the researcher, dependence on prior

knowledge, and philosophical perspectives. More is discussed about the similarities and differences of the three variations in the sections that follow.

Role of the Researcher

The three most followed variations of grounded theory are classical (GT), interpretive (IGT), and constructive (CGT; Sebastian, 2019). The classical variation is based on the original writing of Glaser and Strauss, from which Strauss parted way at a later stage, leaving the approach to be attributed solely Glaser. The three variations differ in part with respect to the role of the researcher. Inspired by a positivist philosophical perspective, Glaser maintained that the researcher should remove themselves from any influential role in analysis of the original data collected from the participants, having total impartiality (Sebastian, 2019). Strauss and Corbin (2008) acknowledged that being an informed expert in the area being studied, the researcher can interpret the observations through their own prism while taking measures to stay true to the original data contributed by the participants. The third variation, constructive, is attributed to Charmaz, who posited that the researcher's role should extend beyond discovering theories, and they should. She believed that upon disclosing their position, researchers and participants should collectively engage "cognitive constructivism" to describe the reality the way it occurs to them. As such Charmaz advocated the highest degree of researcher's latitude among the three competing variations of grounded theory approaches (Sebastian, 2019).

This research followed the IGT design guidelines as proposed by Strauss and Corbin (Strauss & Corbin, 2008). In IGT, the theoretical orientation of the researcher can play a measured role in the study. For the study, I assumed the role of the observer, and

refrained from supplying own data into the study. My background and experience were used to pose questions and probe into participants' data for purposes, including seeking clarity, identifying dissonance with own knowledge and perceptions as well as similarities and differences between grounded data and the reviewed literature.

Being an educator–practitioner, I am a current or recent coworker of all initial participants. Theoretical sampling, as a central feature of grounded theory designs, necessitated expanding the range and type of participants beyond the initial population of scholar-practitioners. No power differential existed, nor developed, with the participants throughout the course of the study.

To counter potential bias, I adhered to the following guidelines provided by Strauss and Corbin (2008) for the IGT design variety:

- The theoretical framework was used at a high level of abstraction to provide general guidance, rather than dictate the direction of the research.
- Remained open to the influx of new ideas as the flow in from grounded data.
- Exercised restraint in expressing emotional reactions that my influence the range and intensity of the participants contributed data.
- Attempted to see issues from the participants' perspectives.
- Remained sensitive to identifying dissonance with the reviewed literature and own perceptions of the initial and emerging concepts.

Methodology

This grounded theory study was inspired by the interpretive variation as explained by Sebastian (2019), which is largely influenced by Strauss and Corbin (2008), who

advocated a version of grounded theory that is based in pragmatism and interactionism as philosophical persuasions. Key characteristics of the interpretive variation of grounded theory include (a) active engagement of the researcher and allowance for their interpretation of collected data, (b) incorporation of researcher's prior knowledge to reinforce data collection processes, (c) allowance for prior literature to shape and influence the progress collecting data, (d) abstractness of research question to leave room for granulation and grounded discoveries, and (e) seeking of participants' perspectives in the verification of emerging theories (Sebastian, 2019).

Participant Selection Logic

Rigor was exercised in the identification of quality participants who could provide reliable data which, upon coding and analysis, resulted in a substantive theory aligned with the purpose and the questions of the study. In the next section, I describe the targeted population, followed by the sampling strategy which was adopted for the study. The specific selection criteria are then outlined as well as the method to establish if a selected participant met the qualifications stated in the criteria. Lastly, a discussion on sample size will close this section. Care was exercised in assuring that the participant selection process was consistent with the traditions adopted by earlier grounded theory scholars and researchers.

Population

The thematic concentration of the current research hinged on the causal connection between two key concepts: critical thinking as the main driver of problem-solving. The former is primarily developed in academic settings and the latter is applied

in practical work environments. As such, the target population for this study was individuals whose careers form a hybrid of (a) post-secondary instructional experience as well as (b) engagement in real-life work environments where the schooling-acquired knowledge is typically applied. The geographical premise of the study also required that the population comprise individuals who lived and operated in the Canadian province of British Columbia. As the unit of analysis, an ideal participant for this project was profiled as an individual who currently serves as a part time faculty, in management or engineering, while simultaneously engaged in a relevant practical occupation, and lives and works in British Columbia.

Due to the specific scope delimitations of the current study, I was not able to locate a publication or database to offer a ready estimate of the population size. Nevertheless, a rough and unscientific estimate was established by gathering sporadic data from available sources and publications. Public records for the government of British Columbia stated that the total student population of the province amounted to 179,385 persons enrolled in public post-secondary institutions (Bowden, 2020). BC's private institution's share is estimated to be 13.3% (Williams, n.d.). This brings the total student population in the province to approximately 207,000. Based on data published by the largest BC university, faculty size is about 9.4% of the student population ("UBC Overview & Facts," 2021), which indicates that there are roughly 19,500 faculty members employed in the province. Of that number, 31%, or roughly 6,000 faculty members, are estimated to belong to the engineering and applied science, or the business and management disciplines of study. This is derived from results of a survey conducted

by the British Columbia government, which offered a breakdown of BC graduate population by discipline ("Survey results of baccalaureate graduates by program cluster," 2020). Finally, about a quarter of those discipline-specific faculty members are reported as part-time by the second largest post-secondary institution of the province ("Quick Facts," n.d.). With this, a rough estimate of the population size of the current study was concluded to be 1,500 scholar-practitioners.

Sampling Strategy

At the time of the study, I fit the profile of the target population. As such, I was associated with a sizable network of colleagues who shared similar hybrid occupations in both academic and work settings. Purposeful sampling has been recommended for qualitative studies in general (Creswell, 2007; Patton, 2002) and for grounded theory in particular (Strauss & Corbin, 2008). Theoretical sampling is one of the key tenets of grounded theory, which suggests that the purpose of sampling should evolve, depending on what collected data revealed, as the project unfolds (Glaser & Strauss, 2017; Strauss & Corbin, 2008; Vollstedt & Rezat, 2019). I anticipated adopting different types of purposeful sampling at different stages of the project. Table 12 provides a summary of the purposeful sampling methods used in the current research.

Table 12

Sampling Method

Research Phase	Sampling Method	Definition
Pilot study	Convenience	"Saves time, money, and efforts, but at the expense of information and credibility" (Creswell, 2007, p. 127; Patton, 2002, p. 244).

Initial round of data collection	Snowball	"Identifies cases of interest from people who know people who know what cases are information-rich" (Creswell, 2007, p. 127; Patton, 2002, p. 243).
	Criterion	"All cases that meet some criterion; useful for quality assurance" (Creswell, 2007, p. 127; Patton, 2002, p. 243).
Follow up data collection	Intensity	"Information-rich cases that manifest the phenomenon intensely but not extremely" (Creswell, 2007, p. 127; Patton, 2002; p. 243).
Final round of data collection	Confirming and disconfirming cases	"Elaborate on initial analysis, seek exceptions, looking for variation" (Creswell, 2007, p. 127; Patton, 2002, p. 244).

Participant Selection Criteria

The following criteria were used to recruit participants:

- At least 5 years of experience teaching management, business, and/or engineering courses at post-secondary level.
- At least 5 years of experience working in a consulting, executive or supervisory capacity in fields related to management and/or engineering
- Works and lives in British Columbia

In recognition of the discovery-driven nature of grounded theory, Glaser and Strauss (2017) suggested that adhering to rigid criteria for selecting participants may defeat the purpose, and some flexibility should be allowed. After all when exploring "theory is the purpose, there are … reasons why representativeness of the sample is not an issue" (Glaser & Strauss, 2017, p. 189). During the simultaneous data collection and analysis processes, necessary deviations from the selection criteria were explained to the

University's Institutional Review Board (IRB), with justification. IRB's approval to the modification was secured before contacting participants who did not fit the initial selection criteria.

Qualifying Participants

Participants sampled from the targeted population were prescreened to assure that they met the selection criteria for the purposes of this research. Two sources were used to pre-establish participant qualification, both of which contain pertinent information available in the public domain. Since the candidates participating in the sample are current faculty members of British Columbian post-secondary institutions, their profiles were found on the websites of the employing institutions. Profile information typically included both teaching and practice-related experiences. As an additional layer of assurance, the LinkedIn profiles of the participating candidates were reviewed for further assurance that their qualifications were consistent with the selection criteria adopted for the current study.

Sampling Size

Little, if any, was found in the writings of the developers and influencers of grounded theory with respect to quantification of sample size. The general direction derived from methodology literature was that grounded theory, as a qualitative design of inquiry, should remain flexible, and the researcher is allowed the latitude of reflexivity throughout the process. Glaser and Strauss (2017) suggested that sampling decisions should remain fluid and decided by the researcher as they swing forth and back between data collection and analysis till saturation is achieved. Corbin and Strauss (2008)

conveyed a similar advice to grounded theory researchers, adding that follow-up data collection should be informed by the concept of theoretical sampling, which means that qualitative and quantitative decisions about sampling should follow an emergent trail that shows signs of moving towards construction of a theory. In the same vein, Patton (2002) asserted that numerical commitments to sample size would be inappropriate in qualitative research, and that sampling should start with the minimum number of participants and expand as needed till the purpose of the study is achieved.

Despite the lack of a pre-determined number of participants, one article reported that the number of samples used in interview-based grounded theory studies ranged within five–114, with a 65% midspan of approximately 10 to 30 participants (Thomson, 2011). The same article indicated that among other factors, sample size is also dependent upon whether the researcher intended to return to the initial participants seeking more in-depth understanding of the core concepts, or opt for a broader coverage of a larger number of participants (Thomson, 2011). For the purposes of this study, I intended to start with a sample size of 10 participants and expand as needed, until such time that theoretical saturation was reached and the purpose of the study was met.

Instrumentation

Interview and observation are the most commonly used data collection instruments in qualitative studies (Creswell, 2007; Patton, 2002) and grounded theory research in particular (Glaser & Strauss, 1999; Strauss & Corbin, 2008). A distinctive advantage of the interview instrument is that it gathers perspectives (Patton, 2002, p. 341). This feature of interviews is critical in grounded theory studies where the researcher

attempts to construct a theory by inductively relying on the tacit knowledge available within the participants.

Concerns about the intrusive effect of observation have been noted by some qualitative research observers (Creswell & Creswell, 2018; Patton, 2002). As a viable alternative data collection method, to observing, the use of audiovisual digital material was recognized by a number of qualitative research methods' influencers (Creswell & Creswell, 2018), including those with an interest in grounded theory (Goulding, 2002; Strauss & Corbin, 2008).

The primary instrument that was used in the current research is interview. The interviewed participants were asked if they were comfortable allowing me to access pre-recorded audiovisual material of concrete settings where critical thinking is applied for purposes of finding solutions to complex problems in engineering or management or both. It was expected that combining interviews with pre-recorded observations, undoubtedly, brought much benefit to the study in that they add clarity of the meaning of the core concepts, besides offering the possibility of triangulation.

Interview as the Primary Instrument

There is an obvious consensus among qualitative and grounded theory methodologists that participant interview forms the most common method of data collection (Glaser & Strauss, 2017; Patton, 2002; Strauss & Corbin, 2008). Patton (2002) proposed three levels of flexibility for interviews. Listed in the ascending order of structuredness these three levels are informal conversational, guided, and standardized open-ended interviews. I found that the guided level of interviews promised the best

outcomes for the current grounded theory study, in that it allows a purposive degree of flexibility, which is informed by the main questions of the research. Guided interviews follow a set of questions to ensure that the same questions are asked, with flexibility allowed for probing questions. Patton (2002) stated:

> An interview guide lists the questions or issues that are to be explored in the course of an interview. An interview guide is prepared to ensure that the same basic lines of inquiry are pursued with each person interviewed. The interview guide provides topics or subject areas within which the interviewer is free to explore, probe and ask questions that will elucidate and illuminate that particular subject. Thus, the interviewer remains free to build a conversation within a subject area, to word questions spontaneously, and to establish a conversational style but with a focus on a subject that has been predetermined. The advantage of an interview guide is that it makes sure that the interviewer / evaluator has carefully decided how best to use the limited time available in an interview situation (p. 343).

This cited description of guided interview suited the purposes of the research project and was found to be consistent with the interpretive variation of grounded theory as promoted by Corbin and Strauss (2008; see also Sebastian, 2019). The guided questions used for interviews are presented in Table 13. They were designed to provide full coverage of the research questions as well as the elements of this study's conceptual framework.

Table 13

Guided Interview Questions

Research Questions	Supporting Questions
RQ #1: What is the operational definition, if any, of critical thinking as perceived by scholars-practitioners, and instructed at management and engineering schools in British Columbia?	Q1.1) What is critical thinking from your perspective? Q1.2) How would you characterize a critical thinker (traits, skills, etc.)? Q1.3) What rubrics would you use to assess a person's critical thinking capacity?
RQ #2: What theory and process, if any, describe critical thinking elements, which drive the development of effective problem-solving skills among engineering and management students in in British Columbia in preparing them for real-world challenges?	Q2.1) Why is there so much emphasis on critical thinking in higher education? Q2.2) How would you describe the relationship, if any, between critical thinking and problem-solving? Q2.3) What kinds of problems employers expect the graduates to address in real-world workplace settings? Q2.4) To what extent employers care about a graduate's ability to solve those problems (identified above)?

Interview Instrument's Validity. I applied several measures to assure the integrity, credibility, and trustworthiness of the data collected from the participants. Among the different measures proposed by qualitative research methodologists, *member checking* and *discrepant information* (Creswell & Creswell, 2018) were applied throughout the data collection stage. The same two measures were suggested as *participant's review* and *negative cases* respectively by Patton (2002). The grounded theory methodology adopted in the current study has built-in measures such as *constant comparison*, which facilitates bringing to light discrepancies in the data collected within

and across participants, and through different instruments (Glaser & Strauss, 2017; Strauss & Corbin, 2008).

