DOES EXPOSURE TO PROBLEM-BASED LEARNING STRATEGIES INCREASE POSTFORMAL THOUGHT AND NEED FOR COGNITION IN HIGHER EDUCATION STUDENTS?

A QUASI-EXPERIMENTAL STUDY

by

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LIST OF ABBREVIATIONS

Abbreviation	Description
PBL	Problem-based Learning
PFT	Postformal Thought
NFC	Need for Cognition
NFCS	Need for Cognition Scale
ANOVA	Analysis of Variance
ANCOVA	Analysis of Covariance

ABSTRACT

While the importance of technical skills has been established for decades, the demand for complex problem-solving and higher order reasoning skills in higher education adult learners has been steadily increasing. In light of these demands, it is important to consider alternative approaches to learning, such a problem-based learning (PBL). Although research on PBL has demonstrated increased higher order reasoning skills, very few studies exist that examine PBL's effects on the development of postformal thought (PFT) and need for cognition (NFC), the motivation to engage in complex problem-oriented tasks. This quasi-experimental study sought to answer the questions whether exposure to PBL has any effects on PFT and NFC in adult students.

A total of 99 adult students from higher education institutions across Central Texas represented the experimental PBL (n=47) group and the traditional lecture-based group (n=52) that served as the control group. To measure potential changes in reasoning, both groups received the PFT and NFC instruments at baseline and posttest. Data were analyzed using One-Way ANOVA and ANCOVA. Results showed increased levels in NFC following exposure to PBL while no significant differences were found in PFT between the groups. Given the findings, PBL may have the ability to foster skills beyond factual learning and hard skills as shown by increased levels in the interest to solve complex problems, indicated by the NFC scale. This study showed that students had a

higher motivation to apply higher order reasoning skills in the context of problem-solving following participation in problem-based learning courses.

I. INTRODUCTION

In the midst of increasing complexity of 21st century life, the ability to deal with unpredictable events characterized by ambiguity and uncertainty is becoming increasingly essential for solving complex and ill-defined problems (Campbell & Kresyman, 2015; Casner-Lotto, & Barrington, 2006; Griffin & Care, 2015; National Research Council, 2012). The Association of American Colleges and Universities published a report in 2015 that disseminates employers' preference for competencies and skills of recent graduates; over 90% of employers think that a candidate's ability 'to think critically, communicate clearly, and solve complex problems is more important than his or her undergraduate major' (Hart Research Associates, 2015, p. 6). The job analysis website O*NET defines these skills as having the ability to solve ill-structured and unfamiliar problems in intricate real-world settings (O*NET, 2018). By definition, ill-defined problems have no set criteria or immediate correct solutions that are available for judging the adequacy or quality of an approach to problem-solving, making the problem-solving process complex und unpredictable (Yan & Arlin, 1995).

However, a survey by Bloomberg Next (2018) revealed a significant gap in higher education students' "hard" and "soft skills"; only 35% of employers think that adult graduates are equipped with complex reasoning, problem-solving skills, adaptability and agility. The aforementioned soft skills are defined by the ability to engage in interpersonal and social activities that allow for successful participation in teamwork, problem-solving and negotiation processes while maintaining a degree of flexibility, work ethic and self-awareness (Dixon et al., 2010; Robles, 2012). More importantly, the study revealed that employers refer to budget restrictions as a major challenge to invest

into training recently hired college graduates on problem-solving and communication skills, implying that higher education institutions should invest in producing graduates with the described skill set (Bloomberg Next, 2018).

While there may be a variety of methods to prepare adult students to face challenges of the 21st century workplace, there is no certainty that these approaches are implemented in every academic program. And if they are, they may not connect foundational knowledge of a discipline to problem-solving. Moreover, while collaborative group projects have been connected with developing problem-solving and communication (Jollands & Molyneaux, 2012; Vogler et al., 2018) learning exclusively through group projects is not inherently or necessarily problem-based (Netshandama & Farrell, 2006; Savery, 2006) or may simply be too short in duration to have an impact on learners' development of problem-solving skills. One educational approach that exposes adult learners to complex problems while integrating theoretical and practice-oriented learning in formal educational settings is called problem-based learning (PBL).

The defining characteristic of PBL is problem-focused learning; adult learners must grapple and work with problem scenarios that are comprised of a dilemma or an ill-defined and complex problem that does not have a preconceived correct solution. Albanese and Mitchell (1993) conceptualized PBL as a learning strategy during which adult students work in groups with assigned roles and engage in self-directed learning, i.e., independent researching and other informative activities, to define the scope and perspective of the problem as it relates to the learners' field of study. One of the distinct and special principles of PBL is that learners spend more time on defining the complex ill-defined problem because PBL requires the learner to consider and synthesize multiple

perspectives and contradicting reasoning patterns, leading to a holistic process of constructing the definition and solution, which considers whole systems rather than limiting attention to fragmented information (Keegan et al., 2017; Savery & Duffy, 2001). Although PBL follows constructivist principles, that is knowledge is co-created and constructed, through active exploration of the problem in groups, PBL courses are guided by the instructor, making PBL a learner-centered approach that follows the principles of adult learning (Keegan et al., 2017). PBL was developed in the medical school field where it is commonly used (Huijser et al., 2015).

While much of the research on PBL focused on adult students' performance and learning outcomes, recent research has begun to examine the psychological gains and cognitive skills that students develop through this approach. PBL is associated with increased student engagement and long-term retention of material (Bijsmans & Schakel, 2018; Hincapié Parra et al., 2018; Strobel & van Barneveld, 2009), and, more importantly, with the development and acquisition of sophisticated reasoning, such as critical (Hincapié Parra et al., 2018; Lopez Brown, 2017) metacognitive (Downing et al., 2009; Loyens et al., 2015) as well as postformal reasoning skills (Wynn et al., 2014).

By definition, critical thinking is the process of constant inquiry and questioning of existing knowledge structures (Hitchcock, 2018) whereas metacognitive thinking patterns facilitate awareness of how one's value system and epistemology influence one's approaches to thinking and acting, giving metacognition a foundational role in the concepts of critical thinking and PFT (Demetriou, 1990; Lai & Viering, 2012; Shrader, 2003; Tarricone, 2011). The core definition of PFT is best illuminated by the difference between formal analytical as well as logic-oriented reasoning and postformal flexible

relativistic reasoning. In theory, the formal reasoning approach is guided by binary, dichotomous and absolute thinking patterns and thus may exacerbate the integration of the new contradicting knowledge into an existing knowledge schema due to a lack of cognitive flexibility. The relativistic and flexible kind of reasoning, however, allows for making sense of discourse and knowledge ridden by paradoxes through dialectical and relativistic cognitive mechanisms (Kramer, 1983). Because the preceding formal stage of reasoning does not allow for synthesizing complexity in a meaningful manner, the succeeding postformal reasoning is considered a type of higher order reasoning (Commons et al., 2014).

All three approaches to reasoning, critical, metacognitive and postformal thinking play a profound role in fostering deep reflection and reconstruction of knowledge structures and epistemologies (Magno, 2010; Tarricone, 2011). On a practical level, these approaches to making sense enable the individual to think in flexible ways and thrive in environments in which ambiguous, uncertain, contradicting value systems and views are prevalent. A factor that may mediate the relationship between these higher order reasoning approaches may be a higher Need for Cognition (NFC). NFC represents the extent or tendencies of an individual to engage in cognitively effortful and rather complex activities that require more cognitive resources and time (Cacioppo & Petty, 1982). To assess these tendencies, Cacioppo and Petty (1982) developed the NFC Scale (See Appendix A) that has been used in a variety of settings to measure skills and dispositions related to learning and cognition, such as higher academic performance (Akpur, 2017; Reinhard & Dickhäuser, 2009) as well as increased engagement in cognitive effort and deep learning strategies, which are characterized by the use of higher

order reasoning to solve novel problems (McInerney et al., 2012; Soufi et al., 2014). A recent study by Rudolph et al. (2018) showed that NFC explained moderate to high variability in CPS while accounting for pre-existing differences in reasoning. They established a link between NFC, complex problem-solving (CPS) and the duration of problem exploration during problem-solving tasks. NFC and CPS exploration time together accounted for 41% of the variance in CPS while NFC alone explained only 6% of the variance in CPS exploration time. An additional SEM analysis combined exploration time, NFC, reasoning ability together that explained 59% of the variance in CPS. Although the study' sample consisted of 474 seventh-graders, such links appear transferable to an adult sample.

Because empirical data suggest that the NFC plays a motivational role that influences the acquisition of complex problem-solving skills through a combination of other cognitive dispositions, such as critical thinking (Cazan & Indreica, 2014), metacognition (Coutinho, 2006) or self-efficacy (Day et al., 2007), it may explain increases in postformal thinking through PBL via a desire to engage in effortful tasks during the PBL process.

More importantly, while there is a moderate link between metacognition and NFC (Akpur, 2017) and critical thinking and NFC (Stedman et al., 2009), NFC was found to significantly predict engagement in complex problem-solving in higher education settings (Coutinho, 2006). However, no research exists that explores NFC levels and PFT together in the context of PBL. Precisely, research has not explored whether PBL as an instructional approach may play a role in developing high NFC levels or whether high

levels of NFC at pre-PBL (baseline) possibly moderate the relationship between PFT and participation in PBL.

Statement of the Problem

Although research shows that problem-based learning stimulates increases in metacognition (Downing et al., 2009), critical thinking (Nargundkar et al., 2014) and postformal reasoning (Wynn et al., 2014) in higher education adult learners, it is not clear which experiences and cognitive processes during problem-based learning contribute to these psychological changes. Most empirical studies use quantitative measures to assess metacognition or critical thinking following participation in problem-based learning. While only one study has focused on postformal thought as stimulated by problem-based learning to this day (Wynn et. al, 2014), no studies exist that directly assess need for cognition in relation to problem-based learning, that is, changes in need for cognition levels post problem-based learning in adult learners. Although quantitative, qualitative and mixed-methods studies provide useful data, the amount of the data to explain the effects of problem-based learning are scarce and insufficient to draw meaningful conclusions about the connections between problem-based learning and cognitive processes as well as the experiences related to cognitive changes. Precisely, empirical data do not provide a comprehensive picture of the cognitive and experiential processes based on adult learners' reflections on problem-based learning.

Additionally, considering the differences between higher order reasoning skills and the need to engage in complex tasks - while postformal thought is an 'enabler', the need for cognition is a 'motivator' for working with complex problems. Assessing motivational levels to engage in complex tasks before and after problem-based learning

may not only reveal the effects of exposing adult learners to problem-based learning on their postformal thought and need for cognition levels but may also control for confounding variables, that is higher or lower levels of motivation to engage in cognitively complex tasks. While there is a good amount of intervention-based research on postformal, metacognitive and critical reasoning showing that reasoning changes with the exposure to complex tasks, research on need for cognition has been primarily associative in that it focused on pre-existing individual differences and other factors associated with levels of need for cognition, such as using structural equation regressions to predict performance with need for cognition (Watts et al., 2017).

Purpose of the Study

Given the positive relationship between need for cognition (NFC) and learning strategies that require higher order reasoning as well as increased engagement in complex tasks, it is important to explore whether participation in working with ill-structured problems over the course of three months has a positive impact on adult learners' NFC following problem-based learning (PBL). To do this, a quasi-experimental design was employed to address two separate research questions in this study. The first intention was to examine whether exposure to PBL significantly increases the levels of sophisticated reasoning, in particular relativistic reasoning as assessed by the postformal thought (PFT) questionnaire (See Appendix A) and the NFC scale (NFCS) (Cacioppo & Petty, 1982; Sinnott & Johnson, 1997).

The second intention was to investigate interactions among the dependent variables of PFT and NFC and covariates of gender, age, attitude towards group work and previous exposure to PBL based on participation in PBL. Specifically, the interactions

between (a) PFT and NFC, (b) PFT and covariates and (c) NFC and covariates were of interest in the analysis. Because the motivation to engage in complex reasoning (NFC) is measured in addition to the ability of complex reasoning itself (PFT), the study also intended to demonstrate that the motivation to engage in complex tasks may facilitate increases in complex reasoning. More importantly, assessing NFC may minimize confounding variables, which are unmeasured, but decisive, variables that explain an existing relationship between variables.

Research Questions and Hypotheses

The quantitative design follows a quasi-experimental static-group pretest-posttest design (Fraenkel et al., 2012). To test for statistically significant differences between group means of the PBL and traditional-lecture groups, analysis of variance (ANOVA) was employed using IBM SPSS Statistics, version 25.0 (SPSS® Inc., Chicago, IL). Although the PFT and NFC scales are based on a categorical ordinal scale of measurement (Likert scale), a parametric test was appropriate when used with the bootstrapping technique (Efron & Tibshirani, 1993). In this study, the bootstrapping method adjusted for non-normality in the distribution of means by using estimation of the sampling distribution. Bootstrapping generates multiple data sets via re-sampling with replacement (i.e., an element or data unit is sampled more than once) (Efron & Tibshirani, 1993). The following research questions guided this study:

(1) Does exposure to PBL strategies increase PFT in adult learners?