Interview Instrument's Sufficiency. Another grounded theory feature, which has been used in the current research project is *saturation*. I knew that sufficient insight has been represented in the collected data, when no new, categories, or axial connections, with respect to the research questions, were discovered (Glaser & Strauss, 2017; Strauss & Corbin, 2008). For consistency and comparability, all participants were presented the same guided interview questions.

Audiovisual Material as an Observational Instrument

For the purposes of this study, observation entails an attentive viewing of episodes where critical thinking was applied for finding solutions for complex problems. Ideally such observation should be made real time and involve in-class, or on-the-floor activities facilitated by one of the participants who might be open to sharing a dynamic episode with me, the researcher. Instead, toward the end of interview sessions the participants were be asked if they are aware of any unrestricted pre-recorded episodes that I could view for data collection and analysis. The choice of resorting to audiovisual recordings, rather than real time observing, is motivated by three factors. First, the method excluded the researcher's potentially intrusive effect on and live proceedings. Second, it is the safest method, given the ongoing COVID-19 pandemic and the social distancing advisories issued by competent health authorities, at the time of the study. Third, videos can be rewound and reviewed for more in-depth extraction of pertinent data, coding, and the ensuing analysis.

While I expected little difficulty gaining access to participants for one-on-one interview purposes, the case for gaining access to archived audiovisual material proved to be different, in view of privacy and confidentiality institutional restrictions. Another alternative which I attempted was to search for existing video material available in the public domain such as on YouTube and LinkedIn.

Audiovisual Material Instrument's Validity. Combined with interview, audiovisual material can enhance the validity of collected data in qualitative studies. This is referred to as triangulation by qualitative research method observers (Creswell, 2007; Creswell & Creswell, 2018; Patton, 2002) as well as the pioneers of grounded theory methodology (Glaser & Strauss, 2017; Strauss & Corbin, 2008). More about triangulation will be discussed later in the chapter and in the context of credibility strategies.

Audiovisual Material Instrument's Sufficiency. Data collection sufficiency is determined in the same way described earlier for the interview instrument. In grounded theory, saturation is used as a sufficiency criterion for collected data, in general, regardless of the instrument or technique used for data acquisition (Glaser & Strauss, 2017).

Pilot Study

I conducted two interviews with participants who currently serve as a part time faculty, in management or engineering, while simultaneously engaged in a relevant practical occupation, and lives and works in British Columbia. The two individuals who participated in the pilot study, were selected using convenience sampling. I intended that the pilot interviews be conducted following the same procedure envisaged for the amin

study, as outlined in the Procedures for Recruitment section, including full adherence to the corresponding IRB approval.

The purpose of the pilot study was to identify and correct any unforeseen issues in in using the virtual media tool for interviews, implementing the full steps of the procedure, and collecting useful data in general. As such, the participants in the pilot study were interviewed using the same guiding questions. Additionally, the participants were asked of the possibility to obtain a recorded session where critical thinking has been applied by their students for problem solving. Since the pilot interviews were successful, the data collected from the initial two participants were included in the main study.

Procedures for Recruitment, Participation, and Data Collection

I assured that the necessary IRB letter of approval was secured from university authorities before making any contacts with the participants of the pilot study or the main study. The next steps of the procedure are described as follows:

Participants' Recruitment

I had access to the sampled participants of the study and faced no difficulty recruiting the first seven scholar-professionals who met the profiled criteria cited earlier. As a contingency plan, qualified individuals could have been recruited from LinkedIn, but that option proved unnecessary. The remaining four participants were recruited by referrals from the initial seven. In total, 11 participants were interviewed, one of whom twice.

Once an individual matching the research profile criteria agreed to consider being a participant, a consent letter was issued to them providing anonymity and confidentiality

assurance, for their agreeing to provide experiential insight and allowing the interview to be recorded for accuracy. The template of the consent and confidentiality letter was vetted in advance by Walden University's IRB. Three or four time-slot options were offered to each consenting participant, to choose from for the interview time. If none found workable, an alternative time would have been mutually agreed upon through a quick live chat or a brief telephone conversation.

To eliminate the possibility of participant under-preparedness, the guiding questions were provided to them for advance information. Using my personal experience, such advance information allowed the participants to reflect on their views and experiences ahead of the interviews, thus contributing better thought-out and more coherent content. I saw little benefit in confronting the participants with pop-up queries, which would have come to them as surprises thus risking (a) elongation of the interview session beyond the allotted time, due to the need for clarification, and (b) the quality of contributed content due to perceived pressure for coming up with ad-hoc responses, at any rate.

Interview

With information provided in advance, interview times were spent efficiently and productively. Each interview session lasted approximately 30 minutes, unless a participant remained interested to engage longer. I monitored the conversation closely for data saturation. Once, no new data is obtained, the session was adjourned tactfully and diplomatically.

Before leaving the meeting, I inquired if the participant was comfortable offering referral to other participants who may provide useful insight into the research question. As well, participants were asked if they were aware of any potentially useful and publicly available, audiovisual material that could be accessed for analysis. I also sought the permission of the participant to contact them again for verifying my understanding of the participant's main contributed points and to seek additional clarifications if required.

Each interview was transcribed to allow for the ensuing qualitative data analysis, referencing and recodes. An excerpt of the transcription was sent to the participant to assure that key ideas have been captured with sufficient integrity. This step was critical to ensuring that accurate grounded data is introduced into the analysis stage, which is expected to eventually result in a theory.

Data Analysis Plan

The purpose of data analysis was for me to develop a deeper appreciation of the concepts that are central to the topic being studied (Creswell, 2007). This deeper appreciation required exploring concept properties and their corresponding dimensions as well as conditions and implications (Schatzman, 1991, as cited in Strauss & Corbin, 2008). In grounded theory, the ultimate purpose of analysis is to construct a theory that is rooted in the data collected from participants who are deemed to be most knowledgeable about the central concepts of the study (Glaser & Strauss, 2017; Strauss & Corbin, 2008). Design of the current study was inspired by the writings of grounded theory pioneers and influencers, Glaser and Strauss (2017) and Strauss and Corbin (2008). Key characteristics of the data analysis phase adopted in this project are discussed next.

Connection of Data to Research Questions

The guiding questions outlined in Table 13 are kept at a higher level of detail, intentionally, so that the participants do not find themselves constricted in providing short and pointed responses. While my intent of was to allow for a broad range of perspectives to flow into the study, I was sensitive to capture the perceived meanings of the key concept, being *critical thinking* and *problem solving*. Descriptions of the concepts' meanings were expected to result in identification of their properties and dimensions. This is particularly the case for RQ1, which concerns the research concept of *critical thinking*. Likely some participants would refer *problem-solving* in describing *critical thinking*. I was sensitive to noting the way the two concepts were related by a given participant without coaching them into such direction.

The primary focus of RQ2 was in exploring any causal relationship that might suggest that *problem-solving* is enabled by *critical thinking*. In this case the later would be considered a condition to the former. The other guiding questions that support RQ2 probed into the context in which problems occur and the implications of finding effective solutions in real-life work environments. I was aware of the abstract level of the guiding questions, which I found necessary to allow greater freedom of choice for the participants to contribute experience-based data to the study.

Coding Procedure

Upon transcribing conducted interviews with participants, data were coded with the initial intent of identifying conceptual categories, or codes. In grounded theory, the data collection and analysis are intertwined by the process of constant comparison. Glaser

and Strauss (2017) advised against separating data collection, coding and analysis, and I planned on following such advice from grounded theory pioneers. Specifically, I planned to allow for the nonlinear grounded theory process to play itself out by adopting established strategies of theoretical sampling and constant comparison. The latter strategy facilitated effective coding of data and organizing emerging categories of concepts in logical ways. Theoretical sampling allowed me to tailor the next sessions of data collection informed by what the data had revealed partway into the analysis stage (Strauss & Corbin, 2008), rather than deferring it to the next study.

Two types of coding were used in the study: open coding and axial coding. I used open coding to break down collected data into manageable groups of concepts, which would eventually define categories. Concepts and categories could be coded in-vivo or using common language derived from literature (Vollstedt & Rezat, 2019). I used language drawn from literature for labeling purposes. This allowed for later comparison of findings with prior studies and potential triangulation. Axial coding was used to establish relationships between and among categories, which led up to formulating a grounded theory: The answer to RQ 2.

Use of Software

I acquired the license to use NVIVO 12 Pro. This choice was triggered by my familiarity with the software from coursework experience and its popularity among the qualitative research community, at large. Additionally, the licensor offers high quality and responsive technical support, with rich availability of tutorial videos on their website and YouTube channel.

Treatment of Discrepant Cases

Comparative analysis is central to qualitative research in general and to grounded theory. I was sensitive to the emergence of differences and nonconformities throughout the process of data analysis. In the study, once a discrepancy was detected, its sources were investigated deeper to determine if it was rooted in the supporting properties of a central category or in the conditions surrounding the description offered by the data-providing participant. The outcome of the investigation occasionally warranted the addition of a new category or expanding the properties of an existing one.

Issues of Trustworthiness

Credibility

The primary strategy which was adopted to establish credibility of this study was *member-checking*. Upon transcription, and filtering noise out of collected data from interview sessions, I prepared an excerpt of the key points extracted from the interview and sought the participants' endorsements in advance of coding. Researcher's reflexivity is considered another strategy to assure credibility in qualitative research (Creswell & Creswell, 2018; Korstjens & Moser, 2018; Patton, 2002; Strauss & Corbin, 2008). I exercised *reflexivity* by way of reflecting on memos and transcripts to assure that participants' in-vivo content is interpreted and coded as intended by the participants rather than being the products of my own assumptions. Doubts were cleared through member-checking and prior to coding.

When the opportunity presented itself, *triangulation* was used by verifying or contrasting, interview data with data observed through audiovisual material.

Triangulation is widely used to enhance research credibility in general (Noble & Heale, 2019), in qualitative studies (Creswell, 2007; Patton, 2002), but also in grounded theory (Strauss & Corbin, 2008). The primary method of triangulation, which was used in the study was built of the constant comparison approach of grounded theory. Data collected from various participants was compared for similarities and differences. This form of triangulation is referred to as people-based triangulation of data (Denzin, 1970 in Noble & Heale, 2019). Finally, the data collection process continued until data saturation was reached as recommended by grounded theory methodologist (Glaser & Strauss, 2017; Strauss & Corbin, 2008).

Transferability

Data were sources in two practice fields of business, namely management and engineering. Although the two fields overlap to some degree, they contain branches that are clearly separate. For example, some highly specialized functions in finance or human resource management are distanced apart from typical engineering functions such as mechanical design. Such differences bring us closer to allowing limited transferability of the findings by way of *variation in participant selection*. However, more effectively, transferability was demonstrated through *thick description*. In the analysis phase, the key categories were coded with respect to conditions. Such coding was expected to provide the justification for transferability to contexts sharing the same conditions under which the research data were collected. Yet, given a qualitative study with limited nonrandom participants and a small geographic study area, findings are not likely transferable; however, the process will be, given the thick description provided earlier for the process.

Dependability

Consistency of data collection processes was assured through the adoption of an *interview protocol*. Such protocol comprises of two parts: (a) the standard steps listed earlier under Procedures for Recruitment, Participation, and Data Collection; and (b) the guiding questions.

Consistency of the analytical component of the research was secured by the intended use of software, where all codes, categories, definitions, properties and dimensions are centralized and readily accessible to me along with visualization tools. Dependability of the finding was promoted through asking a select number of participants to verify the sensibility and plausibility of the conclusive outcomes before moving ahead to the next steps leading up to publishing.

Confirmability

Confirmability was demonstrated by providing a detailed description of the research steps. Such steps are described in the proposal. The steps were augmented with post-mortem analysis upon completion of the study. This method of confirmability demonstration was adopted from the writing of Korstjens and Moser (2018).

Ethical Procedures

I did not initiate communication with the participants of the main or pilot study prior to obtaining full clearance from Walden University's Institutional Review Board (IRB). Upon receipt of IRB approval, I solicited the cooperation of pilot participants and be forthcoming in providing written assurances with respect to confidentiality and unanimity of the data collected. The same treatment was extended to the participants of

the main study, after the pilot stage. The participants were contributing their individual experiences and be acting on their individual capacities independent of any organization. Hence, neither divulgence of organization-specific material were expected or required, nor institutional permissions be applicable.

I maintained a neutral relationship with typical participants as both sides operate as independent actors with respect to the proposed research project. Although they may have instructed at the same educational institutions, but there was no conflict of interest foreseen in the bilateral relationship between me and the participants. I avoided recruiting participants who, beside instructing, may occupy administrative duties that may translate into power-charged relationships.

In the absence of power-differential in the relationship between me and the participants, there expected to be no risk of coercion or forcefully obliging participants to either agree to contributing to the study or remaining engaged beyond their will. I provided participants a written an assertion that they can depart the survey at any point without restrictions. Possible withdrawal of a few participants, partway into the research process would not influence its progress as the pool of qualified participants is deep and broad, within the technical and geographic scope of the project. I enjoyed a vast and rich professional network, which was populated with individuals who match a participants' profile intended for this study.

All data and documentation related to the study was stored in password-protected digital environments, including on-board personal computer memories and Microsoft OneDrive cloud-based storage. Finally, in adherence to the local research norms in

Canada, I revisited the *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans Course on Research Ethics (TCPS 2: CORE)*, and obtained a fresh completion certificate, prior to commencement of the data collection phase of the study.

Summary

Chapter 3 contains details of the research method intended for use in the current study. Description of the method is structured into three sections: design rationale, implementation methodology and outlining how concerns of trustworthiness was addressed. The overarching premise of the study, which is distilled in its two research questions, involves exploring two complex concepts, namely critical thinking and problem-solving, as well as any interactive relationship that might inform the potential and extent of causality. In adhering to tradition, this research project was conducted following the qualitative tradition; specifically, the grounded theory design. More specifically, the grounded theory design in this study was influenced by the constructive variation as proposed by Corbin and Strauss.

Participants were sampled from a population of scholar-practitioners with experiential insights into the key concepts of the study. Several sampling strategies were adopted for enrolling participants, which would match the different stages of the study. A pilot study was intended for this study to allow for testing of the interview protocol and adjusting where warranted. Following the initial round of data collection, coding was performed in conjunction with the use of constant comparison, as one of the keystone features of grounded theory design. Finally, issues of trustworthiness were addressed, including countermeasures that I put in place to address a myriad of concerns that

qualitative studies are typically scrutinized for. Next, the results of the qualitative examination of the collected data are presented, which include visual objects derived from the software used in the analysis processes of this study.

Chapter 4: Results

The purpose of this study was to explore the perception among the scholar–practitioner community of British Columbia of the concepts of critical thinking and creative problem-solving. This is achieved through posing two research questions, the first of which constructed a multifaceted definition of the phrase critical thinking, as understood by the targeted population. The second question uncovered causal or relational connections between the concepts of critical thinking and problem-solving.

This chapter begins with describing the data collection setting, demographics, and process, which includes a pilot study at the front end. It continues with a report on the procedures and steps that I adopted in analyzing collected data and an illustration of the trustworthiness measures used in conducting the study. The chapter concludes with a presentation of the study's results.

Pilot Study

The pilot phase of the study involved testing the main data collection procedure and instrument for troubleshooting and refinement purposes. Two participants were interviewed in the pilot phase, which revealed the need for the changes to the transcription tool by (a) assigning anonymous participant codes for clearer visualization of their contributed content and (b) formatting the transcript to integrate seamlessly with videos in the NVivo environment. Other changes were the reduced the frequency of interjections into the conversation when the participant paused to put their next thought together; greater patience in allowing the conversation to venture into tangential topics, some of which were insightful contributions to the study; and streamlining the member

checking process by providing participants with key contributed points in a refined format rather than lengthy verbatim transcriptions.

Research Setting

All interviews were conducted using Zoom as the video conferencing medium. Participants seemed comfortable with the online setting, and interview times were determined based on their convenient availabilities. Technologically, all interview sessions were conducted free of any connectivity interruptions or background noise. All interview questions were shared on screen while in session.

I had had prior professional connections with six of the 11 participants. Such connections excluded any current or anticipated power-laden relationships or concerns about potential conflict of interest. Participants were generous with their time and eagerness to contribute rich and thick insights into the study. I found the level of interest expressed by all participants to be encouraging as a testament to the fact that critical thinking and problem solving are considered critical qualities from the employers' community and educators' perspectives.

Demographics

The data collection process started by inviting and interviewing participants who matched the criteria approved by Walden University's IRB. Among others, the criteria limited participant qualifications to possessing a minimum of 5 years of experience as educators and as practitioners. However, during the third and fourth interviews (P6 and P7), it became apparent that much insight could be obtained from individuals who may not have the minimum required number of years of experience as educators or as

practitioners. To prevent missing out on inputs that are relevant and useful for the study, a supplementary IRB approval was sought and secured to allow for the relaxation of the experience criteria from 5-year in each setting—educator and practitioner—to either setting–educator and/or practitioner. Table 14 offers a summary of the study participants' demographics.

Table 14

Demographic Summary

Attributes	Values
Gender	Male 8 Participants Female 3 Participants
Education	Bachelor: 2 Participants Doctorates: 7 Participants Post Doctorate: 2 Participants
Age	45-54: 1 Participant 55-64: 5 Participants 65+: 5 Participants
Expertise	Management: 6 Participants Engineering: 3 Participants Both: 2 Participants
Educator experience	Average: 18 years Spread: From 0 to 38 years Median: 16 years
Practitioner experience	Average: 30.7 years Spread: From 0 to 53 years Median: 35 years

Data Collection

A total of 11 participants were recruited and interviewed after having provided consent and completing the demographic form as illustrated in Appendix A. I had a follow-up interview with P5 after coding of the initial round suggested that an opportunity may exist to obtain case examples in the use of cross-disciplinary analogies

that enhanced critical thinking and led up to solving important design problems. Data saturation was reached after nine interviews, with no new categories emerging afterwards. Interview durations ranged from 30 to 50 minutes.

Participants were sampled in three ways. Convenience sampling was used at the front end of the data collection process. Four participants with whom I had professional acquaintance from experience were interviewed. Next, the conveniently recruited participants were asked if they felt comfortable offering snowball referrals. They invariably and graciously did so, and the referrals rolled out in two consecutive waves. Lastly, triggered by an interim analysis process theoretical sampling was beneficial to the study. As such, the need for more focused experiences became evident, resulting in the use of criteria sampling. The shift to criteria sampling also meant that there was a need to slightly modify the IRB-approved qualifications criteria of the research participants. A supplementary IRB approval was sought and secured to enable the recruitment and interviewing of three participants who possessed invaluable insight into the study, even though they lacked the initially intended 5 years of experience on both fronts: academia and practice. The perspectives shared by these participants contributed to contextualizing and reaffirming much of the data collected from the participants who preceded them.

All interviews were conducted and recorded on Zoom. Following each interview, the audio file was uploaded to a cloud-based transcription tool available from Microsoft Word's in the One Drive space. But some additional work was necessary to edit the transcript so that the critical parts of an interview were not lost. To prepare for coding,

both the video and transcript files were imported into the data management and analysis application used for this study: NVivo 12 Professional.

Three interviews into the data collection stage, I determined that it would be useful to ask for case-in-point examples of the interviewed participants, if available. Such subtle reminders worked out well, as many of the participants had interesting cases to share, without reservations. For example, one participant recalled a design-related incident in which navigational stability of a small vessel was sought in the face of rugged high sea conditions. A solution was found inspired by the stability observed in a squirrel's tail.

Data Analysis

This study followed the general guidelines of interpretive variation of grounded theory that is influenced by Strauss and Corbin (2008), who offered the following insights into data analysis:

> Concepts are derived from data. They represent an analyst's impressionistic understanding of what is being described in the experiences, spoken words, actions, interactions, problems, and issues expressed by participants. The use of concepts provides a way of grouping/organizing the data that the researcher is working with … There are basic-level concepts and higher-level concept that we call categories. Lower-level concepts point to, relate to, and provide the detail for higher-level concepts. (Chapter 3, p. 7)

At a more granular level insights from Charmaz (Charmaz, as cited in Gibbs, 2015) were adopted to execute some of the canonical features of grounded theory, such

as open coding, constant comparison, and focused coding axial coding, memo taking and saturation. The analysis steps were performed in the NVivo 12 Pro environment and are further elaborated in the following sections.

Open Coding

Interview recordings and the corresponding transcriptions were used as the primary source for the initial round of coding. Participant-contributed data had to be cleaned up to filter out unrelated contents such as greetings, pleasantries, and casual chats. Creswell and Creswell (2018) called this step "winnowing of data." Open coding, or line-by-line-coding as termed by Charmaz (Charmaz, as cited in Gibbs, 2015), is where the grounding of grounded theory originated. I went through the individual interview transcripts, meticulously, and identified a total of 77 codes as shown in Appendix B.

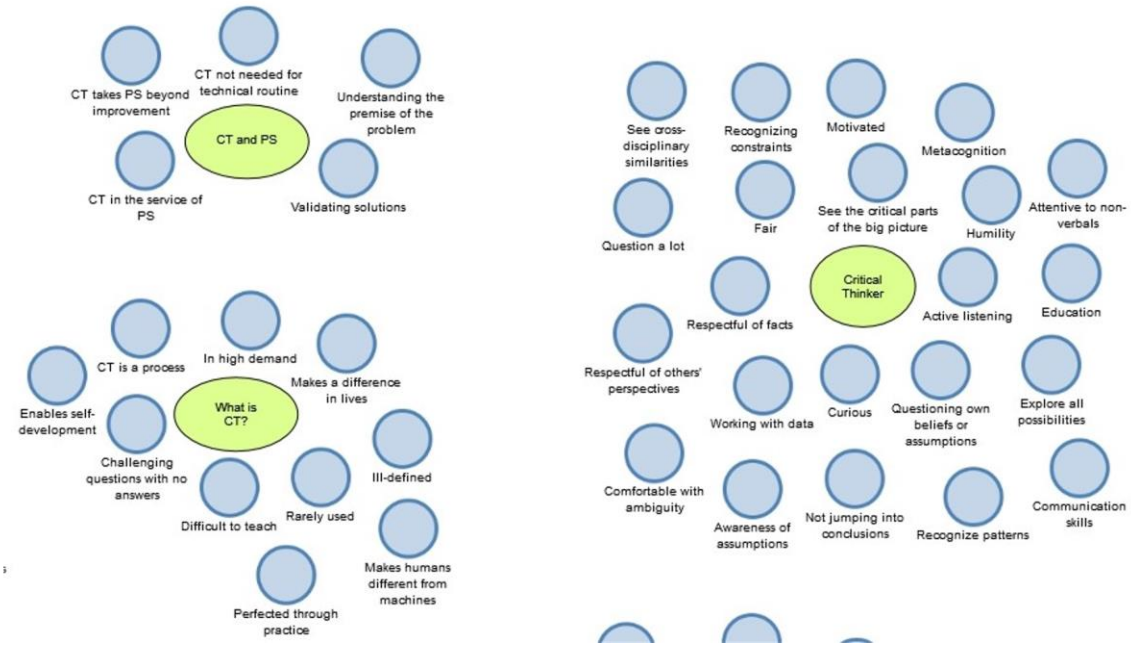
Constant Comparison

Constant comparison is a qualitative data analysis technique that is often used throughout the analysis phase of grounded theory research (Strauss & Corbin, 2008). As an ongoing reflective technique, constant comparison allows for the open coding process to advance forward without necessarily altering previously coded data (Charmaz, as cited in Gibbs, 2015). I used constant comparison to tentatively cluster data as the coding process progressed. The forming of the initial clustering structure was loosely influenced by the elements of the study's conceptional framework and shaped by the guided interview questions. Such inductive approach to clustering served two purposes. Firstly, it provided an organized basis for completing the individual member-checking forms in a

way familiar to the participants. Secondly, the tentative clustering facilitated the next phase: focused coding. Figure 2 shows a partial view of the initial clustering of the codes that followed the open coding stage.

Figure 2

Partial View of Initial Clustering of Open Codes



Focused Coding

Strauss and Corbin (2008) advised that following the initial round of open coding, some integrative work must be done with the aim of identifying higher level concepts or themes. Such concepts or themes were then ordered in some logical form for constructing what is termed a *conceptual pyramid* or a *concept map* in NVivo 12 Pro. Similarly, Charmaz described focused coding as the thought process through which the researcher combines line-by-line codes into larger ideas (Charmaz, as cited in Gibbs, 2015).

I studied the initial codes and found conceptual duplications that resulted in combining some codes, renaming the others and re-clustering the resultant codes into a conceptual pyramid. Table 15 shows the initial codes on the left and the resultant final codes on the right, after moving and combining data.

Table 15

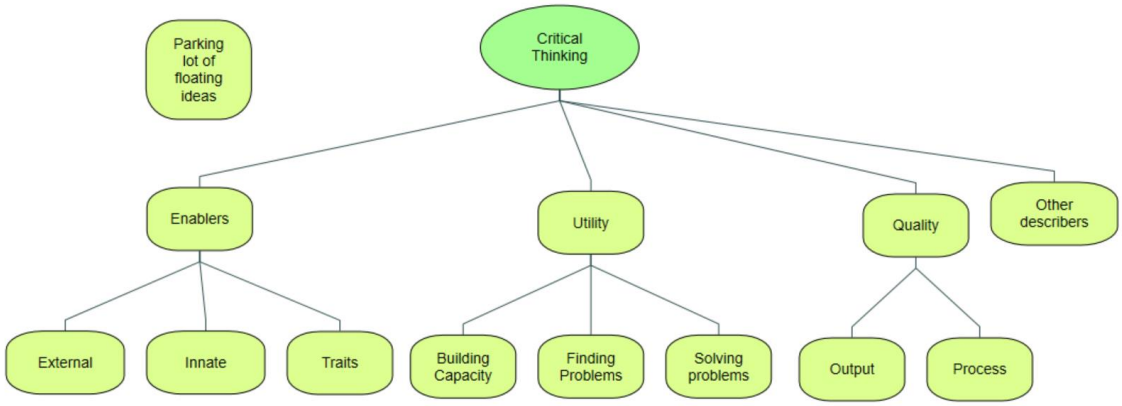
Summary of Moving and Combining Codes

Initial codes	New codes
-See cross-disciplinary similarities -See the critical parts of the big picture -Recognize patterns -Connecting the dots	Bird's eye view (combined)
-Thinking outside of the box -Finding non-conventional paths	Openness to change (moved to)
-Fair -Humility -Letting go of prejudice -Questions own beliefs and assumptions	Unbiased (combined)
-Curious -Motivated -Questions a lot	Purpose orientation (combined)
-Sensibility checks	Validating solutions (moved to)
-Active listening -Attentive to non-verbal -Communication skills	Bidirectional communication (combined)
-Seeing other people's perspective -Respectful of other's perspective	Empathy (combined)
-Respectful of facts -Working with data	Objective mindedness (combined
-Comfortable with ambiguity -Not jumping into conclusion	Tolerance for ambiguity (combined)
-Awareness of assumptions -Recognizing constraints -Questioning assumptions -Questions own beliefs and assumptions	Recognizing constraints and assumptions (combined)
-CT not needed for technical routine -Technical routine -Emergency response	Leave CT out (moved to)
-Problems with no answers -Problems with no solutions	Open-ended Problems (combined)

With the combining and moving of the codes, the code count dropped from 77 to 61, which contributed to the conceptual pyramid illustrated in Figure 3. The pyramid contains concepts that describe critical thinking from multiple perspectives, which include characteristics of the critical thinker, the premises where critical thinking is applied, and two approaches for evaluating the outcome of the process. Three codes left unassociated with any of the key concepts at this stage. These codes, however, contain useful data which contributed to the enrichment of the discussion. The unconnected node labeled "Parking lot of floating ideas" is the holding place for the three codes.