Null Hypothesis: H_0: There is no difference between mean scores on PFT between the PBL and control groups at post-test. The null hypothesis was tested against the

alternative hypothesis, denoted as H_1: The group means of the PFT levels of the PBL group will be higher than the PFT levels of the control group at post-test measure.

(2) Does exposure to PBL strategies increase the NFC in adult learners following participation in PBL?

Null Hypothesis: H_0: There is no difference between mean scores on NFC between the PBL and control groups at post-test. The null hypothesis was tested against the alternative hypothesis H_1: Alternative hypothesis: H_1: The group means of the NFC levels of the PBL group will be higher than the NFC thought levels of the control group at post-test measure. The null hypotheses (H_0) would be true if no statistically significant differences were detected between the experimental PBL and control groups at the two-tailed post-test measure at the $p < 0.05$ level.

To answer the research questions and test the set hypotheses, the study employed a quasi-experimental design using a PBL (experimental) group and a control group. Adult learners in both groups were administered the PFT instrument and NFC Scale (NFCS), consisting of 10 items each following a Likert-scale format, before and after the exposure to PBL for the experimental and to traditional-lecture courses for the control group.

Significance of the Study

Given the hypotheses and research questions, this study seeks to illuminate learners' positive cognitive development of higher order postformal reasoning and increased NFC facilitated by problem-based learning. From an empirical and academic point of view, the findings of this study may add to the discipline of learning and

instruction in higher education. The results and limitations of this study will likely identify the need for further investigation.

The significance of the study extends pragmatically to professional and educational areas. If PBL facilitates the development of desirable skills, such as higher order reasoning, communication and team collaboration skills, employers may favor hiring graduates previously enrolled in PBL courses. Further, studying these psychological processes and changes of learners in an academic context may yield a positive impact on the policies and curriculum of the higher education system. For example, evidence-based insight of this topic may help educators, decision-makers, leadership in higher education as well as policy makers decide whether it is worth investing time and resources into integrating PBL into the curriculum across a variety of disciplines. This study in particular answered the question whether the effects of PBL are of value to undergraduate adults as measured by the psychological changes of increased PFT and higher NFC levels from which adults may benefit as learners.

Assumptions and Positionality

From the moment of selecting a research topic to the moment of interpreting the results, there are certain assumptions at work that guide a researcher's thinking processes (Malterud, 2001). Although these assumptions are necessary to make sense of the topic of interest and its results, they need to be raised to the surface through the process of reflexivity (May & Perry 2011; Rudestam & Newton, 2014). I synthesize my assumptions as they pertain to learning and development in higher education as my personal framework or, according to Kolb (1984), as an abstract conceptualization based on my experiences and values.

Axiology

I think that learning is more complete when theory connects to practice. Learning via practical approaches is complemented by theoretical or theory-based learning. Learning that is problem-oriented is more purposeful than abstract learning (Lave, 1988). Meaningful connections between theory and practice may facilitate engagement and psychological enrichment leading to changes in the learner's mindset.

Ontology

I assume that during PBL adults experience various levels of discomfort, be it when working in groups or when working in less formal learning spaces, e.g., communities, labs or other open public places, that are outside the traditional classroom. Thus, I suspect all adults change their views and mindsets through formal, informal and non-formal paths of learning to various degrees over the course of their lives.

Epistemology

Finally, a synthesis of my ontological and axiological assumptions produces an epistemology of knowledge acquisition that occurs in interaction between the person's cultural and historical background and the cultural and historical background of the learning environment which the learner enters. In the learning process, the learner and the learning environment are reciprocally influencing each other. It is through such interactive means between the learners and their learning environments that knowledge and meaning-making are co-created in interaction with others.

Positionality

My assumptions stem from my past experiences with learning in higher education. I believe that my educational career did not offer interactive curriculum-based

learning opportunities. Internships were an option and not a requirement; there is no certainty that the intern will be learning in a group to identify a problem, as is the case in PBL. Because internships were not a requirement but an option that students could seek out on their own, I was also tempted not to take on an internship and instead preferred to focus on the heavy and intricate coursework needed for passing tests with high grades. However, my past experiences working with groups were not always pleasant or positive. There were disagreements and there was no time to resolve these because we worked on small projects with limited time. Therefore, I was aware of potential conflicts within groups, which can damage or distort learners' experiences, and in turn inhibit the development of reasoning, if not resolved successfully in a timely manner, during PBL. While I was curious about adult students' experiences with PBL, I had to respect their perceptions of any kind of experience these adult learners may be going through, regardless of my preferences and expectations.

Operational Terms and Definitions

- **Postformal Thought/Thinking (PFT)** occurs when an individual is able to perceive, comprehend and acknowledge multiple perspectives, logics and views that may contradict each other. Despite these contradictions, reasoning postformally allows the individual to perceive these knowledge structures as equally viable and true. Such an insight facilitates a synthesis of the complex and contradicting *multiple frames of reference* or knowledge and belief systems (Inhelder & Piaget, 1958). This reasoning approach has been operationally linked to relativistic thinking, reflective thinking, dialectical reasoning and problem finding (Yan & Arlin, 1995).

- **Need for Cognition (NFC)** translates into the tendency to engage in complex task on a broad level (Cacioppo & Petty, 1982). NFC's operations are defined by perseverance of working on a complex task. A person scoring high on NFC is expected to show commitment and willingness to engage in a prolonged complex problem-solving process that requires cognitive effort. In contrast to high NFC behaviors, operations of low NFC are characterized by the common use of heuristics and refusal to engage in extended elaborations and analyses of issues to complete the task more efficiently (Petty et al., 2009).
- **Ill-structured or Complex Problems** are problems that cannot be easily defined and solved. Such problems are represented in daily life of moral, political or professional dimensions, which makes them highly debatable (Morgan, 2006). When a problem is highly ill-structured, stake holders tend to disagree on a variety of causes of the problem and the generated solutions to the contested problem. To successfully manage a complex problem and to generate a viable solution on a practical level, multiple negotiations are necessary to accommodate the conflicting needs of the stakeholders affected by the problem. Typically, a complex problem is ongoing because the generated solutions have no objective measure of success due to its high complexity. In the end, this ongoing process of managing the ill-structured problem requires regular revisiting and reformulation (Morgan, 2006).
- **Problem-based Learning (PBL)** is a hands-on approach to learning about a subject matter of an academic discipline that is highly student-centered, problem-focused and semi-structured. Learners are presented with an unresolved issue,

situation or problem that is ill-structured or open-ended. As such, these problems must be carefully chosen, must engage the learner and they must be based on real-life problems (Boud & Feletti, 1997). Learners must then actively engage in the process of defining what the problem is by participating in field experience activities in various forms. Ideally, the learners apply their previously acquired knowledge and theory in the PBL situation. The complex, ambiguous or uncertain nature of the process of problem-finding (i.e. defining the problem by considering multiple views and possibilities) is expected to foster the development of desirable skills and attributes, such as team communication, acknowledgement of different and conflicting views, critical thinking and tolerance for ambiguity. The learner-centered aspect fosters self-directed and active learning through first-hand experience including independent research, reaching out to experts and stakeholders and participation in the agency, industry or community of the discipline (Boud & Feletti, 1997; Strobel & van Barneveld, 2009). Because PBL can have multiple foci depending on the discipline, this learning approach can also be referred to as and categorized into community-based learning (CBL) or service learning (SL).

- **Critical Thinking** is a thinking process in which a person analyzes knowledge through the method of questioning to form a judgment. To think critically requires the ability think in logically consistent, skeptical, highly evaluative and unbiased ways. To engage in a logically consistent evaluation of one's arguments, the process of reflecting on one's thinking is required (Glaser, 1942).

- **Metacognition** is the mental process of thinking about thinking. It is the ability to engage in "knowing about knowing" through the awareness of what, how and why a person thinks in a particular manner. Because of the ability to think about thinking, metacognition is considered a higher-order reasoning skill. Given the ability to be aware of the ways in which a person thinks, thinking metacognitively provides access to knowledge about when and how to use certain strategies for learning or problem-solving. Metacognition is a premise for regulation of cognition (Hofer & Sinatra, 2010).
- **Dialectical Reasoning/Relativistic Reasoning** is conceptually similar to postformal reasoning, dialectical thought is defined through the cognitive process of seeking a synthesis of multiple seemingly opposing viewpoints. To facilitate the dialectical thinking process, relativistic thinking is the basis for dialectic thinking. In relativistic reasoning, beliefs and values are considered viable and true relative to the culture, language and history in which these knowledge structures emerged (Grossmann et al., 2008).
- **Higher-order Thinking/Reasoning** involves analysis, evaluation and synthesis to make sense of a complex subject matter and to create new knowledge. Given that these skills require more cognitive effort and processing, they are considered to be of a higher order that go beyond the learning of facts and concepts (Griffin, 2014). Complex judgmental thinking skills such as critical thinking, metacognition and postformal and dialectical thinking fall under the category of higher order reasoning skills.

- **Problem Finding** is a phenomenon that has been shown to follow problem solving, according Yan and Arlin's (1995) factor analysis. Before developing cognitive abilities of intricate problem finding, the individual first engages in concrete problem-solving that has a set of correct solutions. The experience of solving concrete problems is essential for developing problem finding abilities that are associated with ill-structured problems that have no defined set of solutions. Because problem-finding is inherently dialectical and relativistic, its operations have been linked to paradigmatic transformations in a variety of disciplines (Yan & Arlin, 1995).

Summary

In light of the research that indicates changes in adult learners' reasoning following metacognitive and problem-oriented instructional interventions, reasoning approaches are part of a cognitive developmental process that occurs in interaction with the individual and the environment. While there is a good amount of intervention-based research on postformal, metacognitive and critical reasoning showing that reasoning changes with the exposure to complex tasks, research on NFC has been primarily associative in that it focused on pre-existing individual differences and other factors associated with levels of NFC, such as using structural equation regressions to predict performance with NFC (Watts et al., 2017).

The purpose of this study was to examine the cognitive developmental effects of PBL on adult undergraduate students. The first intention was to assess whether levels of PFT and levels of NFC, as measured by the NFC scale (NFCS) and PFT questionnaire (Cacioppo & Petty, 1982; Sinnott & Johnson, 1997), increase significantly following

participation in and exposure to problem-based learning over the course of a semester. The second intention was to investigate interactions among the dependent variables of PFT and NFC and covariates of gender, age, attitude towards group work and previous exposure to PBL based on participation in PBL. Specifically, the interactions between (a) PFT and NFC, (b) PFT and covariates and (c) NFC and covariates were of interest in the analysis. Because the motivation to engage in complex reasoning (NFC) is measured in addition to the ability of complex reasoning itself (PFT), the study also intended to demonstrate that the motivation to engage in complex tasks may facilitate increases in complex reasoning. More importantly, assessing NFC may minimize confounding variables, which are unmeasured, but decisive, variables that explain an existing relationship between variables.

II. REVIEW OF LITERATURE

This literature review consists of two parts. The first part is a conceptual and empirical overview of theory relevant to the topic as disseminated by seminal research. A background of PFT, metacognition and their connections to critical thinking will be presented in the first part followed by a background and empirical overview of PBL. Each of these aspects will be considered in the context of learning and education. The second part is the actual review of the literature that focuses on studies that examined a particular type of higher order reasoning skill in the context of PBL. In this review, selection of literature was based on set inclusion criteria, including a timeframe that encompasses recent research.

Considering the organization into two parts of this review, the purpose of this literature review is to not only review existing studies on the connections between critical, postformal and metacognitive reasoning and PBL in the context of higher education, but to also provide an empirical overview and theoretical background of relevant concepts. More importantly, the third purpose is to identify and clearly outline the unstudied factors, or a combination thereof, to this date. In addition to research gaps as they pertain to this topic, the common limitations of the employed research designs should provide a justification for subsequent research design to be used to study the unexplored factors.

The inclusion criteria for this review sets the limits to published studies that focused on examining changes in thinking and learning through PBL in university students and were published from 2005 to 2020. The review also includes, however, dated seminal research that has established the theoretical links between reasoning skills

and other relevant concepts, such as exposure to learning and educational strategies, empirically. The studies were organized into the major types of research design because the design (i.e., quantitative or qualitative) is connected thematically to the topic and constructs being studied. In the available literature, two major thinking styles, in addition to PFT, were deemed important for the review as they pertain to my topic of PFT and PBL. Studies focusing on metacognition and critical thinking in the context of PBL were considered important cognitive skills that theoretically overlap with PFT.

In the empirical overview, the cnceptual connections between postformal thinking and other higher order reasoning skills (Lai & Viering, 2012; Demetriou, 1990) in educational and learning contexts will be clearly presented. For example, because metacognition is the process of knowing about knowing, the metacognitive experience is a profound approach to thinking via a heightened sense of awareness of cognition. This awareness of cognition is likely to foster critical thinking. Through critical thinking, learners have the ability to question not only the learned content and concepts, but they are also required to justify their views and critically evaluate their own views and the views of others (Casey, 2012). Given these connections, studies that focused on PBL as an intervention that may or may not foster the development of these higher order reasoning skills were considered particularly relevant for this literature review.