Figure 3

Conceptual Pyramid



A detailed codebook for the above conceptual pyramid is presented in Appendix C.

Theoretical Sampling

Like constant comparison, I used theoretical sampling in alternating between the data collection and analysis tasks. As an example, through the open coding process, I

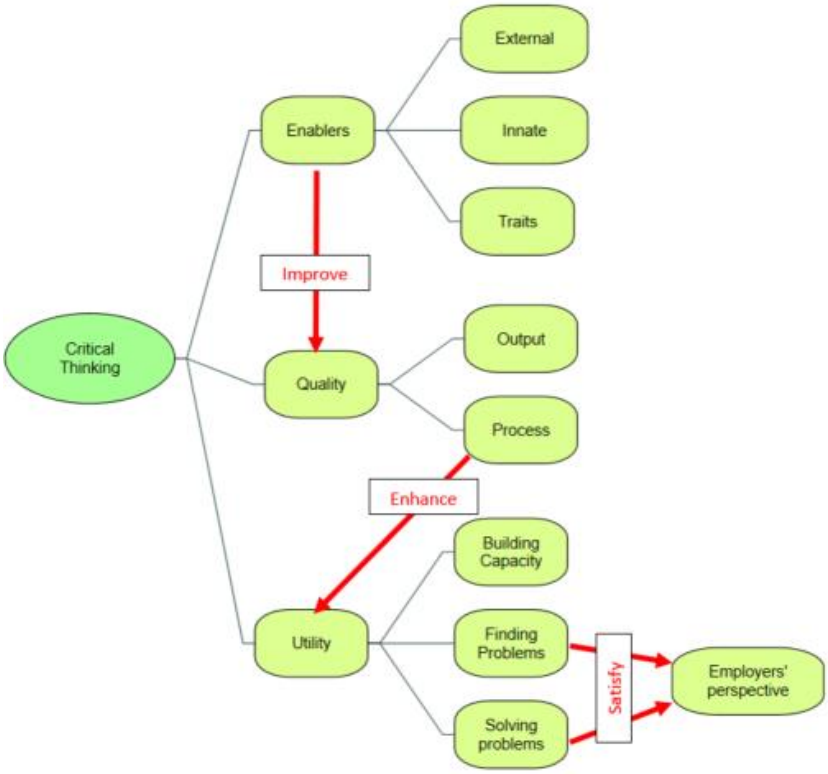
identified an incident, contributed by P16, in which design gridlocks were untangled through inspirations derived from the animal kingdom. In pursuit of further similar incidents, I contacted participants with product design background and could arrange a follow up interview with P5, who contributed two incidents where similarities found in animals unlocked stubborn design problems. On another occasion, P6 shed light on how the ability to see patterns, could transfer solutions found in one domain into another. The same thematic thought was contributed by P7, which triggered my further probing into the role of pattern recognition in the upcoming interviews.

Axial Coding

The distinguishing line between focused coding and axial coding is rather blur in grounded theory literature. When asked to describe both, Charmaz made no distinctions and implied that merging and combining codes into higher level conceptual meanings, constituted the intent (Charmaz in Gibbs, 2015). Charmaz' description entails identification of relationships among codes and categories, but in a hierarchical sense. I used axial coding to describe other nonhierarchical relationships that may by hypothesized through data analysis. This interpretation of axial coding is aligned with the nonprescriptive descriptions found in the writing of Strauss and Corbin's (2008) on the collection of data analysis tools available for grounded theory studies. Apart from the hierarchical relationships described earlier under focused coding, the lateral (axial) relationship extracted from codes and categories are depicted in Figure 4.

Figure 4

Axial Coding



Memo Taking

I created memos where transcribed content required did not capture the intended meaning of a participant's contribution. Also, mems were created to transcribe data captured through video clips and in coding such observations to nodes. Finally, reflective memos were created to explain the rationale behind the relationships subject of the axial coding structure as shown in Figure 6.

Discrepant Cases

Also, referred to as negative cases (Strauss & Corbin, 2008), discrepant cases were earmarked in the open coding process. Examples included the influence that education and prior learning has on the critical thinking ability of an individual. Some participants though education mattered, while the others thought it did not. Another example related to the use of critical thinking. Unlike most participants, P12 and P14 contributed thoughts on situations where critical thinking was not only not required, but may be unwelcomed.

Evidence of Trustworthiness

Credibility

Member checking was used to assure credibility of the grounded data collected through interviews. Following each interview, its recording was transcribed for subsequent content analysis. I identified, summarized, and entered key points derived from the transcripts into a member-checking formed, which had been formatted in a way to consistent with the standard interview guided questions. The member checking form used in the study is shown in Appendix D. Other measures used to assure credibility included reflexivity through memo writing and the application of the constant comparison technique. On occasions, I could triangulate interview data through confirming evidence found in video clips.

Transferability

Two techniques were used in this research project, namely variation in participant selection and thick description. Perspectives from participants with varied backgrounds

and disciplines were sourced to assure that the observations and findings are not deeply rooted in specific contexts. Thick description manifested itself in the length of interview transcripts which ranged from 20 to 51 pages and averaging 29 pages. As this was a qualitative study, the findings are not transferable given a small sample size and geography, but as the research process was well defined, it may be transferable.

Dependability

Throughout the data collection process, I implemented a standard procedure, which included a standard interview protocol. Such procedure and protocol were compliant with the IRB approval for the current study. Standardizing procedures and protocols allowed for comparability of collected data, and their subsequent aggregation into categorical concepts. Dependability was also enhanced during the data analysis process using NVivo 12 Pro. The software facilitated standardized holding, organizing and data and presenting inferences through visual means.

Confirmability

Korstjens and Moser (2018) suggested that leaving an audit trail facilitates confirmability by offering transparency describing the research steps. I maintained confidential interview data and provided a thorough description of all steps in this writing. All data and records were digitally documented for confidential safekeeping, for a period of 5 years, as prescribed by the Walden University's IRB approval for this dissertation.

Study Results

This dissertation is centered on addressing two central research questions. The first question sought to obtain an operational definition of the concept of critical thinking as perceived by the scholar-practitioner community of British Columbia. The second question concerned obtaining an appreciation of the connections between critical thinking and problem-solving. The focused coding process resulted in the conceptual pyramid. The axial coding process provided the foundation for the explanatory theory for connecting the key concepts together. The elements associated with each research question are described in the following part of this writing.

RQ 1: What is Critical Thinking?

Inspired by the conceptual framework shown in Figure 1, and the ensuing reviewed literature, data were generally organized to assist in defining critical thinking through (a) the traits and other enabling factors pertaining to the critical thinking actor, (b) ways that the outcome of critical thinking is assessed with respect to its quality, and (c) the kinds of outcomes a critical thinking process produces. The coding structure presented in Appendix C details the supporting elements of the three conceptual categories, consistent with the conceptual pyramid. Further explanation of the results is presented next.

Enablers

One way to understand what critical thinking is, is to look at how critical thinkers behave and how their personalities are characterized. This view is consistent with the spirit and intent of grounded theory, as it seeks to understand the reality the way it is,

rather than what it should be. Figure 5 provides quotes contributed by participants on personality traits, and Figure 6 contains quotes on external enablers.

Figure 5

Participants' Quotes on Personality Traits

Communicator
"I think the value that and again I've seen it in my own career. The human connection. Our clients are all humans. Eventually, when you get up the ladder of the … corporation, there's a man. And being able to engage with him brain to brain, human to human has been a key" (P6).
"I call it active listening" (P5).
"appreciative inquiry skills" (P12).
Bird's eye viewer
"It needs to be taken from data into story. And processed so that you have a story about it and when we do that, we have a story" (P7).
"Well, I'm a dyslexic so I'm going to say a person who can see patterns ... Because that's the critical thinking. Oh, that pattern … Oh but look, it shows up over there. The patterns is what they see in that. So … he starts linking the patterns" (P7)
"As we say, connect the dots. In other words, there are many things going on, but how do they relate to each other?" (P9).
"see the big picture of things and see ways to solve those kind of problems in the technical world" (P15).
"like transfer some ideas you know from like completely, let's say strange and foreign environment into your environment" (P16).
Empathetic
"See other people's perspectives. The critical thinker would come up in open. 'cause they're willing to look at what other people think" (P7).
"They also had great respect, great respect for other people and their points of view" (P9).
"Perhaps it will also raise … their level of empathy, their level of relationships" (P14)
Resourceful
"They explore the possibilities of why this event is here" (P9).
"So from my perspective, critical thinking is the ability in someone to put together or look at a topic from different angles, gather evidence about about potential solutions rank these potential solutions based on the success chances for each of them and then

based on this assessment come up with the conclusion for what is going to be the best approach" (P10).
"It's a willingness to widen your perspective" (P8).
Metacognitively aware
"I don't think you can think critically without a high level of self awareness … You have to know what you're thinking you're feeling in your emotions, not just thinking because I don't think we do ever just think. I think we're emotion 1st and then beautiful abstract added on but it's all fed by the energy of the hormones" (P7).
"It requires internal ability, discipline, willingness". (P12)
"It's a willingness to be uncomfortable in a process of self exploration … So looking at how we're thinking about what we're observing so and this may not be a reflective piece. It may be looking at the nature of the thought process is we're going through, so those are two dimensions, self reflection and thinking about the way we're. Thinking about a situation" (P8)
Objective
"I am collecting the facts and I need to use the fact that are observable and the reliable of course" (P4).
"They would say, oh, well, that's interesting. I wonder what's behind that. Wonder how that came to that kind of a conclusion they were looking for components that were leading to an answer and to see if some of those components should be there should not be there so" (P9).
"Gather information and then make judgments based on the fact. Assessing the facts" (P10).
"Analyze, qualify, and analyze the process" (P12).
"Critical thinking works when you've got data. It's not the only thing you need, but you need data in order to think about it or say what if and do that" (P16).
Open to change
"In my mind and the most powerful solutions are ones that are … there's sort of an a-ha moment that comes in at WOW would not have found that on the traditional linear path you had to jump something conceptually, jump … to a different path" (P6).
"Where the box is. Yes, yes. Where sometimes the box is just the domain of engineering, right? We need to think outside of that" (P6).
"Critical thinking to me starts with open(ness) to change" (P7).
Motivated
"They're not reactive, they're more proactive and they're thinking, uh? They have done a lot of thinking behind it, planning before. Reflecting" (P5).
"I can find myself just enjoying the unconventionality of the solutions" (P6).

"To be a critical thinker is vital. To address the world most pressing problems and to make this place a better planet" (P12).
"Critical thinking is something where it's grounded in curiosity" (P8).
"The people I knew they were always curious as little kids are probably looking underneath things all the time" (P9).
"I mean they should care. For one thing, it is also one thing that comes to mind, because if they don't care if they are not interested in the topics or anything, I mean, why should they bother?" (14).
Realistic
"I know what are the assumptions that I'm making" (P4).
"Challenging of assumptions constantly" (P9).
"we need more out of the box thinking. And this this woman said, well maybe ... we need is bigger box (for) thinking. I said what do you mean? She said well when you're out of the box, there are no parameters. There are no boundaries. There's nothing. You're out in space seemingly floating around doing whatever you want. She said what I mean by bigger box thinking is that it's bigger you're allowed to think about things, challenge them, but you still are within a framework of safety and rules and certain kind of conditions that you have to be in" (P9).
Adventurist
"The willingness to handle ambiguity" (P12).
"Critical thinking is not trauma not meant to be traumatic. It may be uncomfortable, but it's not meant to be traumatic, so it's a willingness to be flexible and open to exploring new ideas. Even if we end up still … where we started, but it's a willingness to do that. Those are the traits" (P8).
Unbiased
"separating themselves from their ego because everybody has a viewpoint. And if you allow your ego to interfere with. Uh with that? Uh, we are not in my opinion a critical thinker" (P7).
"Part of critical thinking is to set aside your own prejudices" (P9).
"It's a willingness to be uncomfortable in a process of self exploration, and it's also a process that ideally may lead to either changing the assumptions or supporting the assumptions we presently have as being relatively valid in that moment" (P8).
Investigator
"The first step is again to understand what it's going on" (P4).
"So one of the reasons why problem solving is challenging is we're not the assumptions we're working under that. Find the problem. May in actuality be more

symptoms of the problem and not actually addressed. Focusing on the problem itself." (P8).
"First of all, examine the way we're framing the problem. Even the language we're using to describe the problem that gets into neurolinguistic program … So the way we're actually even the words we're using, and then also looking at the assumptions that we're making about the problem and the context within which we're operating in that problem" (P8).
"Sometimes the root causes of problems are really somewhere else. I mean, the reflection is only on maybe the operations, but deep down there are other things going on so the person who is able to just dig deeper into what's going on in here" (P14).
Validator
"We still get employers who say the students cannot recognize garbage answers garbage out. Well, the finite element program said the stress was such giga pascals must be true, but. It can't be. Can you feel it? And the employers are usually describing it in terms of can you feel it. Because that's how they learned it. So that the first step is definitely that ability just to vet the output from the model" (P6).
"Majority of the time the students have to rely on simulations in the computer. How valid these simulations are, again, are under questions" (P10).

Figure 6

Participants' Quotes on External Enablers

Education
"What I really like these students to take from my courses are not memorizing the formula, although the courses that I'm teaching are mostly … math involved a lot of questions, I want them to get the sense and build the sort of engineering sense because if they have it, they never forget it. So these are the things that's no matter if you are. 25 years old, recently graduated or 55 years old, 65 years old. You never forget." (P10).
"I think when you're a trained professional, I think you can't help looking at any problem except in the context of your skill set. You know, I look at boats out on the water and I can assess you know whether they're good, bad, or indifferent fairly quickly just by looking at them, but I guess that's critical thinking you know is that a good boat or not? Does it perform well? Does it look good?" (P15).
"Part of the way I work as a designer and other people I respect it's a combination of critical thinking. Intuition heuristic rules experience fit together and they fit in different proportions depending on the scope of the problem" (P16).