This chapter reviews existing research that demonstrates the effectiveness of PBL in promoting postformal thinking and metacognitive awareness in higher education students. Following the review of existing studies, the discussion section will outline the gaps that current research has not addressed and provide recommendations for research

design for prospective studies on the effects of PBL on cognitive development in college students.

Parameters of the Review

The subsequent sections will delineate the methods used to retrieve and screen through sources before reviewing existing research on the effectiveness of PBL to foster cognitive growth in adult college students. The review was guided by the following questions; 1) To what extent is PBL effective in helping college learners develop higher order reasoning skills as defined by thinking metacognitively, critically and postformally; 2) In what ways does the developmental process of postformal and metacognitive thought occur?

Methodology

For this review of the literature, a primary search through Education Source (EBSCO), Dissertations and Theses (ProQuest), and Google Scholar databases for research articles and dissertations published between 2005 and 2020 was conducted. Key terms for the search were problem-based learning, metacognition, PFT (and Thinking) and critical thinking. Examples of key term combinations for the search were *postformal* AND *problem-based learning*; *metacognitive* AND *problem-based learning* AND *(undergraduate OR graduate) students.*

A secondary search involved the snowballing technique, also called forward and backward reference searching, through which I was able to find other very useful studies and articles by screening reference lists of relevant studies. Based on the database search, 160 sources were found for further screening. A total of 22 research studies and one meta-analysis, found through database and reference lists screenings, met the inclusion

criteria for a full review process. The following section will briefly explain and justify the inclusion criteria.

Inclusion Criteria

The main focus of this review is to investigate the effects of problem-based learning on university students' cognitive development. For this review, cognitive development of metacognitive awareness and PFT were of particular interest. This review intends to explore whether cognitive changes, associated with metacognition and PFT, are fostered through PBL. The study sample of the reviewed studies consists of adults of all ages, although a few studies with teenage samples were included. The criteria for this exception were based on (1) the findings were substantial and meaningful, and (2) no studies with similar foci and an adult sample were available.

Empirical research studies that focus on intervention-based effects of PBL as a learning approach on cognitive growth were considered relevant for this review. These include exclusively quantitative or mixed-method studies employing true or quasi-experimental design. The review is organized by quantitative and mixed-methods and qualitative research design. Because the reviewed mixed-methods studies were predominantly quantitative with a subsequent qualitative component, they were included in the same section with quantitative studies. Further, to offer an explanatory insight to cognitive changes, studies with students' perceptions and reports on PBL as they pertain to changes in thinking and learning patterns were also deemed relevant for this review. Studies were excluded that investigate various PBL effects or outcomes other than cognitive elements related to Metacognition or PFT.

Related Theoretical Frameworks

Considering the effects of postformal thinking on reasoning, learning and problem-solving, postformal operations of thought should be prompted in adult higher education. Moran (1991) argued that it is possible to cultivate postformal thinking in adult education. In addition to presenting research findings that confirm cognitive changes towards postformal operations of thought in adults, he proposed a model consisting of six steps that should be embedded into adult education to promote such cognitive development. The nature of the steps to be employed is problem-focused, that is, the approach involves dilemmas and other ill-structured aspects of a situation. It also reflects the dialectical process as a means of working through a problem with others to arrive at the realization that multiple perspectives are equally valuable (Moran, 1991).

An early study by Demetriou (1990) also laid the groundwork for promoting postformal and metacognitive reasoning through the exposure to ill-structured problems in college settings. Demetriou (1990) studied how adults make sense of ill-structured problems by presenting four different problems and recording their explanations of how and why they arrived at their conclusions using different metacognitive categories. Not only did his findings demonstrate a strong link between PFT and metacognitive reasoning, but he also observed a high occurrence of this link particularly in adult university students. He explained that adult learners in higher education contexts are exposed to a variety of problems on a frequent basis and thus have developed reflective processes and awareness of their thinking because their environment demands this type of cognitive development.

More importantly, Demetriou (1990) connected the operations of PFT to metacognitive reasoning because both constructs involve the synthesis of multiple, sometimes contradicting, views and concepts through reflection. Further, being able to integrate various systems of thought means that problem-finding may be more meaningful for critical reflection than problem-solving because the process of defining the problem determines the quality of solving it. While the process of engaging in problem-finding requires problem-solving, problem-solving alone does not sufficiently explain problem-finding (Yan & Arlin, 1995). Given the convergent validity between metacognition and PFT from Demetriou's (1990) study, PFT and metacognition will be treated as interchangeable concepts in the literature review of the second chapter. A more recent study by Vukman (2005) connected metacognition and dialectical and relativistic thinking when studying adults' thinking-aloud problem-solving approaches, in addition to questionnaire data. Vukman's main finding was that dialectical and metacognitive thinking patterns increase with age and reach their highest level in mature adulthood, indicating that these operations of thought are learned and acquired.

Another empirical contribution to cultivating PFT in adults is based on multiple small-scale studies by William Torbert (1994). Torbert (1994) proposed an action inquiry approach to cultivating postformal thinking in employees and leaders. Action inquiry, as the term reveals, is the practice of inquiry or reflection during action. As opposed to reflecting on one's actions at later stages, reflection is embedded into action through inquiry "in the very midst of one's workday action" (Torbert, 1994, p. 182). Blending action and inquiry throughout one's learning process allows the practitioner to reframe and re-appraise assumptions during the process of action. Using a variety of measurement

tools, such as sentence completion forms and inventories, Torbert (1994) found that employees with leadership positions practiced the action inquiry approach and employed reasoning at the postformal stages of cognitive development. A key difference of the leadership practice that promotes postformal development was attributed to holding an influential position in multiple organizations in a given timeframe. In other words, working with a variety of organizations promotes, if not demands, and inter-systemic or inter-paradigmatic worldview due the different nature of each organization (Torbert, 1994).

Given the established link between postformal reasoning ability and environmental factors (Sinnott & Johnson, 1997), I suspect that it is possible to develop postformal reasoning skills by exposing adult learners to complex and challenging ill-defined problems and dilemmas during which they must immerse themselves into various problems and perspectives before reaching a conclusion. PBL is one method for promoting and cultivating such skills in college adults. Although there are few studies that investigated the effects of PBL on the development of postformal reasoning, plenty of research exists on the effects of PBL on developing metacognition in adult university students. Theoretically as well as empirically metacognition and postformal thinking are connected which will become evident in the review of the research on PBL.

Postformal Thought

PFT involves multiple operational thought processes that are distinct from formal and conventional thinking approaches. Unlike formal thinking structures, for example, postformal operations allow for constructive organization of contradicting and complex knowledge systems and perspectives. The realization that multiple perspectives are of

equal value implies that no truth is absolute and complete, making purely objective knowledge and decisions impossible to achieve (Sinnott, 1994).

The inability to achieve purely objective and complete truth stems from the selective nature of the human mind. When attending to a variety of factors, adults and children automatically fail to attend to other factors, making it impossible to reach a complete view of the world or the phenomena of interest (Kegan, 1994). The selection of factors that play a role in adults' reasoning is contingent on individual past experiences and subjective preferences. Thus, adult postformal reasoning is context-bound and contains a certain level of subjectivity (Kegan, 1994). When adults begin to understand that their beliefs and assumptions guide their thinking, they realize that it is their beliefs and assumptions that influence their actions and thinking. In other words, these beliefs and assumptions create a reality based on their value system (Kegan et al., 2009). During problem-based learning the adult is expected to create a synthesis of various world-views and realities, which allows the learner to integrate various perceptions of truth (Kramer & Bacelar, 1994).

Postformal thinking emerged as a reaction to the cognitive developmental stages developed by the developmental psychologist Piaget. Piaget's theory imparts that a child's developmental process is represented through the interaction between environment and the child's currently dominating cognitive stage (1972). As the child's cognition gradually develops into qualitatively more abstract and sophisticated structures, knowledge acquisition and learning are influenced by socialization, environment and maturation (Lefrançois, 1972). The major changes that take place cognitively allow the individual to transition from thinking in concrete terms to thinking in abstract and logical

terms. Analytical and logical reasoning allows the individual to evaluate hypothetical situations. This type of thought is called formal reasoning or formal operations, and, according to Piaget, development reaches a threshold in adolescence at the highest formal stage, indicating a halt of cognitive development in adulthood (Lefrançois, 1972).

Following Piagetian theory, psychologists and other developmental theorists observed relativistic thought patterns among adults that are not exclusively limited to logical formal reasoning. As a result, a reconceptualization of adult cognitive development was proposed in an effort to represent reasoning in adulthood adequately (Cavanaugh et al., 1985). Following this re-conceptualization, the theorists associated with PFT were referred to as Neo-Piagetians (Belsky, 1999). What differentiates postformal reasoning from formal analytical thought is that postformal operations involve dialectical and relativistic approaches to discourse to make sense of the world and, specifically, paradoxes that are not easily integrated into a mindset guided by binary, dichotomous and absolute thinking patterns (Kramer, 1983). PFT is context-based and thus more flexible than formal thought. The dialectical and context-based structure of such thinking allows adults to synthesize and integrate various points of view meaningfully by recognizing the equal value of each truth.

Past research revealed that adults continue to develop cognitively beyond formal operations (Sinnott, 1994). Adults demonstrate postformal reasoning when logical and formal reasoning fails to provide answers to ill-defined problems (Basseches, 1984; Kramer & Woodruff, 1986; Markoulis, 1989; Sinnott, 1994; Sternberg, 1984). The PFT questionnaire (See Appendix A) was developed by Sinnott and Johnson (1997) in a study with research administrators whose written responses corresponded with their self-

reported rating on the PFT items. The items in the questionnaire measure the levels of complex thinking, metacognitive reflection, perception of paradoxes and other postformal elements. Cartwright et al. (2009) tested the scale for its internal validity and validity based on three studies. With an alpha coefficient of .63, the questionnaire is only a moderately reliable and valid measure for assessing adults' postformal thinking levels.

As Sinnott's (1989) study indicated, adults may adjust their thinking style to the type of setting, e.g., concrete or ambiguous problems. As a result of these observations, it has been proposed that PFT may not be a distinct stage but is rather an approach to thinking that is part of adults' sets of reasoning skills (Belsky, 1999). While the debate surrounding the question whether PFT is a separate developmental stage following the formal stage or whether it is an extension of the formal stage, this study was less concerned with the nature of the concept of this reasoning style. The focus was on PFT as a malleable trait that can be developed and employed effectively when facing ill-structured problems.

The Role of Postformal Thinking in Higher Education

Research on postformal reasoning and metacognition that addresses learning and performance factors in adult university students establishes the link between these reasoning styles and learning outcomes in higher education. Research on postformal thinking is presented followed by research on metacognition and learning in higher education.

Postformal Thinking in Higher Education

Postformal reasoning has been associated with advanced adult learning and development (Friedman, 2004; Markoulis, 1989; Sonnleitner et al., 2013; Stadler et al.,

2016). Precisely, it has been associated with the ability to work with ill-structured and complex problems constructively in the higher-education settings (Gidley, 2016) as well other contexts. For example, Sinnott and Johnson (1997) established a link between PFT in adults and exposure to complex problems at work.

Given the importance of preparing adults to face ill-defined and complex problems, here I focus on the effects of postformal operational reasoning in the context of higher-education. Past research has shown that postformal reasoning is associated with many aspects of learning in undergraduate and graduate students. Lawson et al. (2007) studied the effects of postformal reasoning and self-efficacy on academic achievement. They found that postformal reasoning abilities were a stronger predictor of academic achievement than self-efficacy. Self-efficacy alone does not predict academic achievement, rather, it is the adults' reasoning abilities that play a role in assessing and estimating their own competencies and abilities to perform a task. The study showed that postfomal reasoning precedes self-efficacy and thus predicts self-efficacy levels. Lawson et al.'s (2007) study confirmed previous claims that focusing solely on improving adults' self-efficacy may not be an effective approach in educational settings (Baumeister et al, 2005).

Following an argumentation-based inquiry course, Acar and Patton (2016) showed that pre-service science teacher students who reasoned postformally showed the ability to solve complex scientific problems and outperform concrete and formal reasoners significantly at pre-test measures of Classroom Test of Scientific Reasoning developed by Anton Lawson (1978), an initial (mid-term) and final exam, and a conceptual knowledge test that measured interpretations of algebraic expressions,

buoyancy, uncertainty, volume, mass temperature and other concepts of the Physics discipline with large and medium effect sizes. These measures were also used to identify the pre-service teachers reasoning styles of concrete, formal and postformal at baseline before the instruction intervention. However, these differences among reasoners decreased following the participation in the argumentation-based inquiry course at post-test measures. These results support the hypothesis that instruction-based interventions or approaches that require adult learners to think at higher levels may change their reasoning styles or skills (Acar & Patton, 2016).

Although these adults employing formal and postformal reasoning styles did not differ in their abilities to understand and retain scientific concepts, postformal reasoners were able to apply acquired knowledge on novel problems more effectively than their concrete and formal reasoner counterparts. In a qualitative case study by Wynn and Okie (2017) prospective teachers showed increased postformal thinking after being exposed to and guided in PBL activities that prompted these teachers to analyze how their perceptions and thinking processes relate to PBL activities and how these synthesized reflections relate to the principles of the National Curriculum Standards of Social Studies (NCSS, 2010). The NCSS principles emphasize the value of building knowledge and continuing to integrate novel concepts as a life-long learner. The adult learners in this study reported that the activities required them to generate multiple solutions to problems ridden with dilemmas. According to one participant, the acquisition as well as the application of higher order reasoning skills becomes a subconscious process.

This finding is in line with Sinnott's (1989) research on the interrelation between the type of problems and the type of thinking patterns in adults. In settings with concrete

problems, adults showed the tendency to employ formal and concrete reasoning approaches to solving problems. In settings with ill-defined and ambiguous problems, adults showed an increased tendency to use postformal reasoning patterns when approaching a complex problem. This shows that PFT is not a fixed trait but can be developed if fostered within the environment through, for example, learning strategies and other interventions. As a formal and predominant learning environment, the higher education context is suitable for fostering post-conventional reasoning abilities in adults to help them estimate their competencies accurately by boosting their self-efficacy (Lawson et al., 2007). In future studies, it would be interesting to determine how much variance is accounted for by postformal reasoning through metacognitive awareness in self-efficacy.

Another study by Chiou (2008) showed that students with a relativistic postformal thinking and learning style were able to choose from various learning approaches to adjust their thinking style to the subject matter. If the subject matter was of a technical nature, relativistic thinkers were able to employ absolute thinking that is more effective in that context (Chiou, 2008). However, the absolute thinkers in the study adhered to their absolutistic reasoning style during learning regardless of the study and subject context. This context-based flexibility and agility in thinking, problem-solving and learning styles among relativistic learners and postformal thinkers indicates a desirable learning approach among college students. This finding indicates that adults with a high degree of flexibility in learning styles are better prepared to satisfy the demands stemming from the different contexts of the real world (Chiou, 2008). Although this section presents only a

few studies of the effects of this reasoning style, it is safe to argue that there are cognitive advantages associated with this thinking pattern in learning contexts.

The Role of Metacognition in Higher Education Adult Learners

Flavell (1979) developed the concept of metacognition in the 1970s. Flavell along with other theorists, distinguishes metacognitive awareness, from metacognitive knowledge and metacognitive experiences, as well as metacognitive monitoring. Flavell (1979) pointed out, these meta-related entities differ in their content and function but remain the same in terms of quality and order of existence. Meta, meaning beyond or above, always implies that an entity, such as an experience or the process of monitoring, occurs with a heightened sense of awareness. Thus, metacognition is the process of knowing about knowing. Metacognition, metacognitive awareness and metacognitive knowledge are used interchangeably in general as well as in this paper.

Metacognition occurs beyond conventional cognition because one possesses knowledge of one's mental processes. When metacognition occurs, one is aware that one's thinking patterns influence how knowledge acquisition and learning occur (Davidson et al., 1994). According to Schraw and Moshman (1995), metacognitive awareness consists of declarative, procedural and conditional knowledge. Declarative knowledge means that the learner remembers to use the acquired skill set, procedural knowledge means that learner knows how to use that skill set and conditional knowledge helps the learner regulate the application of acquired knowledge in accordance with time and other situational factors.

Given the ability to think about thinking, metacognition has been shown to predict and facilitate academic achievement (Isaacson & Fujita, 2006; Pang, 2009; Wagener,

2016), such as high test-performance (Vadhan & Stander, 1994), as well as psychological well-being (Isgör, 2016). For example, despite differences in their approaches to writing, Campo et al. (2016) found that high metacognitive levels of a total of 462 Colombian and French undergraduate students' correlated positively with academic writing performance. While the responses were based on the subscales of Metacognitive Knowledge and Planning Strategies in Writing, it is important to note that the correlations were relatively weak.

Hargrove and Nietfeld's (2015) who used an intervention-design to measure metacognition before and after exposing adult learners to complex activities found slightly better correlations and effect sizes. In their study, adult learners had to think out loud during problem solving in pairs and identify potential obstacles as well as make use of their judgment to rate their problem-solving progress. They used the Metacognitive Awareness Inventory (MAI) to show increases in 122 learners' metacognition using a pre- and post-test design with a control group. The intervention group performed better on a summative subject-specific project as was judged by multiple experts from the discipline. Similar to other studies, which showed increased levels of higher order reasoning following problem-based instruction, Hargrove and Nietfield's study demonstrated positive changes in learners' creative problem-solving and metacognition following metacognitive instruction.

On a psychometrical level, metacognition can be measured using self-report measures or using measured differences of students' expected and actual learning performances (Everson & Tobias, 1998). A small difference between expected and actual performance indicates higher self-efficacy and capacity to assess one's competence to

perform. Therefore, metacognition is associated with better learning outcomes via higher self-efficacy because the learner is accurate at assessing one's capacity and ability to perform a task. The role of metacognition in assessing one's expected performance accurately as compared to actual performance has been studied empirically with significant results (Bell & Volckmann, 2011; Renner & Renner, 2001). The ability to assess one's learning accurately serves as a predictor of positive learning outcomes.

However, metacognition does not automatically lead to successful learning outcomes. In other words, a student with high metacognitive awareness does not automatically and effortlessly employ adjusted study strategies according to difficulty levels (Cao & Nietfeld, 2007). Motivation to study plays a major role in producing the positive learning effects associated with metacognition (Onyekuru & Njoku, 2017). In Onyekuru and Njoku's (2017) review of research on metacognition and motivation to study, it is evident that metacognition and motivation to study correlate positively. Although there is disagreement regarding the directionality of metacognition and motivation to study (Onyekuru & Njoku, 2017), it is clear that without motivation to study learners would not translate their metacognitive knowledge of effective study strategies into actions, that is, would not adjust and re-direct their study habits. In theory, it is thus expected that knowing how to study effectively through metacognitive processes should motivate the learner to adjust their successful study strategies accordingly.

In addition to successful learning outcomes, metacognition is of practical value in the realm of problem-solving. On a theoretical level, the metacognitive problem-solver is aware that the process of problem-solving depends not only on what one knows about the problem but also on how one knows about it. Simply put, the result of a problem-solving

process problem is influenced by the process of finding and defining the problem definition, which can take on various perspectives and epistemologies (Davidson et al., 1994). The variety of definitions of the problem is attributable to the various value and beliefs systems under which individuals operate mentally. However, successful engagement in complex subject matters and problem-solving may require not only metacognition with increasing PFT but it may also require the motivation, or NFC, to sustain one's engagement in complex activities of problem-solving to cultivate and enhance one's awareness of these higher order reasoning abilities. In this regard, PFT and metacognitive awareness intersect and interrelate conceptually (Demetriou, 1990) whereas NFC may moderate the relationship between the application of higher order reasoning skills and PBL.

Need for Cognition

As previously noted, Need for Cognition (NFC) is the tendency to engage in complex effortful tasks. It can also be described as the intrinsic motivation to solve complex or challenging problems that require cognitive effort (Cacioppo & Petty, 1982). Although Cacioppo and Petty (1982) popularized this concept and created a psychometrical measure of NFC, Cohen et al. (1955) originally developed the theory. At its beginning stages, Cohen et al. posited that NFC is an individual's predisposition to engage and acquire a deeper understanding about their surroundings and experiences. The concept was later expanded to include enjoyment of cognitive stimulation, preference for complexity, commitment of cognitive effort, and desire for understanding (Lord & Putrevu, 2006). Because plenty of research exists on NFC, only research that pertains to

the topics of interest in this study, such as cognition related to learning, problem-solving and academic outcomes, will be presented.

A meta-review of 100 empirical works showed that NFC is associated with high self-efficacy, intrinsic motivation to learn and study, attentional control, educational attainment, and other learning outcomes as well as higher aptitude levels of general knowledge and verbal reasoning (Cacioppo et al., 1996). Given these points, it is not surprising that individuals with higher NFC demonstrated attentional resource allocation during information processing and the personality trait of high openness to ideas in confirmatory factor analysis study (Fleischhauer et al., 2010). A more recent path analysis study by Grass, Strobel and Strobel (2017) established strong predictive power of NFC to predict academic performance, high satisfaction with one's studies, and fewer thoughts about quitting/changing one's major as indicators. Correlation analyses showed that NFC has the strongest relationship with study satisfaction (Grass et al., 2017).

However, satisfaction with studying and learning does not uncover which type of learning takes place among individuals with high NFC. Wang et al. (2010) conducted a longitudinal study with over 4,000 undergraduate adult learners to investigate multiple effects of clear classroom instruction on learning approaches, critical thinking dispositions and NFC. While the findings showed a moderate correlation between critical thinking, the deep-learning approaches of higher-order learning, reflective learning, and integrative learning showed stronger relationships with NFC.

More importantly, this study showed that exposure to clear and organized classroom instruction strategies significantly increased NFC levels among adult university students from pre-test measure in 2006 to post-test measures in 2010 while

accounting for a number of factors (Wang et al., 2010). Finally, high NFC predict divergent thinking and creative problem-solving (Butler et al., 2003). Butler et al.'s (2003) study showed a strong relationship between NFC divergent thinking; individuals with higher levels of NFC generated a higher number of solutions and categories compared to individuals lower in NFC. Interestingly, although this study illuminated the facilitating role of generating alternative solutions during ill-structured problem-solving tasks, there was a non-significant relationship between NFC and the quality of solutions. This implies that NFC is a motivational or ideational effort rather than a qualitative representation of a reasoning approach, such as dialectical thinking or PFT.

Taken these empirical findings together, NFC may be a catalyst in the development of higher-order dialectical and divergent reasoning approaches not only through exerted cognitive effort but also through prolonged persistence and engagement in problem-solving. According to Cohen et al., (1955), "an ambiguous situation which lacks sufficient cues for understanding will block the satisfaction of the need, result in a state of tension and frustration, and lead to negative affect toward the frustrating situation. The resultant tension may then lead to active efforts to structure the situation and increase understanding." Considering this assumption, NFC may play a crucial role in the context of PBL where ambiguous situations may arise more than once and may stimulate the need for meaningful integration of the experiences of adult learners. The increased need to understand complex situations may also promote relativistic thinking approaches or to making sense of the multiplicity of views and perspectives.

Problem-Based Learning - The Independent Variable

The term problem-based learning emerged in the 1970ies in the field of medical education (Barrows & Tamblyn, 1980). Problem-based learning is an educational model that arose as a response to medical students' dissatisfaction with the educational structure that was theoretical in nature and merely focused on information retention. Problem-based learning extends beyond memorization of information as students' apply the learned material on a case or problem in the classroom or learning environment. This approach to learning is meant to ease students' transition from theory to practice in the real-world environment.

Although there are many versions of PBL design that vary in the number of steps or emphases of such, most of the designs or frameworks share common principles or elements that must be present to be considered PBL. Hung (2013) comprehensively outlines five major principles under which PBL should be practiced: (a) the problem must be sufficiently complex to which no right answer is immediately evident; (b) self-directed learning should be stimulated by encouraging students to explore possible solutions and options, preferably in small groups; (c) the instructor's role and level of intervention must be well-balanced in that they neither direct nor ignore the students' process of working through the problem - the role of the instructor is to facilitate the process by stimulating inquiry and problem-finding; (d) the problem should be pragmatic and connected to a real-world context to make immediate application of learned material outside of the educational context possible; (e) students engage in a self-reflective process that fosters their ability to independently evaluate and judge their problem-solving skills that are thought to have been influenced by their reasoning leading to the outcome. To do this,

evaluative methods that involve assessment and inventories are employed. Needless to say, PBL principles may be modified for instructional and context-related purposes. However, the main objectives and goals of PBL remain highly similar, if not the same.

Concerning the application of PBL, one of the widely used PBL versions is the Seven Jump approach that was developed at Maastricht University in the Netherlands, which consists of seven steps (Albanese & Mitchell, 1993). The first step involves clarification of terms, theories and concepts. The second step is dedicated to finding and defining the problem through brainstorming. The third step involves the analysis process of the problem during which potential solutions are considered via brainstorming. Outlining a set of solutions and suggestions systematically is the fourth step while the fifth step involves gathering information independently in accordance to the learning objectives. Sharing results gathered independently in the PBL group is the sixth step. The final, seventh step includes synthesis, discussion, reflections and an evaluation by the facilitator (Schmidt 1983).

Although agreement concerning the overall effectiveness of PBL in medical education has been mixed (Albanese & Mitchell, 1993; Vernon & Blake, 1993), using this approach in teaching and learning is highly effective in undergraduate learning contexts (Hmelo-Silver, 2004). Strobel and van Barneveld's (2009) meta-analysis showed that while PBL may be less effective in preparing students for standardized tests that assess students key term and concept memorization, it is a highly effective method of promoting long-term retention of learned material from which students benefit in skill-based settings.

In addition to long-term retention, Strobel and van Barneveld (2009) reported that in PBL conditions, student engagement and perceived satisfaction were significantly higher than in traditional learning contexts. While there are many outcomes associated with PBL, e.g., long-term retention of learned material, self-directed learning and increased interest in the course material (Hmelo-Silver, 2004; Strobel & van Barneveld, 2009), this study focused on PBL's ability to promote elements that comprise the phenomenon of postformal reasoning or PFT.