Education (discrepant)
"I don't think education has to do with that, because, uh, you know. You could have critical thinkers in all aspects of, all areas of, the society. So that's not a part of the rubric." (P5).
"Like Google teams, research doesn't matter the skills in problem solving. You don't have to have that to be able to contribute … You come in and you bring that … you don't have to have expertise in the problem. What you do is you have expertise in forming a story that's valid and being able to understand how things impact each other and then you can take that from you know, building a bicycle wheel to running your operating room" (P7).
"I was going to say maybe well educated, but actually it's perhaps not necessary. If you have, uh, an ability to question things and not really take things as they are, then I mean it doesn't necessarily mean that you have to be highly educated or anything. It can be also somebody who is just the man on the street, as they say, the lay person" (P16).
Practice
"perfected by practice" (P4)
"Part of the way I work as a designer and other people I respect it's it's a combination of critical thinking. Intuition heuristic rules experience fit together and they fit in different proportions depending on the scope of the problem. That's where you need the conceptualization. Do you need to understand this is a problem we felt dealt with before?" (P16).

Two participants (P4 and P15) also believed that critical thinking is an *innate property* which some people possess, while the others do not. P4 said it is "difficult to teach," and P15 said,

> I don't know how to teach that. I think you know I regard it as an innate capability. You know you either are or you aren't. You can teach people certain aspects about painting or technical or drawing. But yeah, it's. It's not an easily learned skill.

P8 also noted that, in some quarters, there is hesitation to engage in discussions requiring critical thinking as they may cause discomfort, or controversies of different sorts.

Quality

The discussion about quality concerns the degree to which the critical thinker performed the task well. A job well done could be judged either by evaluation the output as to whether it meets preset expectations, or by verifying if key measures have been taken the process, which suggests that reasonable efforts have been exerted in executing the steps of the process. Figure 7 summarizes those output quality dimensions, which provide evidence of a job well done. Figure 8 offers outlines some of the key measures that should be taken in executing critical thinking processes which assure that reasonable efforts have been exerted to produce the output.

Figure 7

Participants' Quotes on Elements of Output Quality

Feasible solutions
"We still get employers who say the students cannot recognize garbage answers, garbage out. Well, the finite element program said the stress was such giga pascals must be true. But, it can't be. Can you feel it? And the employers are usually describing it in terms of can you feel it. Because that's how they learned it. So that the first step is definitely that ability just to vet the output from the model." (P6).
"gather evidence about potential solutions rank these potential solutions based on the success chances for each of them and then based on this assessment come up with the conclusion for what is going to be the best approach." (P10).
Social change
"What is critical thinking in my opinion, I think, critical thinking is a thinking that makes a difference in your life and others … providing changes that make a difference in everybody life … You have the potential to make a difference in people's life and your life in general these are the people who end up in companies, later they become managers and the success of these companies depends on the way you think" (P5).

Figure 8

Participants' Quotes on Elements of Process Quality

Assumptions validated
"Part of the element of critical thinking is a reflective process. That is grounded in challenging those taken for granted or uncritically assimilated assumptions that we hold and I say take it for granted. Because in part, oftentimes, we're not aware of those assumptions. Many times we are but many instances we're not …and it's also a process that ideally may lead … to either changing the assumptions or supporting the assumptions we presently have as being relatively valid in that moment and helpful to us in that … looking at the assumptions that we're making about the problem and the context within which we're operating in that problem" (P8).
"to challenge the assumptions" (P9).
Implications reviewed
"and then I come up with my implication and consequences (P4).
"but definitely when it gets to a level, that's the decision is going to affect an organization or the future, or it is going to have great consequences." (P10).
System view
"the problems and being able to (put) critical thinker three or four or five in a team, all with different perspectives that are all relevant, they can make the hologram. … the hologram, giving you a fuller perspective and" (P5).
"Have we asked all the questions?" (P9).
"One of the things about naval architects that I've always enjoyed is that when you create a ship, you have to know about so many things. I mean, when the ship goes to see with people aboard, the people have to be safe. They have been fed. The sewage has been taking care of, power, has to be done. There's no extension cord back to the shore. There's no fire department. There's no ambulance, there's no hospital. And then the ship has to do its job and has to go into still a very hostile environment. It has to cross an ocean as to make money for the owner ... It's the closest thing to play in God when you're creating something that is almost a living entity in itself" (P16).

Utility

In the context of this study, utility refers to the business or technical areas where critical thinking may provide value. Upon coding of collected data, three areas were

specifically identified. Figure 9 offers a summary of how professional lives could be advanced and developed because of critical thinking. Figure 10 exposes specific ways where critical thinking informs the critical task of finding and defining the right problems. Finally, Figure 11 contains a list of a large variety of business problems, where critical thinking is required to arrive at feasible and effective solutions.

Figure 9

Participants' Quotes on Building Capacity

Influences career advancement
"It's absolutely the tie breaker in the hiring process" (P6).
"I have some data that I show them in a in an economics lecture. I have salary histories of real engineers that worked for me in different companies and you can see the ones that plateaued, or the ones that grew flat and the ones that just kept growing and I can identify those breakpoints because I knew the men involved, the people involved and I can identify this is where he peeked out, and he became a good structural breakpoint analyst, but he never became a structural synthesist" (P6).
"That's gonna be their career builder as I tell the students. That's what will make your career: your being able to problem solve through change and crises. You got a career" (P7).
"To what extent do we (employers) care about it, uh? A great deal. You know, because though those are the people that will become the business leaders" (P15).
Enable self development
"And this is not just in their career. So it can also help them in their life experiences as well. So it doesn't matter what discipline you are going to graduate at the end. If you learn these skills, it's going to be helpful everywhere and it's going to be something that can save you from some of the uh dangers that's maybe in front of you in future. So this this is very important. It's not just for the education, it's for life experience… To teach them something that is going to be used for their life. It's not just for the. Career" (P10).

Figure 10

Participants' Quotes on Finding Problems

Beyond improvement
"Critical thinking is necessary. You cannot just look at your work and continue it to make it better" (P5).
"Creativity in my mind and the most powerful solutions are ones that are, how to say it? It's dumb. There's sort of an a-ha moment that comes in at WOW. (I) would not have found that on the traditional linear path you had to jump something conceptually, jump to a different path" (P6).
Defining problem
"The first step is again to understand what it's going on" (P4).
"So, one of the reasons why problem solving is challenging is we're not the assumptions we're working under that. Find the problem may in actuality be more symptoms of the problem and not actually addressed. Focusing on the problem itself." (P8).
"just questioning issues or digging deeper into the root causes of problems. That is what critical thinking does, of course it helps people to get deeper in the roots of the problem and they would be able to just fix that ..." (P14).
"First of all, really understanding the problem. You know, if you don't understand the problem well, you're never going to come up with a sensible solution. So, I think that's kind of a really short answer to it, you know and understand the problem … So I mean understand the problem. What is your client or your user or your question? Is it clear, do you really understand what problem you're trying to solve?" (P15).
"One of the things I see people sometimes, when I discuss critical thing, is that it's about analysis as a starting point. For me it's not the starting point. It is conceptualisation and I think maybe when we come to talk about specific examples I can give better idea. For me, both in our education system and how a lot of engineers work, they jump too quickly to analysis by assuming what a design is and then starting to analyze. I think a lot more thinking should happen at the front end and identifying in a conceptual way the problem itself. That's not always well done. You're seldom presented with a problem that's either properly defined or well enough to find to analyze. And then you have to go through a systematic process of critical thinking" (P16).

Figure 11

Participants' Quotes on Problem Types

Open-ended problems
"I have a lot of open-ended problems. Destination could be anywhere and only the ones that do the critical thinking take this project to the right direction … and I will stay with them on a weekly basis, challenging their thoughts and trying to show them the alternatives? Uh, is there another solution? Why don't you come up with another design? Maybe 50 designs. Don't get attached to what you're done because it's easier. You know, so things like that are very important." (P5).
"I gave them questions that seemingly are simple and yet, frankly, they posed no answer. Now when they say why do you do that? I said, well, you know what, the human brain likes to have answers. We like to have stability. We like to have security. We'd like to know what. The Heck is going on … This is the fascinating thing that I have seen throughout life is. It's a complex or simple question, but it does not have a solution" (P9).
"In engineering majority of the problems are open ended and students for open-ended problems need to be critical. Thinkers need to be problem solvers" (P10)
Competition problems
"But the problems employers certainly face are, yes. Uh, the problems faced with competition, the problems faced (with) planning the production all those kind of as they say, technical issues and they would like certainly. Uh, a student, and a new employee to understand that and but also to understand the human dimension of the workplace" (P9).
"Nowadays, everybody, even the established companies, have to compete with others." (P10).
Consulting problems
"it's a continual process are getting critical thinking definitely in in my in my activity as a consultant … As a consultant, when I go in front of the client and I say, hey, this is the problem and this is the symptom. This is how it's manifested. But this is the root cause. Right, so I can demonstrate the why, why, why, for everything" (P4).
Ethical dilemmas
"I'm putting ethics, morals, values that basket that some. They're going to be presented with a lot of those types of issues. And that's that will require critical thinking … So, issues that require probably compromises or require trade-offs, and I guess to simplify it, to me would be like the triple bottom line issue. This is again simplifying, but I'm trying to go back to critical thinking. Sometimes I try to. Put things together that normally wouldn't go together and so even though we're talking about ethics, I'm

going to that triple bottom line concept of profit, not just profit but profit planet and people. And so I think that in the future, and perhaps even in the present a lot of our issues need to be looked at from those three perspectives, so that's the kind of problems I meant that simply taking trees out of a forest to make paper. It's not that simple anymore. You know, how do we make sure we take care of the society and the planet at the same time?" (P12).
"People should be able to stand up if need be for the rights or for any wrongdoings" (P14).
Sociocultural problems
"The other thing I wanted to say is that a lot of the real world problems that are coming up are no longer this sort of mathematical stresses type problems. They are information flow. There are communication challenges" (P6).
"The kind of problems employees are facing in the workplace, are the human problems. We see a huge rise in failure of emotional wellness, high levels of conflict and workplaces human conflict. We see a lot of emotional dimensions about morale and job satisfaction. They would like to have somebody who understands these things" (P9).
"It's not about fixing things all the time. It's also sometimes the organizational dynamics, the politics involved, and the relationships and everything" (P14).
Leave CT out (discrepant)
"There are technical problems that requires technical solutions that are very hierarchical. Very straightforward, where critical thinking is not necessarily at the top" (P4).
"But problem solving. And critical thinking may be disconnected because you can solve a problem without thinking. Or just following a path that others have gone without challenging the direction" (P5).
"Sometimes the situation calls for critical thinking and sometimes it doesn't. So like an extreme example for me would be if someone in the room fell down and was having a seizure, I wouldn't think critically about it, just kind of go to my rote memory thing so in that …" (P12).
"For intern type jobs they (employers)probably don't want it (critical thinking). They don't want to be argued with and so and it kind of ties in well with transformational leadership to me those transformational leaders think critically. And when I'm hiring, if I'm an employer and I'm hiring a student right out of school I don't expect them to be transformational. I don't expect some sort of fact that might be problematic because they don't have the foundation yet. They don't know my company … And therein lies the rub because if I'm a critical thinker and you hire me to not think critically for a few years, it might be frustrating and demotivating. So, I'm not saying that I have the answer, it's just interesting" (P12).

Urgent problems
“The pressure to be outside the box comes from the time constraint. It comes from the need to have that 30-second answer to finding the centroid, because I don’t have time in a timed exam to perform some computation. So, what are real world examples of that? Field work will generate that type of situation because you have a laborer standing there with a welding torch in his hand waiting for the answer, and so you end up making or building quickly a mental model. It’s only one significant figure accurate. But I think I have captured the significant figures for the parameters that are important. I’ve ignored 20 parameters, because I think they are unimportant. I’ve taken the three that I think are truly important to this problem. I model them mentally so very crudely and I tell him use the one inch plate and weld on both sides. And he starts striking an arc, and I run back to the office and get out a paper and an excel and perform some computations and check my work and I was right. Turns out he could have used three quarter inch, but at least I was safe on that. If it comes out I was wrong or should have been 1 1/2 inch then I design him some brackets and we’ll go add some modulus to the problem ‘cause I know I can add modulus. I have had that type of situation having to be in the field fingerpoint engineer based on a quickly constructed mental model. Some clients like that the boss likes that because it keeps the productivity up. If instead my answer is: Good question. Give me a week. I’ll work it up and I’ll send you a memo. I got a welder sitting on his fingers just doing this.” (P6).
New cases
“There are certain industries, historically, such as financial services or some military, actually you know they are pushing for people because not everything is according to the manual. Right? So, nobody wakes up in the morning, or if this has happened, go to page 72 and do such and such ... Nobody has the crystal ball and nobody has all the answers, but we need to support the answer so that’s why critical thinking helps” (P4). “It’s got a quote that goes something like science seeks to discover what is engineers create what has never been. And for me, that’s sort of the essence of how thinking works ‘cause it’s not something you can just logically go and say this is how it is. You have to create and within the creation isn’t only the creative thinking isn’t just critical thinking, but critical thinking is a key part of creative thinking” (P16).
Obstacle removal problems
“Today, with the pandemic almost two years now there’s no question about it. And even before the pandemic, of course common problems. What is their purpose? What is their goal? How do we achieve that? What obstacles stand in the way?” (P9). “We got interference between these two pieces of equipment. What’s what’s the best way to resolve that in a in a practical way?” (P15).
Product development

"great deal of training to see you know who the customer is, what the customer needs, you know what are the product development cycles, et cetera, et cetera" (P5).
"And part of that is how soon you can come up with the new product. So that's and the other thing is that the critical thinker relevant to this topic (new product) … so the creativity of the critical thinker is gonna be helpful for future products that the company will have so that person is going to monitor what is going around, thinking what is lacking, what the users want and bring all of these elements together to come up with creative solutions" (P10).
Realignment problems
"But in the real life we have an adaptive system where everything is constantly changing and so having an ability to understand you know peripherally and everything that is going on is a key element today in business because the majority of the problems we have our again those adaptive kind of problems" (P4).
Resource allocation problems
"common problems. What is their purpose? What is their goal? How do we achieve that? What obstacles stand in the way? What is the risk management associated with that? What kind of resources?" (P9).
System level problems
"The student moves up and moves from being a graduate to being a journeyman or a practitioner ... so will his problems move up from being very specific. Should this be a one-inch beam or a 2 inch beam? To being … And again I'm using simplistic, accessible solutions but they have to be given a total system problem. To be able to find such total system solutions, the graduate when he's still at the level that his title is graduate, he will not be getting total system problems. He will be getting component level problems and the opportunity for total system solutions to a component level problem are reduced." (P6).
Risk management problems
"common problems. What is their purpose? What is their goal? How do we achieve that? What obstacles stand in the way? What is the risk management associated with that? What kind of resources?" (P9).
Team contributions
"So, corporations as CEO's and all the talk if you want, uh, committees are always bringing their critical thinking, and you know, as one of the major requirements for employees today" (P4).
"they're (employers) also expecting graduates to have the relationship skills too. To create communities of practice and organizations that allow people to solve problems too. So, it's not only their individual but also the ability to create communities in which people can problem solve too" (P8).