Quantitative and Mixed-Methods Studies: Problem-based Learning and Higher Order Reasoning Skills

Generally, intervention studies show to what extent a change in metacognition and PFT occurred while qualitative studies explore experiences, perceptions and other relevant phenomena that may explain the development of metacognition and postformal reasoning during PBL. Given these criteria, the literature review intends to reveal the extent to which PBL promotes metacognition and postformal reasoning and the cognitive processes involved during the PBL experience as shown by quantitative and qualitative research design.

Postformal Thought and Problem-based Learning

A few recent studies have shown that PBL promotes PFT in college students (Wynn et al. 2014; Wynn & Okie, 2017). Using a three group mixed methods design, Wynn et al. (2014) compared postformal thinking skills and engagement level of a total of 106 first-year university students that were recruited using convenience sampling and allocated across three groups. One group was taught in a PBL environment, a learning

community (LC) group (interdisciplinary group) was also taught in a PBL environment, and the third group was taught in a traditional lecture and discussion (TLD) environment.

The instructor presented a story related to a historic event containing dilemmas to the students in the PBL courses. The students in the PBL courses were divided into groups to represent each of the three parties that hold conflicting and contradicting positions. What distinguished PBL from traditional history lecture and discussion is that PBL included simulations of conflicting positions that were meant to intensify the reasoning experience and experiential problem-solving through the evaluation of various perspectives. At the end of their PBL instruction, students completed the metacognitive reflection questionnaire that asked them to evaluate and explain the adequacy of reasoning styles (Wynn, 2015). Wynn et al., (2014) call the process of evaluating each reasoning style "meta-systematic scaffolding" (p. 6) or "cognitive scaffolding" (p. 16) to develop postformal thinking abilities.

After one semester, students demonstrated significantly higher gain in postformal thinking skills and engagement compared to students in the TLD course. The PBL Learning Community group demonstrated the highest gain in metacognition and postformal thinking compared to the non-LC PBL and the TLD groups. However, the non-LC PBL group significantly scored higher on the PFT questionnaire than the TLD group.

Following the statistical data analysis, qualitative data analysis identified that emerging themes were dialectic in nature. Students highlighted the importance of understanding contradicting perspectives before evaluating them as evident in the qualitative responses. They also learned how context influences decision-making. The

TLD group's responses highlighted a grasp of content and the awareness of the existence of two conflicting sides rather than postformal elements. Given these distinct cognitive effects that Problem-Based Learning had on students, it would be reasonable to expect an increase in college students' ability to question taught content critically. Next, I review several studies that have shown the increase in critical thinking through PBL.

Critical Thinking and Problem-based Learning

Theoretically, elements of critical thinking are connected to metacognition and postformal reasoning. It is the cognitive process of questioning one's beliefs and approach to thinking that connect meta- and post-conventional cognition (Bassett, 2016; Cummings, 2015). Several studies showed that students who were engaged in critical thinking developed metacognition as the process of inquiry stimulates awareness of how one arrives at conclusions (Arslan, 2015; Magno, 2010; Uzuntiryaki-Kondakci, & Capa-Aydin, 2013).

In light of these theoretical connections, Gholami et al. (2016) found significantly increased metacognitive awareness and critical thinking skills after teaching 40 nursing students using PBL. The participants' critical thinking levels were obtained via the pre- and post-test method. The PBL intervention was administered over a period of two months by trained facilitators with four years of clinical experience.

Results demonstrated that critical thinking skills significantly increased after the PBL intervention and two metacognitive components of deduction and evaluation as measured by the Metacognitive Awareness Inventory (MAI). While deduction, the ability to apply learned knowledge and material on an upcoming problem in the real-world, is a generally valuable and useful skill for higher education students, it is the developed skill

of evaluating one's problem-solving competencies and processes that directly connects to metacognition. Findings also showed that students improved their abilities to identify and clarify the complex problem and experiment with hypotheses before initiating debates on alternative solutions. The authors also suggest that acceptance of divergent views occurred to increase critical thinking scores as well.

Given that both Gholami et al.'s (2016) as well as Wynn et al.'s (2014) studies employed a static-group pre-test post-test design, a threat to internal validity exists as alternative explanations that are not attributable to the effects of PBL could be responsible for the results. The static-group design implies that already existing groups were employed. A research design without random assignment creates room for errors or extraneous variables that are not controlled for but could contribute to the results. For example, commonly shared student characteristics that stem from environmental factors to which students are exposed in a particular area could have facilitated the outcomes.

The positive effects of PBL could be connected to the external factors of the classroom, such as a positive non-judgmental learning environment that fosters reflection effectively and employs a trained PBL facilitator, indicating that not every environment is receptive to positive outcomes of PBL. Administering the Critical Thinking instrument along with the MAI prior to the intervention may have primed students to increase their critical thinking and develop habits related to metacognition. More research is needed on the factors that interact with the effectiveness of PBL. Finally, the small sample size of 40 students (Gholami et al., 2016) limits the ability to generalize the results beyond the scope of this study.

EL-Shaer and Gaber (2014) conducted a quasi-experimental study with a considerably larger sample (*n*=200) consisting of undergraduate nursing students (mean age of 22). EL-Shaer and Gaber's (2014) study also revealed that increases in critical thinking are not correlated with increased knowledge, implying that changes in reasoning are incidental and occur in addition to knowledge acquisition during PBL. Interestingly, Choi's (2004) quasi-experimental study with 76 nursing undergraduate students did not find any increases in critical thinking but significant increases in metacognition. This can be related to the inventories or instruments used to measure critical thinking (e.g., low face or construct validity) or the small sample size. However, this result indicates that metacognition consistently increases after PBL.

Nargundkar, Samaddar and Mukhopadhyay (2014) studied the effects of PBL on critical thinking among business school students with similar positive results characterized by increased critical thinking skills. The novel aspect of Nargundkar et al.'s (2014) study is that they reversed the traditional instructional order by presenting a business-related problem first to stimulate possible solutions before introducing subject-specific business concepts using a textbook. In this study, students improved on their final exam scores, obtained higher scores on the team project performance and, most importantly, significantly increased critical thinking as evidenced by students' analyses of various scenarios. However, it remains unclear what the authors defined or considered as indicative of increased CT as demonstrated by students' answers and analyses.
While Nargundkar et al.'s (2014) study design is a static-group quasi-experimental approach that includes a control group, no random assignment was employed to assign students to groups. They also did not provide details of students' demographic

characteristics and the instructors' level of familiarity with PBL practice. The study's total sample of 268 business students is a robust sample size.

According to another study by Hung et al. (2015), PBL proved to be effective in promoting critical thinking skills in mental health students. Unlike the previous studies, this study used a true experimental design by assigning 44 mental health students randomly to the experimental and control groups. The experimental group received a program with a combination of PBL and conventional lecture-based sessions and the control group received only lecture-based sessions over a five-week period. A pre-test post-test measure of all participants' critical thinking skills was conducted using the Critical Thinking Disposition Inventory with no differences in critical thinking scores between both groups at baseline. After five weeks, the post-test results of the experimental group showed a drastic increase in critical thinking scores compared to statistically insignificant increase in critical thinking of the control group. The increased factors included systematic analysis and curiosity of the PBL students.

Following the PBL program, Hung et al., (2015) interviewed students of the PBL group to obtain reflections on the program. The emerging themes included reasoning and thinking through a diversity of perspectives, systematic thinking skills to improve or adjust performance, application of knowledge on real-world problems and brainstorming approaches to problem solving. Hung et al.'s (2015) study illuminated the current education system does not support or cultivate an environment where critical thinking is facilitated through creativity and ongoing inquiry. They identified "routine work schedules, linear and rigid thinking patterns, and pre-occupied judgments" (Hung et al.,

2015, p. 174) as common obstacles to the development of critical and postformal thinking in a clinical work environment.

Hung et al.'s (2015) study stands out in that they employed a mixed methods approach, and randomly assigned participants to the experimental and control groups. They also provided comprehensive demographic data of all participants. The triangulated data showed that reasoning based on diverse perspectives and exploring the problem through brainstorming were competencies that participants acquired through PBL.
In addition to interviewing PBL participants, investigating the learning experiences of students from the lecture-based program would allow for an accurate comparison and credible interpretations of the findings. The small sample size accompanied by purposive and convenience sampling remain common issues of the research on PBL as a means to foster cognitive change.

A stronger case for PBL's ability to foster critical thinking in adult learners can be made with a systematic meta-analysis that reviewed eight randomized-control studies with adult nursing students of various ages (Kong et al., 2014). Kong et al.'s (2014) thorough review and analyses of the study designs and pooled effect sizes indicated higher critical thinking skills in nursing students post PBL compared to traditional-lecture students. Their review also added that learners in PBL courses showed improved skills in using deduction compared to learners from traditional-lecture. Kong et al. (2014) concluded that there is a need for more research with lager sample sizes.

Despite the sample size and sampling strategy issues, the above reviewed studies share common findings; students' tendencies to think more critically increased in an environment in which students were encouraged to analyze the causes of a complex

problem from multiple perspectives in a team and to engage in debates to synthesize these perspectives. In other words, students were not only allowed, but had also to reflect on their thinking to progress in discussions.

Problem-Finding as a Way of Reasoning and Problem-based Learning

The way by which a person defines a problem determines the solution of such (Getzels, 1979). The amount of time and effort spent on finding and defining a problem impacts the quality of the proposed solution. Getzels (1979) argued that the time invested into finding, creating and identifying the problem is more important than the time spent generating the solution to it. During PBL, students spend a substantial amount of time finding the problem and discussing their proposed definition of it. As the study by Yoshioka, Suganuma, Tang, Matsushita, Manno and Kozu (2005) showed, problem-finding is a sophisticated cognitive activity that requires students to not only examine multiple perspectives of what constitutes the problem but to also come to an agreement to synthesize the problem into one concept.

Using a group-comparison design, Yoshioka et al. (2005) hypothesized that PBL focusing on problem-finding activities, including a self-assessment sheet that measures one's problem-finding skills, increases problem-finding abilities among medical school freshmen students. A total of 184 female medical students were randomly assigned to PBL and non-PBL, and the traditional lecture, conditions. The intervened PBL students were presented with medical problems and were explicitly encouraged and reinforced through evaluation sheets to self-direct their learning and identify as many potential problems as possible by trained PBL tutors. The high number of generated possible

problems was an operational indicator for the high level of participants' problem-finding ability.

The intervened PBL group demonstrated a significantly higher number of extracted problems than the conventional non-intervened group. Specifically, the focus on problem-finding during PBL motivated them to consider the complexity and interconnection of different areas as they were able to leave the realm of what they know to identify what needs to be known (e.g, epidemiological and pathological knowledge).

Yoshioka et al.'s (2005) study design is an experimental two-group relative comparison design; the intervention of interest is being compared against another intervention of another group. In this case, the control group is the comparison group because it receives a different intervention, as opposed to not being administered anything (Fraenkel et al., 2012). While the sample size was moderate, the participants consisted exclusively of female students. Hence, the results are not generalizable to the average medical school first-year mixed-gender population.

Metacognition and Problem-based Learning

A number of studies exist that show a direct relationship between PBL and increased metacognition in higher education students. Knowing how to adjust one's learning strategies and study behavior is facilitated by metacognitive elements of being aware of how one knows and how one learns. Downing, Ning and Shin (2011) studied the effects of PBL on learning behavior and metacognition in undergraduate construction students. They used a quasi-experimental static-group design with a total sample of 132 students that were matched for age, gender and college housing type across the PBL and the non-PBL groups, each consisting of 66 participants. Both groups' Learning and Study

Strategies Inventory (LASSI) scores were measured to ascertain that they are not significantly different from each other.

After a 15-month long exposure to PBL and to traditional lecture, the PBL group showed significant improvement in their ability to approach evaluation of their learning, self-regulation, self-testing and learning strategies components based on the LASSI scores administered at the end of the programs. According to Downing, Ning and Shin (2011), PBL enabled students to make their learning process and learning habits transparent to adjust them for better performance, all of which occur through metacognition.

An important factor to consider when studying the effects associated with PBL is the duration of implementation. Because Downing et al. (2011) employed PBL for 15 months, a maturation effect in students' thinking may have occurred (Fraenkel et al., 2012). However, the non-PBL group controlled for this threat. Further, because the PBL group consisted of first-year associate degree seekers and the non-PBL group consisted of university degree seekers, systematic errors, such as confounding variables that influence the outcomes without being accounted for, stemming from the group differences between associate and university degree seekers could impact the results. While both groups studied construction, associate degree seekers may be more inclined to engage in "hands-on" education and may have been more receptive to the effects of PBL.

To confirm that PBL is effective for a variety of learners, it is crucial to ensure, as much as possible, that groups do not differ from each other in terms of educational focus and preparation. If there are group differences, assigning the associate and university degree seekers randomly into groups counteracts the issue. Thus, random cluster

sampling accompanied by random assignment across groups is highly recommended for higher internal validity (Fraenkel et al., 2012).