> "One of the things that I found, but I've been very lucky in my life to work with a lot of female engineers and there's a difference between male and female engine and I've always tried to work on teams and the one thing I know (is that) the guys do the guy thing which is I know how to solve that and they rush off. The girls quite are quite often the ones that say oh there's maybe another way to look at that. There's a gender difference in terms of how they look at things and that's why I've always had to have, I've always enjoyed having a team mixed gender team because of that … To be a successful mix when you can mix genders because of the different psychology of how you look at problems so." (P16).

RQ 2: Theory and Process

There were three hypothesized relationships among the concepts and categories depicted in the conceptual pyramid, which offer a sequence of causal relationships derived from analyzing the body of data for the current study. Enablers are personal assets available to the critical thinking individual. Well-developed enabling factors support (a) executing higher quality critical thinking processes, and (b) producing higher quality results. A critical thinking process executed with high quality results in the enhancement of the utilities, namely building the critical thinker's capacity, and allowing for relevant problems to be found and defined, and eventually solved satisfactorily. Finally, employer's expectations can be better met through contributions, by the critical thinking employees, to find the right problems and solve, or manage, them effectively.

Summary

This chapter provided answers to the two research questions of the study. For the first question, the concept of critical thinking was defined from three perspectives, namely the traits that characterized the critical thinker, ways to assess the quality of a critical thinking process and exploring the kinds of outcomes a critical thinking process

generates. For the second question, a system view was adopted to visualize and hypothesize the nature of relationships among the stated three elements used to define critical thinking. In sum, I theorized that critical thinking enablers improved the quality of the outcome, which in turn enhanced utilities, which in turn satisfies employers' expectations. The findings of the chapter form the basis for the next, where the elements of the critical thinking definition will be discussed in greater depth, leading up to conclusions and finally a self-assessment narrative on the implication of the study.

Chapter 5: Discussion, Conclusions, and Recommendations

The purpose of this study was to bring clarity on British Columbia's scholar-practitioners' perceptions on critical thinking within the context of the management and engineering. I explored if and how critical thinking capabilities informed and enhanced the effectiveness of an individual to solve engineering and managerial problems in real-world settings. The research journey led to 12 interviews of 11 British Columbia scholar-practitioners. Interpretive grounded theory was used as a research design, which uncovered several personality traits and external factors that contributed to an individual's critical thinking abilities. Another set of findings concerned assessing the quality of the work performed by a critical thinker. Data analysis revealed that critical thinking quality may be assessed by evaluating identified characteristics of the output and/or by reviewing the process through which the output was generated. Based on the participants' experience, areas in which critical thinking could provide value were discovered and aggregated into three categories: finding problems, solving problems, and building the critical thinker's capacities as a professional actor. Finally, theoretical relationships were hypothesized suggesting that the identified critical thinking enablers improved quality both in terms of the output and the performed process leading up to the output, which resulted in improved alignment with employers' expectations.

Interpretation of Findings

Although the study was based on the specific data sourced from British Columbia-based participants, I found the contextualized findings to be partially consistent with the findings reported the body of literature reviewed in Chapter 2. I

provide a comparative interpretation of the findings in the following sections, noting similarities or discrepancies with reviewed literature. The organization of this discussion is loosely influenced by the conceptual framework of the study.

Critical Thinking Enablers

A key finding of the study was the list of personality traits that are typically exhibited by critical thinking individuals in performing challenging tasks such as complex problem-solving. One of the traits was being a communicator; critical thinkers communicate effectively, they listen attentively in pursuit of data and facts and read between the lines, and they are sensitive to nonverbal signs and gestures. This was supported by the literature indicating that creative expression is how the critical thinker transfers newfound outcomes to others (Thompson, 2018), and effective communication is critical in engaging the stakeholders of the subject being challenged (Chester & Allenby, 2019; Dörner & Funke, 2017; Howard et al., 2015; Wright et al., 2019). Another trait was being a bird's eye viewer, meaning critical thinkers can transfer identified patterns from one discipline to another (i.e., from nature to engineering). Contextual and environmental assessment of the subject situation needs to be performed by the critical thinker's view of the big picture (Dörner & Funke, 2017).

Empathetic was another trait of critical thinkers; they appreciate the perspectives and concerns of people affected by implementing their solutions or decisions. The literature similarly the use of stage appreciation, which suggests that one should imagine assuming the position of an affected stakeholder (Dodd, 2019). Critical thinkers are also resourceful, which means they tend to explore multitudes of possibilities (Aboukinane et

al., 2013). Further, critical thinkers are metacognitively aware. Several observers noted the significance of the use of metacognitive traits to the work performed by a critical thinking problem solver (Carriger, 2015, 2016; Dwyer et al., 2014; Lönngren, 2019). The findings also indicated that critical thinkers are objective, grounding their work in hard data and verified facts rather than hearsay (Dörner & Funke, 2017). Despite being objective, they are also open to change (Aboukinane et al., 2013). Critical thinkers are also motivated, performing their tasks with a sense of purpose (Mejía et al., 2019; Wilkin, 2017).

Other findings indicated that critical thinkers are realistic. They appreciate the limitations to possibilities, including those imposed by the operating environment. They understand that a given observation may be true under certain conditions and are careful with unbounded generalization. According to the literature, it is important to investigate the premise of the problem itself before working toward a solution (Aldave et al., 2019).

In addition to being realists, critical thinkers are adventurists. Critical thinkers are willing to patiently venture into uncharted territories and gradually make sense of unstructured scenarios, even if it takes some time to arrive at clarity. There is a need to exercise calm and patience as the cognitive and emotional processes evolves toward conclusion (Dorner & Funke, 2017). However, critical thinkers are unbiased. They are at ease with altering long-held beliefs and starting the thinking process afresh, and they are fair in their judgements and balanced in their assessments. This is a finding that was not referenced in the literature.

Finally, the findings revealed that critical thinkers are investigators and validators. Critical thinkers question the premises to make sure that they are working on the right problem and not on wrongly perceived ones. The process requires the critical thinker to take the time to perform historical and background research on the issue at hand (Díaz Martínez, 2019; Wright et al., 2019). For complex situations, adopting a classical research methodology might prove beneficial to some problem-solving processes (Kavanagh & Rich, 2018). Critical thinkers also engage in validation and sensitivity analysis of the outcomes of their work to distinguish sensible from non-sensical answers. They are aware of model imperfections, including computer programs. The literature noted the need for vetting data and telling apart facts from fictions (van Laar et al., 2018) as well as need for validating the outcome of the process to assure that it is feasible for implementation (Wright, 2019). Other observers also highlighted the importance of testing, evaluation, and verification in critical thinking processes resulting in solutions (Thompson, 2018; Vernon et al., 2016; Zuber & Moody, 2018).

Other than personality traits, I identified two factors that were external to the critical thinker: education and practice. Discrepant views were contributed by the participants of the study with respect to the effect of prior education, training, or acquired subject matter knowledge on an individual's critical thinking ability. Some thought of prior subject matter knowledge to be an essential enabling factor. They argued that a person without possession of pertinent expertise would hardly qualify to arrive at sensible and feasible results. Others expressed a different opinion and thought that an individual could exhibit impressive critical thinking performance for reasons other than prior

knowledge acquired through formal education or training. Despite such split of opinion, the reviewed literature suggested knowledge as an enabling factor, particularly in addressing complex situations (Lönngren, 2019; Mejía et al., 2019; Ester van Laar et al., 2018).

Another external enabler that came out of the data collection and subsequent analysis processes was practice or experience of the critical thinking individual. Coaches can train students to problem-solve by stimulating their thought process into the desired direction (Carvalh, 2016). Three of the participants (P4, P15 & P16) mentioned that critical thinking is developed through experience, with two of the three sharing own stories on how experience came to their help when faced with new challenges.

Another discrepant case emerged in the study regarding whether critical thinking is innate or teachable. This was not noted in the literature, but two of the 11 participants of the study (P4 & P15) suggested that critical thinking is either difficult to teach or unteachable altogether. This is a topic that could lead to controversy, as P8 suggested, and should be handled with professional tact and sensitivity.

Further, as an enabling factor, short-term memory (Dwyer, Hogan, & Stewart, 2014) or working memory (Manalo & Sheppard, 2016) came up in the reviewed literature, but no participant contributed thoughts about it. Perhaps this enabling factor was not found to be significant enough to warrant mentioning. This could be explored in future research.

Critical Thinking Quality

Critical thinking may be performed at different level of quality. Data collected from the study's participants suggested that the quality of the critical thinker's work may be evaluated by looking at the output of the process in terms of feasibility and social implications or through evaluating the process and measures taken to arrive at the output. This output-process perspective was found in the reviewed literature and discussed in Chapter 2 using the terms summative and formative criteria.

Although the criteria extracted from literature are more thorough and comprehensive than the study's data revealed, there were some similarities between the two. For example, I found that a quality output should be a feasible one (see Cooney, 2014; Wechsler et al., 2018; Wright et al., 2019). The same could be said about social change as another output-oriented quality element. As illustrated in Chapter 2, many observers noted that solutions should characterized by usefulness (Dörner & Funke, 2017; Rittel & Webber, 1973), impact (Figl & Recker, 2016; (Mejía et al., 2019; Cooney, 2014), and stakeholder satisfaction (Chester & Allenby, 2019; Wright et al., 2019; Rittel & Webber, 1973).

Regarding process quality, the study findings pointed to three factors that had relative resemblance with literature. I found that it was important for the critical thinker to have validated the assumptions in the process, which was confirmed in the literature (Cooney, 2014). The same applies to system view as found through the study, which aligns with the need for contextual assessment and implies that, in the process, the critical thinker should have taken the context of the issue, including the social environment into

consideration (Dörner & Funke, 2017; Cooney, 2014; T. Rhodes, 2010). Literaure pointed to other process-related factors that did not come up in the study, although some of them were identified under other headings, such as the critical thinker's personality traits for information quality (Cooney, 2014; Manalo & Sheppard, 2016; Mejía et al., 2019). Thses missing-from-the-study factors include engagement (Chester & Allenby, 2019; Dörner & Funke, 2017; Howard et al., 2015; Wright et al., 2019), and throrough risk analysis (Cooney, 2014; Lönngren, 2019; Wright et al., 2019).

Critical Thinking Utility

I found that critical thinkers themselves were the obvious beneficiaries of their engagement in critical thinking. This finding conforms with the observation made by Bandyopadhyay and Szostek (2019) that critical thinking contributed to landing better job opportunities by college graduates. Another finding of the study pointed to the enhancement of problem-finding ability through the disposition of critical thinking. This finding agrees with the findings of Awange et al. (2017) that critical thinkers tend to demonstrate better capabilities in finding *unseen* problems. Aldave et al. (2019) also named exploring the problem space to be the first step in a two-stage problem-solving process. Other observers who saw identifying and defining the problem to be part of the critical thinking process included Cooney (2014), and Podolskiy and Pogozhina (2016).

Almost all interviewed participants asserted that critical thinking informs effective solving of problems of different types. Such assertions are broadly supported in the reviewed literature and a summary of the different types of causal effects. Derived from participants' contributions, Figure 12 contains a list of problem types, which British

Columbia engineering and management professionals are challenged within. The same figure also includes references in the reviewed literature where such problem types were mentioned, if at all.

Figure 12

Types of Management and Engineering Problems per Reviewed Literature

Competition problems: Finding optimal ways to respond to competitor's moves and counter their disruptive pressures. Literature references: • Juran, 1998.
Consulting problems: Assessing a problem scenario on behalf of a client and offer solutions with lasting effects. This includes identification and treatment of root causes rather than just the symptoms. Literature references: None. Emerged from the study.
Ethical dilemmas: Ethical conflicts which often require difficult resolutions. These include balancing among the triple bottom lines of profits, people, and planet. Literature references: • Baird & Parayitam, 2019.
New cases: Unpredictable problems that emerge out of nowhere. They are typically unique and have no off-the-shelf solutions. Literature references: None. Emerged from the study.
Obstacle removal problems: Finding and removing obstacles that stand in the way of achieving pre-set goals. Literature references: • Vernon, 2016 • Altshuller, 2004
Open-ended problems: Problems with no definitive solutions in a classical sense. The effort of the critical thinker turns to managing the issue at hand in a satisfactory, or *good enough*, way. Literature references: • Smalley, 2018 • Rittel & Webber, 1973 • Szarucki, 2015

- Lönngren, 2019
- Wilkin, 2017
- Chester & Allenby, 2019

Product development problems: Identification of customers' needs in terms of problems the customer is seeking to solve. Then designing a product/service to assist the customer in solving such problems.

Literature references:
- Juran, 1998
- Lönngren, 2019

Realignment problems: Responding to changes in organizational eco systems.

Literature references: None. Emerged from the study.

Resource allocation problems: Finding ways to resolve resource allocation problems, including shortages, with the least negative impact on the expected results.

Literature references:
- PMI, 2017

Risk management problems: Identifying risk, as a problem requiring solution, and finding ways to manage it.

Literature references:
- PMI, 2017

Sociocultural problems: Problems related to interactions with other individuals in a social setting. This includes managing personality conflicts.

Literature references:
- Dörner & Funke, 2017
- Termeer et al., 2019
- Aldave et al., 2019

System-level problems: System optimization problems that require global solutions as opposed to component-level or localized solutions.

Literature references:
- Szarucki, 2015
- Marquardt, 1998

Urgent problems: Problems requiring good solutions under time pressure.

Literature references: None. Emerged from the study.

Team contribution: Problems assigned to teams, such as task forces, which require critical thinking contributors.

Literature references:

- Carriger, 2015
- Lönngren, 2019

As a discrepant case, I found that suggested critical thinking was not always required, and in some cases unwelcomed, in real-world business settings. Situations such as following policies and established procedures or solving a routine problem do not typically require much critical thinking, if at all. Peters and Tarpey (2019) named a class of problems as tamed, implying that they are simple enough that they do not require much critical thinking to arrive at an acceptable solution.

Compared to reviewed literature, two problem types that require critical thinking did not emerge from the study's findings, or at least were not identified in clear ways. These include quality problems (Juran 1998), and closing gaps problems (Rittel & Webber, 1973; Ramazani & Jergeas, 2015; Wright, Cairns, O'Brien, & Goodwin, 2019). Other problem types found in the study, lacked counterparts in the literature. These problem types comprise consulting problems, new cases, realignment problems, and most notably, urgent problems.

Limitations of the Study

The data collection phase of the study coincided with the global lockdown due to the COVID-19 pandemic. My initial intention was to meet interview participants in person and look for opportunities where critical thinking was either consciously exercised or performed on an ad hoc basis. Forced by the mandatory lockdown, video conferencing tools had to be used, which took away the benefit of making nonverbal observations and creating stronger rapport with the participants. Such shortcomings were compensated by

finding the participants under less time pressure and in relaxed states which allowed for meaningful interaction under stress-free conditions.

I was also hoping to triangulate interview data through audio-visual material when opportunities presented themselves. Although, I located a four video clips with relevance to the topic, only one was prepared in British Columbia. However, the remaining three contained insight which confirmed some of the sentiments contributed by the participants, which could well be applicable regardless of the special context decided for the study.

Finally, a limitation with respect to dependability imposed itself during the data collection sessions. Although the interview protocol was fully adhered in compliance with the IRB approval, some deviations occurred during the live interactions from participant to participant. These deviations included the order in which the interview questions were addressed and the lack of consistency as far as the depth and breadth of the answers were concerned. Some of the participants, for example, had little to say about this interview question or the other, whereas others focused the bulk of the time discussing one or two questions. I found such inconsistency to be unavoidable, and caused less harm than the alternative of me interjecting to bring the conversation back on the standard track.

Recommendations

The purpose of this study was to discover the perceived meaning of critical thinking as it relates to problem-solving from the perspective of British Columbia's

scholar-practitioner community. By comparing the findings of the study with the reviewed literature, interesting questions surfaced, which are worth further exploration.

The Role of Education

The extent to which the critical thinker's education affect their critical thinking ability was a subject of disagreement among the participants of the study. Some thought that lay people can present thought-provoking questions regardless of their depth of prior knowledge and expertise on the subject matter being challenged for finding a resolution. Other participants valued education in the subject matter to be an essential prerequisite for the exposition of critical thinking. The reviewed literature consistently favored the sentiment that education mattered (Lönngren, 2019; Mejía et al., 2019; Ester van Laar et al., 2018).

What ties into the conversation is another discrepant case that came out of the study, which concerns the question of teachability of critical thinking. Some of the participants believed that critical thinking is a natural quality inherent in a person, and that some people possess that quality, and some do not. This is a subject worth exploring through a separate research project, the findings of which would have significant implications in adopting effective strategies in preparing individuals, including students, for challenges requiring critical thinking.

Short-Term Memory

Reviewed literature pointed to short memory, or working memory as an enabling factor that enhances critical thinking, particularly for problem-solving purposes (Dwyer, Hogan, & Stewart, 2014; Manalo & Sheppard, 2016). Such enabling factors did not

appear in the data collected for the study. Exploring intervention strategies, if any, to develop and strengthen short term memory, as a cognitive resource, would be another research topic worthy of undertaking.

Critical Thinking Quality Determinants

Several factors were identified to inform the quality of the critical thinking process, which are believed to be critical to generating a good outcome. In Chapter 2, such factors are clustered under the umbrella term *formative* quality criteria. While most formative criteria found in the literature overlapped the ones emerged from the study, two went unaccounted for in the participant-supplied data. The two missing criteria are engagement (Chester & Allenby, 2019; Dörner & Funke, 2017; Howard et al., 2015; Wright et al., 2019) and risk analysis (Cooney, 2014; Lönngren, 2019; Wright et al., 2019). The latter criterion was partially included in the study's inferred findings, but due to its significance I believe there is benefit in investigating the effect performing risk analysis, in a critical thinking process, would potentially have on the outcome. Likewise, engagement of third parties, including key stakeholders, seem to be essential to successful execution of a critical thinking process.

Quality and Closing Gaps Problems

In probing for problem types from the study's participants, two types of problems were absent, compared to the reviewed literature: quality problems (Juran, 1998; Liker & Meier, 2006) and problems involving closing, or bridging, identified gaps (Ramazani & Jergeas, 2015; Rittel & Webber, 1973; Wright et al., 2019). The two types of problem were central to effective management of operations functions in organizations, and I

would recommend a follow up study to be conducted to uncover the approaches and strategies used in British Columbia to overcome challenges of these two types. Of importance is the gap-closing types, which are often faced in strategy deployment to transform the organization from its current into the future state determined by its vision and strategic goals.

Urgent Problems

These types of problems emerged from the study and it is significant enough to justify a deeper investigation. Participants shared scenarios from practice where a situation called for an urgent solution, even though it may not be the best solution. There seems to be a practical demand for addressing ad hoc problem which cannot be subject to thorough investigation, due to operational imperatives or emergency. How would a critical thinker perform their problem-solving task when time if a pressing factor? A question worth investigating.

Implications

Social change forms an integral part of Walden University's mission. In structuring this final section of the dissertation, I adopted the social change model developed by the Definition Task Force of the University (Callahan et al., 2012). The model breaks down the concept of social change into three groups and eight dimensions. The retrospective narrative that follows is associated with my self-rating of the dimensions a subjective 1-5 Likert scale, which are summarized as a web map in Figure 13, at the tail-end of this section.

Group A: Knowledge

Dimension 1: Scholarship

In my dual role as scholar-practitioner, embarking on this journey was an opportunity for me to expand my knowledge on a subject that I work with daily. The newly acquired knowledge has already influenced the reshaping of my worldview at a personal level. Gaining awareness of contributing factors to critical thinking--*enablers*- and discovering ways to assess and assure *quality* outcomes of the critical thinking process, so that specified purposes -*utilities*- are met, has given me added capacity to perform my own tasks at a more focused and purposive level. I am hoping that this publication will be found equally beneficial to the readers. *[Likert rating: 5]*

Dimension 2: Systems Thinking

Augmented by the reviewed literature, the wealth of participants' contributions allowed me to connect fragmented elements of a value-chain-like system. Such system starts at the individual critical thinking actor's level, relating them to learning opportunities that are typically available through trainers and educators, which in turn to the employers' community, taking into consideration their practical expectations on the types of challenges new professionals are expected to assist with. *[Likert rating: 4]*

Dimension 3: Reflection

The adopted social change model proposed two forms of reflections to be made, namely *extrospective* and *introspective*. From the extrospective point of view, I expect the findings of the project to inform a larger dialogue which would result in a more efficient alignment between the critical thinking content of university curricular with the

practical expectations, by the employers' community, of engineering and management graduates. Introspectively, the study brought to the surface some important knowledge gaps, such as (a) the extent to which education and training informs critical thinking ability, (b) the impact short term memory may have on an individual's capacity to perform tasks that demand critical thinking, and (c) the use of critical thinking in addressing quality problem as well as strategy deployment challenges. Another important introspective finding related to uncovering a type of practice-driven problems which are characterized by a sense of urgency, rather than perfection. *[Likert rating: 5]*

Group B: Skills

Dimension 4: Practice

As a practitioner, I can envision how the findings of the study can translate into new ways of thinking, which would lead to reconstructing some of the tools and techniques, which I use in my consulting and training practices. However, such outcome was not intended to immediately such tangible impact. *[Likert rating: 2]*

Dimension 5: Collaboration

The findings of the study may be used as a point of departure to initiate collaborative efforts, leading up to improving the links presented in the *systems thinking* perspective presented under Dimension 2. A visual presentation of the system's linkages may be visualized in Figure 6 – Axial Coding. *[Likert rating: 3]*

Dimension 6: Advocacy

The study's purposes excluded advocacy. However, as an unintended consequence, the findings included participants' reflection on the forms and types of

expectations of an important component of the value-chain-like system described earlier: employers. Contributions from the participants exposed a disconnect in the informational flow of the value chain. Some of the concerns were voiced out by the scholar-practitioner participants, which gives voice to the employers' side in potential follow-up discourses on the topic. *[Likert rating: 2]*

Dimension 7: Civil Engagement

Although civil engagement falls outside of the scope and intent of the study, but the resultant findings provided a knowledge foundation for potential engagement with key stakeholders which include educator and employer communities. *[Likert rating: 1]*

Group C: Attitudes

Dimension 8: Humane Ethics

As social entities, organizations are expected to deliver on their social responsibilities, including environmental stewardship. This has given rise to popular concepts, such as the triple-bottom-line, which places demand on the part of organizational actors to maintain a feasible balance among profitability, planet sustainability and people's welfare interests. Striking such balances is a challenging undertaking, which requires the disposition of critical thinking. This study contributed to bringing such societal imperative to the forefront.

As a final thought, there is another ethical implication of the study in the potential it created for follow-up efforts to improve on the alignment between educators' output and employers' input. There is a perceived supplier-customer relationship at play, which is not formalized by contracts or legislations. However, as a scholar-practitioner, I

assume a social responsibility to protect societal resources from unintended leakages of value, or wastages, due to deficiencies of the two groups–educators and employers–in communicating and reconciling differences between the outcome of the education system and the expectations of the practical world as may be articulated by the employer community and other societal forces. *[Likert rating: 5]*

Figure 13

Web Map Based on Walden University's Social Change Model

Conclusions

Improving on the value of the body of work performed by educators, begins with understanding the expectations of key stakeholder communities as well as clarifying the operating definitions of the key terms used in the discourse on the topic. This dissertation satisfied both ends. Supported by data that is grounded in competent participants with dual experiences as educators and as practitioners, it was possible to uncover the meaning of critical thinking and its relationship with problem-solving as perceived in British Columbia. The wealth of the practical experiences of the participants, injected the voice

of the employers' end of the value chain, into the study. This allowed for a focused investigation and the discovery of interesting causalities along the educator-employer value chain. My sincere hope is that this study will contribute to follow-up dialogues that would result in an improved alignment between the key components of the value chain, to ultimately allow for the best use of human capital as the most precious societal resource.

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Appendix A: Demographic Questionnaire Form

Demographics Questionnaire

Your identity and responses will remain confidential and used only in aggregated form for the purposes of the study.

1. Name of Consenting Participant

Enter your answer

2. Gender

- ◯ Woman
- ◯ Man
- ◯ Non-binary
- ◯ Prefer not to say
- ◯ Other

3. Education

- ◯ Post doctorate
- ◯ Doctorate
- ◯ Master
- ◯ Bachelor
- ◯ Prefer not to say
- ◯ Other

4. Age

- ◯ 65+
- ◯ 55-64
- ◯ 45-54
- ◯ 35-44
- ◯ Under 35
- ◯ Prefer not to say

5. Are of expertise

- ◯ Management
- ◯ Engineering
- ◯ Both
- ◯ Other

6. Years of experience as an educator

The value must be a number

7. Years of industry or professional experience as a practitioner

The value must be a number

Appendix B: Initial Open Codes

Name	Description	Files	References
Active listening	Critical thinkers listen attentively in pursuit of data and facts.	2	2
Attentive to non-verbals	Reads between the lines. Sensitive to circumstantial evidence.	1	1
Awareness of assumptions	Appreciates that a given observation may be true under certain conditions. Careful with generalization.	3	5
Challenge the assumptions	Employers expect graduates to challenge assumptions.	1	1
Challenging questions with no answers	Some problems have no particular answer.	1	1
Comfortable with ambiguity	Willing to patiently venture into uncharted territories gradually make sense of unstructured scenarios, even if it takes some time to arrive at clarity.	4	4
Communication skills	Critical thinkers communicate effectively.	5	8
Competition problems	On how best to compete in the market or respond to competitive moves/pressure.	2	2
Consulting problems	Consultants are expected to assess a problem scenario and offer solutions at root-cause levels.	1	2
CT - Letting go of prejudice	Being at ease with altering long-held beliefs and starting the thinking process afresh.	1	2