In a recent quasi-experimental pretest-posttest study, Kuvac and Koc (2019) used the Metacognitive Awareness Inventory (MAI) to assess levels in metacognition among young adult pre-service teachers (*n*=51) following participation in an environmental science PBL course. When compared to the control group, pre-service teachers enrolled in the PBL course showed significant increases in the following three metacognitive components: (1) procedural knowledge, which is a person's knowledge of the strategies and methods required to perform cognitive tasks effectively by taking notes, distinguishing important from irrelevant information, using mnemonics, as well as testing the acquired knowledge periodically; (2) planning, which refers to a strategic selection of suitable strategies and the process of time management for the successful completion of a task.

Planning may apply using existing knowledge on a subject to set aims before initiating a task; and (3) debugging which is the ability to recognize errors in the process of learning in order to revisit and adjust one's strategies accordingly during problem-solving. Such adjustments may include asking for help or reaching out to experts. Upon the completion of a PBL course, increases in these metacognitive components are expected to benefit learners in problem-solving environments. Liu and Liu (2020) demonstrated this relationship in their study with 159 undergraduate learners. Surprisingly, high learner metacognition and high goal orientation scores negatively impacted problem-solving performances in a laboratory setting using a virtual game environment that adheres to the problem-based learning (PBL) model aimed at teaching

space science. Regression analyses produced a model that demonstrated a negative trend. As metacognition and goal orientation decrease, problem-solving performance increases.

Liu and Liu (2020) refer to the literature and stimulated recall interviews in their study to explain the inverse relationship between high metacognition, as measured by the MAI, and low problem-solving performance. They believe that a cognitive bias, also referred to as the Dunning-Kruger Effect (Kruger & Dunning, 1999, as cited in Liu & Liu, 2020), by which individuals with low metacognitive ability tend to overestimate their metacognitive and performance abilities. It is possible that some learners who indicated high metacognition mistakenly did not benefit from using metacognitive skills to solve problems in the virtual PBL environment. Another possible explanation they provide relates to problem complexity in this study. Problems in PBL are designed to be ill-structured and relevant to real life (Hmelo-Silver, 2004). Learners' preconceived notions and attitudes towards problems could have affected their problem-solving strategies during problem-solving tasks (Phillips, 2001, as cited in Liu & Liu, 2020). For example, learners might prefer a simple answer over a complex solution.

It may have also be possible that participants with high metacognition did not find the problem-scenarios challenging or stimulating enough because the tasks are designed for sixth-grade students originally to learn science. Thus, it is possible that learners with lower metacognition levels were more motivated to engage in problem-solving more deeply compared to participants with higher metacognition level (Liu & Liu, 2020). Another possible explanation could be the inverted indication of metacognition scores from the MAI instrument. Those who indicated low metacognition may actually have high metacognitive skills as they are more cautious, modest towards, or rather critical of,

their metacognitive abilities. Being critical towards one's performance and precautious during problem-solving may have contributed to elevated concentration levels to solve problems in the PBL virtual environment.

Other studies using the MAI to assess metacognition among adult learners following participation in PBL showed similar results with a few distinctions. For example, Tosun and Senocak (2013) have explored the factor of educational preparation that may impact susceptibility to the effects of PBL. Their study compared the metacognitive awareness levels of 70 prospective teacher trainees with a strong science background to teacher trainees with a weak science background. Upon administering the MAI at baseline, there were significant differences between the two groups prior to PBL in metacognition. At baseline, the group with an advanced science background scored significantly higher on the MAI compared to the group with a basic or weak science background.

The duration of PBL for advanced science group was five weeks with 4 weekly sessions whereas for the basic science group the duration of PBL was ten weeks with bi-weekly sessions. After the PBL sessions, the group with a weaker science background scored significantly higher on metacognitive awareness inventory, particularly on dimensions of conditional and procedural knowledge as well as evaluating, at post-test measure. The metacognitive awareness of the group with an advanced science background did not increase significantly after the PBL experience, which indicates that their advanced science background made them less receptive to an increase in metacognition through PBL.

However, it is important to note that the duration of PBL for both groups differed between five and ten weeks. The group with an advanced science background in chemistry may not have had enough time to absorb the elements of PBL and develop metacognitive and postformal facets in only five weeks. This may have systematically contributed to the lack of metacognitive gain in the advanced science group. This would also mean that the group that had ten weeks to work through a project using the PBL approach matured in skills and cognition through prolonged exposure to PBL and other environmental factors.

As the previous studies show, the effects of PBL on metacognition have been examined across various disciplines. Although PBL emerged as intervention in the medical education field, it is not limited to natural and applied sciences. Aliyu et al. (2016) applied PBL in an English Writing setting with Nigerian undergraduate students, who study English as a Second Language (ESL), to develop metacognition and facilitate the development of writing skills. This study employed a one-group pre-test post-test design with a sample size of 18, albeit few, undergraduate students whose age ranged from 24 to 38 years at a Nigerian University. For a deeper exploration of the effects of PBL on metacognitive awareness, Aliyu et al., (2016) used a mixed-methods approach to data collection.

Results confirmed the study's hypothesis that PBL increases metacognitive awareness of one's learning process and progress in English writing. Task Requirements, Text and Accuracy and Personal Learning Process were the three statistically most significant gains in metacognitive awareness. The qualitative data based on the semi-structured interviews revealed further insight of students' learning experiences. Common

themes included the advantages of the ill-structured nature of the problem that enabled students to use various perspectives to solving the problem. The use of various perspectives also relates to the theme of acquiring knowledge about one's own as well as other students' thought processes through sharing them in public.

Qualitative Studies: Cognitive and Practical Implications of Problem-based Learning

Qualitative data are important in that they may complement quantitative data by offering insights into the cognitive changes and gains among students; as well qualitative data may establish a thematic foundation for a quantitative study. Qualitative research has the potential to present and explain PBL's role in college students' experiences and cognitive development. Most of the current qualitative research, however, explores pragmatic outcomes as they are reported by university students. This section reviews qualitative studies and identifies unexplored phenomena in the realm of PBL and cognitive development in adult college students.

Cognitive Implications Based on Students' Perceptions

A good example of deep insight obtained via qualitative methods is a pilot study by Jumari et al. (2018). They conducted a qualitative exploratory pilot study on PBL's ability to incrementally promote metacognition in three chemical engineering students. Each student was interviewed after each PBL phase. Many metacognitive themes emerged that are highly similar to the themes found in the previously mentioned studies.

During the first phase of PBL students engaged in an intensive problem-finding process, that is, analysis of the causes of the problem to present and define the problem. It was during this phase that students developed self-regulation and control of their learning

and thinking. After identifying multiple interconnected causes, they synthesized the problem holistically. This demonstrates that complex problem-solving may require high self-regulation and control from students.

It is important to emphasize that although this qualitative pilot study has a small sample size, it is not a concern or design flaw. Jumari et al., (2018) intended to explore the PBL experiences of students and their metacognitive processes as they increase incrementally in three phases of PBL. The purpose of the study was not to generalize but provide deep insight into the developmental progression during PBL by conducting a pilot study first. Jumari et al.'s pilot study calls for further research on the incremental changes in students as they experience and progress through PBL.

Practical Implications Based on Students' Perceptions

Other qualitative studies that have explored the effects of the problem-based learning approach are based on students' perceptions. Visschers-Pleijers et al. (2006) interviewed 48 first-year Dutch medical students aged between 18 and 22 years in six focus group sessions to inquire about effective characteristics of the PBL phase during which students reported their synthesized results. To form the six focus groups, Visschers-Pleijers et al. (2006) selected 682 medical students randomly from all PBL tutorials at the end of the semester. From the pool of 682, 48 participated across the six focus groups.

The focus groups most commonly emphasized that asking content-related questions, synthesizing information, and most relevant to the topic of this review, discussing different opinions, perspectives and disagreements were the most effective elements of a PBL discussion results-preparation phase. Students reported that discussing

conflicting interpretations and disagreements forces "students to think more carefully" (Visschers-Pleijers et al., 2006, p. 928). Students' quotes pointed to the challenge of connecting contradicting or disconnected views and information from researched materials in an adequate manner. Handling conflicting knowledge was a common learning activity, which students identified as a collaborative practice of knowledge creation. Being exposed to a variety of opinions is one of the key stimuli for generating cognitive changes towards postformal and matacognitive thinking (Bassett, 2011; Lucas, 2015; Sart, 2014; Sinnott, 2011).

Pepper (2010) conducted an extensive qualitative study about students' perceptions about PBL during their first year in college. She gathered data from 625 students from six science subjects within a period of three years that encompassed student cohorts from 2007 to 2009. Given the large sets of data, Pepper (2010) and another qualitative researcher engaged in an extensive qualitative analysis process during which she organized and re-organized the content thematically into differences and similarities until she generated eight themes. The aspects that students enjoyed most about PBL were working in groups, sharing ideas and completing the task, whereas aspects which students enjoyed the least about PBL were being self-directed learners and assessing the task. The data also showed students' tendency to engage in complex tasks that requires higher-order thinking approaches during PBL.

Student data that were sorted under self-directed learners consisted of the sub-elements of having a sense of achievement because overcoming struggles during problem-solving is a rewarding experience. A very important finding of Pepper's (2010) study is the facilitator's lack of effective guidance. Many students from the larger PBL

classes reported that they did not receive enough information to engage in self-directed learning effectively. The quality of guidance facilitates meaningful learning experiences in PBL (Goh, 2014). Although there are individual differences when it comes to learning preferences, many students in Pepper's (2010) study enjoyed the challenge of wrestling with a problem independently and "moving from their comfort zone" (Pepper, 2010, p. 705). Leaving one's comfort zone is a theme that should be explored in-depth in other qualitative studies as phenomenological experiences of students who had to overcome discomfort may elucidate transformative effects on students' reasoning and cognition.

Other qualitative studies rely on students' perceptions to evaluate the effectiveness of PBL as a learning approach. These studies were conducted to investigate aspects which students thought made PBL an effective and useful learning strategy and which aspects were a deterrent to learning (Eccott et al., 2012; Henry et al., 2012; Leddington Wright et al., 2015). In other words, most of these qualitative studies that questioned students about PBL's effectiveness sought to improve PBL as a learning approach.

Many of the challenges reported by students include the limited time to complete the tasks effectively and not having enough direction or guidance as to what the student is expected to do (Leddington Wright et al., 2015; Pepper, 2010). A study that blends practical implications with cognitive implications based on student feedback was Addae et al., (2012) study in which they compared the seven-step to the shorter five-step PBL program. Although this is not the focus of this review, students believed that the PBL method stimulated reflection, promoted critical thinking skills, teamwork, responsibility for one's learning and higher ability to integrate knowledge at an interdisciplinary

knowledge with higher rating on each for the five-steps approach compared to seven-steps approach.

While these qualitative results are useful in the realm of effective PBL practice and implementation, they do not directly show the developmental process through which students change cognitively. Precisely, none of these studies unveil the experiences and the mental mechanisms through which students create meaning as facilitated by the constructivist characteristics of PBL (Marra, et al., 2014).

Interestingly, empirical research that investigates cognitive changes in PBL students is quantitative or uses mixed-methods approach. There is a need for qualitative, or more mixed-methods studies that offer sufficient in-depth qualitative data, to explain how these increases in metacognition and postformal thinking are connected to activities and experiences during PBL. Another crucial aspect made transparent by this review is that only one study demonstrated increases in PFT in undergraduate students (Wynn et al., 2014). Thus, additional studies that measure postformal thinking patterns in students at baseline and post-PBL using the PFT questionnaire are warranted.

Studies with Inconclusive or Non-significant Findings

To this day, most existing studies demonstrate PBL's ability to promote some type of cognitive change, be it increases in PFT, metacognition or critical thinking, in higher education settings with the exception of a few studies. A dissertation study using the correlation method by Shoop (2014) showed no significant differences in metacognition and 429 medical graduate students' GPA. Shoop was primarily interested in the relationship between students' end-of-the-year GPA and their metacognitive awareness levels following a PBL-oriented study year in medical school. To assess

metacognition levels, Shoop used the metacognitive awareness inventory (MAI) in her entire dissertation research. Following the administration of the MAI, the results showed that there was no significant relationship between metacognitive awareness and students' GPA. Shoop recognized that the low variability in the metacognitive awareness scores in medical students might be related to the filtering process based on academic excellence before entering medical school. Medical students are accepted into medical school based on their academic achievement that presumes effective study strategies, skills and learning adjustment strategies, meaning they that have acquired metacognitive skills in their previous semesters to achieve high scores on the MCAT.

Shoop's (2014) second part of the dissertation research involved testing the effects of metacognitive prompts on concept mapping quality by assigning 19 participants to two groups, one treatment group that received the metacognitive prompts and one control group that did not receive any prompts. The quality of concept mapping, a technique of brainstorming and systematically outlining ideas and procedures, was evaluated by comparing it to a sample map developed by experts and faculty. Although the students who received metacognitive prompts had higher scores on their concept map than the control group, there was no statistical significance between both groups' scores. Shoop explained that the small sample size had insufficient power to show any statistical differences. Interestingly, Shoop observed that students expressed that they enjoyed the practice of concept mapping and emphasized that this strategy helped them pinpoint what they know at the current stage of their learning and what information is missing, that is, what else needs to be known. Thus, it could be argued that concept mapping itself served as a more effective metacognitive activity that led to low variability between the groups.