Name	Description	Files	References
CT connecting the dots	Putting pieces of facts and data together to form a story or the big picture.	4	7
CT finding nonconventional paths to solutions	Allowing the mind to venture into new paths rather than sticking to traditional linear trends inherited from past experiences.	2	2
CT Helps in career advancements	Students who engage in critical thinking tend to have better career success in their work environments.	3	3
CT in the service of PS	If and how critical thinking enables effective problem-solving.	8	13
CT is a process	Critical thinking is a process and not a spontaneous incident or event.	7	9
CT is challenging the status quo	Questioning the utility of current states, rather than submitting to them.	2	2
CT is exploring causality	Tackling a problem at the root-cause level rather than at the symptom level.	3	4
CT is openness to change	Allowing new ideas to stand a chance. The opposite of belief.	1	3
CT is openness to possibilities	Taking alternative solutions into serious consideration.	3	4
CT is questioning assumptions	Consistent challenging of assumptions; Is it safe to assume ...?	2	4
CT is seeing implications and consequences	The ability to predict the implication of implementing a solution, including the entities to be affected.	3	3

Name	Description	Files	References
CT is seeing other people's perspectives	Appreciating the perspectives of people affected by a implementing a solution.	1	1
CT is seeking a 360 perspective	Constructing a 360 degree (or hologram) by gathering multiple perspectives about an issue or a case.	3	4
CT is tackiling uncommon problems	Making an extra effort to identify possible problems which might not be readily obvious.	1	1
CT is thinking outside of the box	Expanding one's thinking beyond their field of study (i.e. engineering). "A bigger box".	3	3
CT takes PS beyond improvement	CT becomes necessary when we have exhausted all incremental improvement opportunities.	1	1
CTnPS ability influence career advancement	Those who exhibit CT capabilities become candidates for promotions and advancements.	3	4
CTnPS ability influence hiring decisions	Employers give preference to hiring individuals capable to demonstrate their critical thinking abilities during recruitment processes.	2	4
Curious	Routinely interested in new discoveries and inquires about the hidden layers of observed facts.	4	4
Difficult to teach	Hard to teach at school. Some believe CT is an innate capability altogether.	3	5

Name	Description	Files	References
Education	The role education plays in the capacity of an individual engaging in critical thinking.	7	12
Emergency response	In emergencies, Ct takes time and is not called for.	1	1
Enables self-development	A critical thinker can manage their life and career more effectively and successfully.	1	3
Ethical dilemmas	Ethical conflicts are abound in business settings and require resolutions. These include balancing among the triple bottom lines.	2	4
Explore all possibilities	The ability to generate alternative explanations or solutions to a given problem.	8	10
Fair	Fair in their assessments and judgements.	1	1
Governments	Government agencies also value critical thinking capabilities of their employees.	2	3
Human relations problems	Related to the sociocultural environment	3	5
Humility	Comfortable acknowledging their shortcoming. Helps in keeping one open to new possibilities. No ego at play.	3	5
Ill-defined	Not many people are clear about the meaning of CT,	1	1

Name	Description	Files	References
In high demand	CT is foundational to success in business and entrepreneurships.	3	4
Leave CT out	Conditions where the use if critical thinking is not required or even discouraged.	3	6
Makes a difference in lives	Critical thinking drives making positive change in lives and societies.	4	9
Makes humans different from machines	Tells apart humans from computers. Computers are incapable of critical thinking.	4	7
Making decisions under time pressure	The ability to use critical thinking under time pressure for expedition of critical tasks.	1	2
Metacognition	Self-awareness and capable management of own cognitive resources.	5	8
Motivated	Perform the CT process with purpose and enjoyment rather than as a task to be done. Solving a problem that touches home at the personal level.	8	12
New cases	Problems that are unpredictable, unique and have no off-the shelf solutions.	2	3
Not jumping into conclusions	Allowing ideas to incubate into their mind and considering alternative possibilities, before making a call.	6	6

Name	Description	Files	References
Obstacle removal problem	Relating to finding and removing obstacles that stand in the way of achieving pre-set goals.	4	4
Perfected through practice	Experience and exposure to problems help develop CT capability.	3	3
Perfection as a hinderance	The ability to tell "good enough" rather than pushing indefinitely for perfection.	2	2
Problems with no particular solutions	Open-ended with high degree of uniqueness.	4	4
Product development	Identification of customer needs in terms of the problems the customer is seeking to solve. Then designing a product/service to assist the customer in solving their problems.	4	4
Question a lot	A person with an inquiring mind. Finds and asks good questions, frequently. Doesn't take observations at their face value.	6	8
Questioning own beliefs or assumptions	Being open-minded and ready to alter their long-held beliefs, where warranted. Also, has revisits assumptions and adjust as needed.	4	8
Rarely used	People are generally hesitant to engage in critical thinking	5	5
Realignment problems	Responding to changes in organizational eco systems.	1	1
Recognize patterns	Seeing patterns across cases and episodes. Also connecting patterns.	2	3

Name	Description	Files	References
	Working toward accumulating evidence to form rules.		
Recognizing constraints	Appreciating the limitations to possibilities, including those imposed by the operating environment.	3	3
Resource allocation problems	What kind of resources are needed and do we have enough of them to allocated to where they are required?	1	1
Respectful of facts	Their work is grounded in hard facts.	1	1
Respectful of others' perspectives	Eager to learn other people's points of view, and sensitivities.	4	4
Risk management problems	Identifying risk, as a problem and managing it.	1	1
See cross-disciplinary similarities	The ability to see similarities across different settings to adopt solution ideas to given problems. For example learning from the animal kingdom to inform engineering design problems.	2	4
See the critical parts of the big picture	The ability to filter out noise (or insignificant elements) from the big picture to facilitate making effective decisions.	5	9
Sensibility checks	The ability to distinguish non-sensical answers that occasionally come out of models, including computer programs.	2	2
System-level problems	System vs. component-level problems/optimization. Global vs. localized solution.	4	7

Name	Description	Files	References
Team players	Employers want employees to contribute CT in team configurations.	2	3
Teams and committees	Including critical thinkers of different sorts in team configurations.	3	5
Technical routine	Simple problems may be solved without much critical thinking.	2	2
Technical routine (2)	Mundane problems that have routine and procedural solutions, often resembling textbook examples. Require little-to-no critical thinking.	3	5
They care	Do employers care about critical thinking and to what extent?	10	18
Understanding the premise of the problem	Use of critical thinking to question the premise to make sure that we are working on the right problem and not on a wrongly perceived one.	6	11
Universities do poorly in addressing CT	Anecdotal assessment of the work done by higher education to prepare students to become effective critical thinkers.	7	12
Validating solutions	Validation and sensitivity analysis and acknowledging the imperfections of any models used in developing solution alternatives.	2	3
Working with data	Versed with data gathering, validation and analysis.	6	10

Appendix C: Codebook

Name	Description
CT is ...	Miscellaneous thoughts describing what CT is.
CT in the service of PS	If and how critical thinking enables effective problem-solving.
CT is a process	Critical thinking is a process and not a spontaneous incident or event.
CT is challenging the status quo	Questioning the utility of current states, rather than submitting to them.
CT is exploring causality	Tackling a problem at the root-cause level rather than at the symptom level.
CT is openness to possibilities	Taking alternative solutions into serious consideration.
Ill-defined	Not many people are clear about the meaning of CT,
In high demand	CT is foundational to success in business and entrepreneurships.
Makes humans different from machines	Tells apart humans from computers. Computers are incapable of critical thinking.
Rarely used	People are generally hesitant to engage in critical thinking
Enablers	Characteristics of a critical thinker.
External	Factors external to the critical thinker's personality, behavior or attitude.
Education	The role education plays in the capacity of an individual engaging in critical thinking.

Name	Description
Effective	Education helps or required.
Ineffective	Education doesn't matter.
Practice	Experience and exposure to problems help develop CT capability, which are perfected through practice.
Innate	Hard to teach at school. Some believe CT is an innate capability altogether.
Traits	Factors internal to the critical thinker's personality, behavior or attitude.
Adventurist	Willing to patiently venture into uncharted territories gradually make sense of unstructured scenarios, even if it takes some time to arrive at clarity. Allowing ideas to incubate into their mind and considering alternative possibilities, before making a call.
Bird's eye viewer	The ability to see similarities across different settings to adopt solution ideas to given problems. For example, learning from the animal kingdom to inform engineering design problems. The ability to filter out noise (or insignificant elements) from the big picture to facilitate making effective decisions. Seeing patterns across cases and episodes. Also connecting patterns. Working toward accumulating evidence to form rules. Putting pieces of facts and data together to form a story or the big picture.
Communicator	Critical thinkers communicate effectively. Critical thinkers listen attentively in pursuit of data and facts. Reads between the lines. Sensitive to circumstantial evidence.
Empathetic	Eager to learn other people's points of view, and sensitivities. Appreciating the perspectives of people affected by implementing a solution.

Name	Description
Investigator	Use of critical thinking to question the premise to make sure that we are working on the right problem and not on a wrongly perceived one.
Metacognitively aware	Self-awareness and capable management of own cognitive resources.
Motivated	Perform the CT process with purpose and enjoyment rather than as a task to be done. Solving a problem that touches home at the personal level. Routinely interested in new discoveries and inquires about the hidden layers of observed facts. A person with an inquiring mind. Finds and asks good questions, frequently. Doesn't take observations at their face value.
Objective	Versed with data gathering, validation and analysis. Their work is grounded in hard data and facts.
Open to change	Allowing new ideas to stand a chance. The opposite of belief. Expanding one's thinking beyond their field of study (i.e. engineering). "A bigger box". Allowing the mind to venture into new paths rather than sticking to traditional linear trends inherited from past experiences.
Realistic	Appreciating the limitations to possibilities, including those imposed by the operating environment. Appreciates that a given observation may be true under certain conditions. Careful with generalization.
Resourceful	The ability to generate alternative explanations or solutions to a given problem. Explores multiple possibilities.
Unbiased	Comfortable acknowledging their shortcoming. Being at ease with altering long-held beliefs and starting the thinking process afresh. Helps in keeping one open to

Name	Description
	new possibilities. No ego at play. Fair in their assessments and judgements.
Validator	Validation and sensitivity analysis and acknowledging the imperfections of any models used in developing solution alternatives. The ability to distinguish non-sensical answers that occasionally come out of models, including computer programs.
Parking lot	Potentially useful thoughts that do not fit particular categories.
Perfection as a hinderance	The ability to tell "good enough" rather than pushing indefinitely for perfection.
Team players	Employers want employees to contribute CT in team configurations.
They care	Do employers care about critical thinking and to what extent?
Universities do poorly in addressing CT	Anecdotal assessment of the work done by higher education to prepare students to become effective critical thinkers.
Quality	How it is evaluated.
Output	Judging CT by looking at the results.
Feasible solutions	Validation and sensitivity analysis and acknowledging the imperfections of any models used in developing solution alternatives. The ability to distinguish non-sensical answers that occasionally come out of models, including computer programs.
Social change	Critical thinking drives making positive change in lives and societies.

Name	Description
Process	Judging CT by looking at the process leading to the result.
Assumptions validated	Have all assumptions been challenged for validation?
Implications reviewed	Have all implication of implementing a solution, including affected entities, been identified?
System view	Constructing a 360 degree (or hologram) by gathering multiple perspectives about an issue or a case.
Utility	Application areas where CT can be of value..
Building capacity	Driving excellence at the individual level.
Enables self-development	A critical thinker can manage their life and career more effectively and successfully.
Influence career advancement	Those who exhibit CT capabilities become candidates for promotions and advancements.
Finding problems	Used in finding problems and defining them, including distinguishing between symptoms and causes.
Beyond improvement	CT becomes necessary when we have exhausted all incremental improvement opportunities.
Defining problems	Use of critical thinking to question the premise to make sure that we are working on the right problem and not on a wrongly perceived one.
Solving problems (types)	The types of problems, solving which can use critical thinking.
Competition problems	On how best to compete in the market or respond to competitive moves/pressure.

Name	Description
Consulting problems	Consultants are expected to assess a problem scenario and offer solutions at root-cause levels.
Ethical dilemmas	Ethical conflicts are abounded in business settings and require resolutions. These include balancing among the triple bottom lines.
Leave CT out (discrepant)	Conditions where the use if critical thinking is not required or even discouraged.
New cases	Problems that are unpredictable, unique and have no off-the shelf solutions.
Obstacle removal problems	Relating to finding and removing obstacles that stand in the way of achieving pre-set goals.
Open-ended problems	Open-ended with no definitive solutions in the classical sense.
Product development	Identification of customer needs in terms of the problems the customer is seeking to solve. Then designing a product/service to assist the customer in solving their problems.
Realignment problems	Responding to changes in organizational eco systems.
Resource allocation problems	What kind of resources are needed, and do we have enough of them to allocated to where they are required?
Risk management problems	Identifying risk, as a problem and managing it.
Sociocultural problems	Related to the sociocultural environment

Name	Description
System-level problems	System vs. component-level problems/optimization. Global vs. localized solution.
Team contributions	Including critical thinkers of different sorts in team configurations.
Urgent problems	The ability to use critical thinking under time pressure for expedition of critical tasks.

Appendix D: Member Checking Form

Confidential Member Checking Summary	
Participant	
Interview date	

Dear XYZ,

- Please don't worry about language perfection. You will not be quoted, and I am primarily interested in the verbatim (in-vivo) version of your input.
- Please add any comments, corrections, additions or clarifications in the right hand column.
- Please return this form back to me at your earliest convenience.

Much appreciated!

Key points captured

Question	Contributions	Interviewee corrections, additions or comments
Q 1.1		
Q 1.2		
Q 1.3		
Q 2.1		
Q 2.2		
Q 2.3		
Q 2.4		

Commented [BA1]: What is critical thinking from your perspective?

Commented [BA2]: How would you characterize a critical thinker (traits, skills, etc.)?

Commented [BA3]: What rubrics would you use to assess a person's critical thinking capacity?

Commented [BA4]: Why is there so much emphasis on critical thinking in higher education?

Commented [BA5]: How would you describe the relationship, if any, between critical thinking and problem-solving?

Commented [BA6]: What kinds of problems employers expect the graduates to address in real-world workplace settings?

Commented [BA7]: To what extent employers care about a graduate's ability to solve those problems (identified above)?