In other words, both groups might have benefited from concept mapping metacognitively, with the reflective prompts group having produced slightly more thorough concept maps. However, given the small sample size, the effects of the prompts did not become statistically transparent.

A slightly older dissertation study by Corliss (2005), but with a similar focus on the effects of reflective prompts on metacognition, also showed no statistically significant effects. In this study, a total of 298 female college students participated in a hypermedia problem-based learning environment. Other sample characteristics, such as age and program level are not provided. The hypermedia approach to learning is mainly distinguished by its heavy use of media learning tools, such as videos, animations and other digital demonstrations that rely on the use of computers and other digital devices. Like in many other studies, Corliss (2005) administered the MAI to measure levels of metacognition. No statistically relevant results were observed across the groups.

There were several flaws with the study design, however, that must be mentioned. The problem-solving program called *Alien Rescue* was designed for 6th graders. College students may overthink tasks that may be simpler than they appear to be, creating mental obstacles to thinking clearly. Upon a closer look, it appears that the students had two hours to work on the problem and do additional research before answering the reflective prompts at the end of the two-hour session. Given this short amount of time, it is not surprising that there were no significant changing effects in students' thinking, despite the prompts. Working on a task for two-hours is insufficient time to stimulate profoundly transformative cognitive changes in learners because such changes occur through a process and are not based on an event, such as the two-hour problem-solving task. As a

matter of fact, this is a problem-solving but not a PBL approach. PBL extends over multiple weeks, with a minimum of three months. In her dissertation research, Corliss (2005) emphasized that collecting qualitative data in addition to the quantitative data, may have added more insight into the non-significant results. Thus, it is recommended to use a mixed-methods approach, if possible.

In another quantitative study, Choi et al. (2014) measured critical thinking skills in undergraduate nursing students. Choi et al.'s study results indicated that the increased critical thinking skills in the PBL group were statistically non-significant. A further investigation of the study revealed that according to a pre-test measure, the control group scored statistically significantly higher on all constructs of interest, i.e., critical thinking, problem-solving and self-directed learning skills, than the PBL group baseline.

Although Choi et al., (2014) mentioned that they controlled for the between-group differences at baseline, they did not elaborate on the technique they used for this. If issues as seen in Choi et al.'s (2014) study are inevitable and significant differences at baseline do occur, using ANOVA of change, instead of ANCOVA, as suggested by Van Breukelen (2006), is an appropriate approach to processing the pre-test and post-test data. Van Breukelen's (2006) analysis between these two measurement tools revealed that ANCOVA produces biased results, i.e, absence of intervention effect, when significant differences between groups are present at baseline.

Summary and Analysis of Literature Findings and Research Design

This review has demonstrated that the Problem-Based Learning (PBL) approach is a valuable teaching strategy for developing sophisticated reasoning skills, particularly metacognitive and postformal thinking abilities in students in higher education.

Thematically, students' postformal reasoning and critical thinking increased following PBL through the processes of using different perspectives, extended processes of problem-finding and making sense of contradictions and ambiguity. While not much research on promoting PFT specifically exists, there is sufficient research on promoting critical thinking and metacognition through PBL that consistently confirms this relationship. From an empirical design perspective, most of this research uses static-group designs without random assignment to groups. Although random assignment may not be feasible in education research most of the time, it is recommended that future quantitative designs strive for randomized controlled trials to reduce confounding effects that may account for the results. Despite these flaws, the high number of studies conducted in a variety of settings at different points in time implies a stable pattern of cognitive changes in university students following learning through effect of PBL.

Upon reviewing existing research, an imbalance in the number of quantitative to qualitative designs focusing on changing thinking patterns among undergraduate students was observed. In other words, there are not enough qualitative studies on college students' reasoning development. Only Jumari et al.'s (2018) small pilot study with PBL students demonstrates the changing processes of thinking ability, increases in problem-solving abilities and other cognitive and competency gains as revealed in their qualitative data collected across three phases during PBL.

Suggestions for methodological improvements involve the inclusion of a variety of qualitative data that may be merged with quantitative data. Iwaoka et al. (2010) suggest that measuring critical thinking skills after PBL by using a variety of qualitative data collection methods, e.g., open-ended questions, detailed laboratory reports, and

documenting reflections in journal entries, may offer a deeper insight into the gains of higher reasoning skills among college students than traditional quantitative measures or qualitative measures via semi-structured interviews or focus groups.

It is also recommended to combine semi-structured interviews with journals and other qualitative sources. Rué et al. (2013) analyzed 38 reflective journals that law students had to maintain during the entire PBL process. The major themes that were evident in the reflections were gains in metacognitive self-regulation (i.e., students were aware of what they already knew and what they still needed to know), critical thinking, as well as gained skills in applying theory to practice. Because the majority of research measures short-term effects of PBL, that is, immediately after PBL interventions, on learners quantitatively, it is recommended that long-term effects be measured qualitatively or via an exploratory mixed-methods approach in which qualitative data might be used to design a questionnaire for further research. The main purpose of examining long-term effects is to not only understand PBL as a learning approach better but to also measure the extent to which PBL is an effective teaching technique for preparing learners for life in the real world of the 21st century.

If extensive qualitative studies with reflective journals or other qualitative data collection methods are not an option, a mixed-methods approach may still be an adequate alternative to purely quantitative measures that do not include students' reported experiences during PBL. For instance, convergent parallel or explanatory sequential mixed methods designs (Creswell, 2014) lend themselves well to gathering reflections or reported experiences from students' qualitatively in a rather efficient manner.

The addition of the qualitative to quantitative measures should either explain or connect to students' ratings of items on a psychological construct of interest for a deeper understanding of cognitive developmental processes. Regardless of the design of prospective research (i.e., purely qualitative or mixed-methods design), the type of cognitive change that needs further attention is PFT. Most research reporting the effects of PBL on students' thinking investigated metacognitive and critical thinking patterns. More importantly, the main technique to measure metacognition in the majority of the studies involved the administration of the Metacognitive Awareness Inventory (MAI). The MAI may not be a suitable measurement technique for every study as the MAI was used in a few studies that produced non-significant results as well.

However, whether and how learning during PBL affects postformal-thinking patterns has not been studied extensively. Only one study (Wynn et al., 2014) focused on postformal development in undergraduate students and only one study (Downing et al., 2011) systematically connected higher order reasoning of metacognition to enhanced or changed learning approaches through administering the Learning and Study Strategies Inventory (LASSI). Through these connections, effects of PBL are not only more pronounced but the correlations between psychological constructs may also provide insight into the mechanisms of psychological development through PBL. Depending on which constructs correlate, the manifestations of latent variables, such as reasoning approaches, can be made transparent. For example, a reasoning approach that correlates with a measure of successful problem-solving is manifested through this behavior.

In light of the potential insights through the connections between constructs, the present study focused on changes in relativistic postformal thinking and on an additional

construct of NFC that has been developed by Cacioppo and Petty in 1982 and described into detail in the first introductory chapter. The rationale of including NFC as a construct of interest is related to its motivation to engage in complex tasks. Taking this into account, NFC lends itself well to measuring motivation for complex task engagement in a learning environment that is problem-oriented. Examining the levels of NFC in a PBL study could reveal whether a problem-focused learning course stimulates the need to engage in complex tasks in students at pre-PBL and post-PBL measures. Increased NFC levels could also explain increases in postformal thinking scores or post-PBL thought their motivation-related nature.

Although quantitative findings of the reviewed research show significant increases in adult learners' higher order thinking skills, qualitative data have the potential to explain how these skills occurred through PBL. The underlying assumption behind PBL that adult learners find themselves immersed in the process of defining and working through complex and ill-structured problems collaboratively over the course of several months. As they engage in this process of problem exploration, they must change and re-structure their habits of thinking and problem-solving, as demonstrated by a seminal piece by Hmelo et al. (1997). Despite this underlying assumption, it may be possible that this type of learning environment might have a different impact on students who would be able to explain the quantitatively unmeasured effects through qualitative data.

Finally, providing evidence on how PBL contributes to students' thinking processes and whether long-term effects impact students' careers may not only help educators implement PBL with higher confidence, but it can also help transform educational leaders' appreciation for practice-based learning and understanding of

learning and cognition in the higher education context. By combining traditional learning approaches that emphasize summative testing with PBL, higher education may be more likely to achieve a balance between theory and practice. Instructional methods and learning approaches that prepare students for the 21st century workforce and adulthood have great opportunity to enhance university learners' education.

III. METHODS

Overview and Rationale of the Design

The previous chapters have outlined a positive relationship between PBL and cognitive changes in adult learners. This chapter describes the quasi-experimental design for studying the effects of PBL on the cognitive development in higher education adult learners. In experimental design the independent variable (i.e., PBL in this study), is manipulated as it is observed and measured in real time (Fraenkel et al., 2012). From an epistemological perspective, an experimental design follows a post-positivist perspective in that the aim is to generalize results to a population of interest while acknowledging the limitations of the implemented research design and the conclusions drawn from it (Creswell, 2014). In this study, the sample was not randomly selected from the population and there was no random assignment to PBL exposure. Therefore, the results herein were limited to a learner population enrolled at higher education institutions in Central Texas at one point in time.

To investigate the effects of PBL on learners' reasoning, I used a quasi-experimental static-group pretest-posttest design that includes a control group without a random assignment of participants to the experimental and control group (Fraenkel et al., 2012). Therefore, quantitative scales were combined into one survey to examine whether and in what ways the participation in problem-based learning significantly stimulates the development of sophisticated reasoning, in particular relativistic PFT and NFC. The goal of this investigation was to statistically test for differences between students exposed to PBL and those not experiencing PBL. Although this quasi-experimental design did not employ random assignment of participants to groups, such a design maintains its positive

features by manipulating the independent variable via pre and posttest and including a control group or comparison group (Fraenkel et al., 2012).

In summary, the PFT and NFC Scales (NCFS) captured differences between the PBL-exposed and non-PBL-exposed lecture-based control group as well as differences between the PBL group's at baseline and post-measure levels. Thus, a participant's exposure to PBL served as the independent (manipulated) variable while the PFT and NFC constructs represented the dependent variables.

Research Questions and Hypotheses

This study followed a quasi-experimental static-group pretest posttest design (Fraenkel et al., 2012). To test for statistically significant differences between the group means, an ANOVA was used with conjunction with the bootstrapping technique, where necessary. Although the PFT and NFC scales are based on an ordinal scale of measurement they frequently violate the assumption of normality – a requirement to use a parametric statistical test. To correct for non-normality of score distributions, bootstrapping was applied within the IBM SPSS statistical program.

The following research questions guided this study:

1) Does exposure to PBL strategies increase PFT in adult learners?

Null Hypothesis: H_0: There is no difference between mean scores on PFT between the PBL and control groups at post-test. The null hypothesis was tested against the alternative hypothesis, denoted as H_1: The group means of the PFT levels of the PBL group will be higher than the PFT levels of the control group at post-test measure.

2) Does exposure to PBL strategies increase levels of NFC in adult learners following participation in PBL?

Null Hypothesis: H_0: There is no difference between mean scores on NFC between the PBL and control groups at post-test. The null hypothesis was tested against the alternative hypothesis H_1: Alternative hypothesis: H_1: The group means of the NFC levels of the PBL group will be higher than those of the NFC thought levels of the control group at post-test measure. The null hypotheses (H_0) would be true if no statistically significant differences were detected between the experimental PBL and control groups at the two-tailed post-test measure at the $p < 0.05$ level.

Population of the Study

The characteristics of the target population of interest in this study included student status at a university representing adult learners. Because it is very likely that students over the age of 25, who may have a full-time job or family-related responsibilities (Choy, 2002; Wolter, 2011), were included in the PBL and traditional lecture-based courses of social work programs, participants of all age groups were considered in the statistical analyses. There is a possibility that increasing age may correlate with higher PFT and NFC levels due to higher maturation and wealth of experience. Mature students may score higher at pre-test or post-test measures compared to their traditional-lecture counterparts. Thus, age was included as a covariate due to the possibility that increasing age and maturity may moderate high levels of NFC and PFT at pre- as well as posttest.

Regarding socio-economic status, no research exists that points to interactive effects between PBL and students' socio-economic background. However, the adult student population was geographically limited to higher education institutions in Central Texas during the Fall semester of 2019. The population was limited to social work majors to control for potential confounding effects specific to the outcome variable resulting from differences in other non-social science majors, such as natural sciences or literature majors. Keeping the majors homogenous in this study was relevant because the nature of discipline-specific problems along with the depth of complexity of the problems and the PBL learning environment may vary across majors. Another reason for choosing social work student participants relates to the accessibility to student participants. Social work programs have embraced PBL models and apply them more abundantly (Boud, as cited in Norman, 2012), facilitating and accelerating the recruitment of participants.

The Sample and Sampling Procedure

The study's sample consisted of 99 participants at post-test whereas at pre-test a total of 111 consisting of 57 in the PBL group and 54 in the control group were recorded. To gain access to PBL participants, this study employed a (a) purposive sampling strategy (i.e., adult learners enrolled in a PBL-based course), and (b) convenience sampling (i.e., sample was limited to learners enrolled in social work courses adhering to either the principles of PBL within the context of community-based learning, or traditional lecture learning models at public Central Texas universities).

The recruitment procedure started by generating a list of faculty and instructors who teach Social Work at five public and private universities in central Texas. The generated list was screened for faculty's specialization in community-based teaching

using the key term search function in Microsoft Word. For example, by typing the key term "field" or "community" or "problem" allowed me to identify instructors who specialize in teaching field-based courses. Upon narrowing the scope to community-based or field-based teaching, over 300 faculty instructors were contacted via email (See Appendix C) and asked if they were teaching a PBL-oriented course the following semester and if they were willing to connect me to their students who would be invited to participate in this study. Conversations about my study emerged with seven faculty members at three large public research universities in central Texas. Five of these professors were going to teach social work courses that included some form of PBL whereas the other two taught traditional-lecture courses at one large prominent public research university, providing access to control group participants.

All of the faculty members shared their course syllabi with me for a focused screening. From the 5 PBL-related courses, only three met the relevant PBL criteria. The main criteria involved (a) a description and identification of major social problems that exist in real-life contexts via independent as well as group learning, (b) finding a solution or definition to the problem via active participation (e.g., volunteering) in the field of the academic discipline (e.g., agency, organization or community), (c) application of abstract course concepts in the field experience to connect theory with practice, (d) a certain level complexity of the problem defined by a presence of contradicting needs of stakeholders affected by the problem, and using multidimensional contextual perspectives to critically analyze and evaluate alternative approaches to the problem and (e) a synthesis of the intricate structures and dynamics encountered during the problem-based field experience based on critical evaluations. Another desirable and relatively common but not decisive

PBL criterion involves (f) reaching out to stakeholders and experts for insights on the problem at hand.

Given the criteria's intensity of the workload and engagement, it is very likely that a large portion of the course grade would factor in the work on the problem. Most of the learners' effort in the course should be exerted into identifying and working on the complex problems while other assignments, such as tests, quizzes, or research papers should either be included in smaller formats with lower intensity or excluded entirely from the course. The other two courses that did not qualify as PBL courses did not include either any or only one of the criteria described above and integrated learning about a complex social topic in the form of a project to be presented at the end of the semester, which comprised 20% to 40% of the course grade. This level of working with problems is insufficient to be considered a full in-depth community-based or PBL-based course.

The other three recruited faculty teaching the qualifying courses came from two large public research universities. Each qualifying faculty was provided with an email invitation (See Appendix C) to participate in this study to be distributed to their students in their class. Upon distributing the email invitation, the participating student sample was instructed via email to follow a link to the survey, which they could complete at their own time or in class, depending on the faculty's preference. All participating learners received two reminders to complete the questionnaires provided in digital form generating 111 responses at pre-test. At post-test this number decreased to 99 responses that were considered for the final analysis. In addition to distributing the questionnaire in digital form, the incentive of $25 gift cards for each completion of the questionnaire were

also distributed digitally. According to Czaja and Blair (2005), empirical evidence indicates no difference in response rate and response quality between surveys that are digitally administered and surveys distributed or administered via other means, such as interviewer-administered and mail distributed surveys. More importantly, a deciding factor in increasing response rates and quality is the provision of incentives, with monetary incentives having the highest effect in yielding higher response rates (Czaja & Blair, 2005).

Accounting for the restricted sample procedure, which is not random and limited to Central Texas universities at a given point in time, the sample did not represent the entire student population in Texas or the United States. It is thus crucial to emphasize that this study's validity is case-based and only represented an adult student population majoring in social work while learning through PBL at two public universities located in Central Texas. This, among other factors, reduces the level of generalizability of findings. For example, the external validity (i.e., validity generalization) of findings obtained in this study relies on multiple replicated studies conducted in other geographic areas across the country with a similar adult learner population majoring in similar core subjects, such as social sciences, humanities or business studies. Covariates and other factors accounted for in this study would have to be also accounted for in replication.

Considering the inferential and comparative nature of the design, the sample size has been carefully determined using the sample and power calculation software G*Power (Faul et al., 2007). Calculating the required sample size to ensure adequate statistical power and control of Type II error rate requires apriori knowledge of effect size and the desired level of statistical power. I chose a medium effect size of $d = 0.65$, which falls

into the range of 0.5 to 0.8 standard deviation units. Having set the effect size to a medium level of $d = 0.65$, I chose the power level of 0.8 to allow 20% for error (1- β) (Cohen, 1988). Using G*Power software, the calculated sample size should be 39 at a minimum per group with a $df = 76$ (Faul et al., 2007). In accordance with the recommended total sample size of 78, this study's sample extended to a total of 99 participants who were compensated with a digital gift card of the amount of $25 per completed survey.

Constructs and Instrumentation

Two instruments were administered simultaneously to adult students during the first week of the semester and one or two weeks after the semester post-PBL. The instruments incorporated the ten items of the PFT and the ten items of the NFC scales. Demographic data and other relevant factors (i.e., potential covariates or confounding variables), were assessed before respondents initiated answering the PFT and NFC questionnaires. These factors include: (1) age; (2) academic major; (3) gender; (4) attitudes toward group work; and (5) previous exposure to PBL.

Demographic Data and Other Characteristics of the Survey

Age, Gender and Academic Discipline

The demographic data along with other respondent characteristics were treated as covariates that may moderate the levels of dependent variables. Participants were asked to indicate their gender, their major and their age to see whether participants' age moderates the dependent variable. It is also possible that a particular academic major may also be more suitable to PBL and thus, students of certain disciplines may be more inclined to benefit from this learning approach. To ensure that respondents in this study

majored in social work, they were asked to indicate their major because enrollment in a social work course does not necessarily imply a students' major. Students majoring in a variety of disciplines may enroll in electives that are not part of their major.

Group Work Attitude

The issue of moderation and/or mediation applies to other factors of attitudes toward group work at pretest and posttest. Learners who may have negative attitudes and experiences with group work may have been less likely to score high on each of the scales. This also means that learners with positive attitudes and group experiences may have been more likely to score higher on either or each of the scales.

Previous Exposure to PBL

Because participants may have been exposed to previous PBL-based strategies, previous exposure was accounted for. To reiterate that PBL is a general approach that may interchangeably be referred to as community-based learning (CBL), when the PBL course takes places in a community setting. The essential characteristics of CBL include the mission to bridge theory or content learned in the classroom to practice and real-world problems and to create a proposal for a community solution at the end of the course (Prast & Viegut, 2015). CBL can also be used interchangeably with service-learning because such type of learning takes places in communities in which learners engage in the exploration and the solving of community issues (Weidner et al., 2018; Zlotkowski, 1998). It may involve policy-related and other change efforts in and for a community in need of a solution to an existing complex problem (Lowe & Reisch, 1998). Because PBL is a general category, specific problem-oriented learning approaches, such as CBL and service-learning qualified as PBL in this study.

Key Elements of Problem-based Learning

It is crucial to clarify the operational definition of PBL in the questionnaire in order to increase accuracy of responses to items by respondents. The definition of PBL must include clear key aspects that distinguish this educational approach from other similar approaches that project are but not problem-based. Netshandama and Farrell (2006) explicitly state that project-based learning is not always problem-based and problem-based learning is not always community-based but community-based learning is inherently problem-based.

These are essential distinctions as they support the complexity of problems that may be present in communities. Given these distinctions, the combination of project-based and community-based learning can be thus problem-based. Educational approaches are considered as PBL if the course starts with an unresolved dilemma-ridden real-world problem for which students acquire and apply knowledge. The acquisition of knowledge is primarily organized around problems, not disciplines and theory (Netshandama & Farrell, 2006).

The majority of the course content must be driven by the acquisition and investigation of material that contributes to the definition, understanding, illumination, and solving of the problem. Additionally, the majority of learning occurs within small groups rather than during lectures although students engage in self-directed independent learning activities on their own time as well (Hung, 2016; Netshandama & Farrell, 2006). To determine whether these key aspects of PBL were included in the recruited courses, faculty members were kindly asked to provide a course design document, such as a

syllabus, learning contract or other documents that demonstrate learning expectations and outcomes.

Assessing Previous Exposure

Based on the principles presented above, the assessment question regarding previous exposure outlined the relevant key factors that comprise PBL. The assessment question for previous PBL exposure was stated as follows:

Have you taken a course previously (in high school or college) where the course was based on problem-based learning, community-based learning, and/or service-learning? *A problem-, community-based or service-learning course is a course in which you spent a great deal of time identifying and defining an open-ended and unresolved problem with your group members before crafting a solution during a full semester. You may have also engaged in various independent learning and research activities frequently to understand the problem and contribute to the solution before suggesting it to and discussing it with your group and class. Your teacher or professor spent also less time lecturing as you used that time for researching and working in groups.*

The participating learners were able to choose from a set of fixed responses of either *Yes, No, Not sure* or *Other*. The option of Other offered a text box where respondents were able to provide an alternative response to address uncertainty about past participation in a similar learning-approach. None of the respondents choosing "Not sure" or "Other" explained their uncertainty about previous exposure to a PBL-structured course.

All responses regarding prior exposure to PBL were considered in the data collection and analyses. Because prior exposure to PBL may or may not moderate or influence outcomes of the dependent variables of PFT and NFC, it is important to include

this into data analysis while accounting for the effects of prior exposure to PBL. On the one hand, it may sound counterintuitive for the rigor of a pre-test post-test quasi-experimental design to include participants that may have been exposed to the independent variable. On the other hand, including scores of respondents who have been exposed to the independent variable of PBL in the analysis of the data should not drastically affect the rigor of the research design if the prior exposure is accounted for. For example, responses on previous exposure to PBL were considered in the analysis for interaction effects to see if previous PBL exposure interacts with the outcome variables PFT and NFC, that is, if previous non-exposure moderates increases in PFT and NFC.

It is also possible for previous participation in PBL-based courses not to have an effect on the dependent variable due to a lapse in time or other factors. Whether that is true, previous exposure needed to be assessed. The imminent exposure to PBL in a given discipline at a particular point in time that may or may not have effects on learners' PFT and NFC levels at the time of measurement was in the foreground of this study.

Following the question regarding past participation in courses similar to PBL, if the respondent has answered either *yes*, or *other*, they were asked *Have you taken such a course in (a) high school or (b) college?* to assess the educational level of the completed PBL course. Because the age of the learner varies from high school, maturity may impact the independent variables of complex reasoning For example, respondents who took a PBL-similar course in high school may (a) not remember much from the PBL course or (b) not have absorbed the effects of PBL in the same manner as they would in college. Participants' exposure to PBL at some point during college may still be fresh in their mind to elicit effects on their reasoning. In other words, it is possible that prior

participation may not have an impact that carried over to this study's results but the exposure to PBL during the study may have had an impact on the dependent variables. This is important because effects of PBL are likely to vary with maturity levels and the education levels at which the learning took place.

Need for Cognition Scale

Developed by Cacioppo and Petty (1982), the NFC scale (See Appendix A) consists of 18 items on a one through five Likert scale with five representing highest agreement with a statement. The scale measures the extent to which the individual likes to engage in and enjoy complex activities that require cognitive effort. Individuals low in NFC thus fall on the opposite side of the spectrum of not enjoying complex task but rather concrete and simple task that can be completed with minimal or less cognitive effort. Although NFC is considered a stable trait, Cacioppo et al. (1996) argued that NFC is an intrinsically motivational, rather than intellectual, trait and that differences between low and high NFC individuals stem from "the consequence of developing a sense of competence and self-satisfaction from repeated or prolonged episodes of effortful problem solving" (Cacioppo et al., 1996, p. 199). Taken together, because motivation is a trait that may be developed or stimulated in rich learning environments, this study treated NFC or the motivation for being immersed in effortful problem-finding and solving activities as a malleable and flexible trait that may increase during PBL experiences in adult students.

The original 18-item NFC Scale (NCS) has been evaluated for score-based reliability and validity with stable and robust results of high internal consistency with coefficient alpha of 0.89 and test-retest reliability coefficient of 0.76 (Soubelet &

Salthouse, 2017). Convergent validity based on correlations between the tendencies to seek out, examine, and use relevant information, which represents thorough problem-finding and solving when making decisions (r=0.5, p <. 01) (Berzonsky & Sullivan, 1992), high openness to stimulate thinking (r = 0.26, p <. 01) (Venkatraman & Price, 1990), and discriminant validity established by low causal uncertainty and low tendency to avoid exposure to complex information (r = - 0.42, p <. 001, one-tailed) (Weary & Edwards, 1994). A shorter ten-item version (Appendix A) has been developed and validated with high internal consistency indices of ω-coefficients ranging from 0.76 to 0.90 with a percent change in the omega coefficients (ω) of 2-3% across the traits (Chiesi et al., 2018).

An even shorter version consisting of only six items has been validated across the United States and the United Kingdom. Reliability estimates in the United States are reported as ω and α = .90 and the United Kingdom as ω and α = .86 (Lins de Holanda Coelho et al., 2018). Convergent validity of the six-item version was determined through positive significant correlations of self-direction (r = 0.41, p <. 01) and negative correlations represent discriminant validity of conformity to the status quo indicating avoidance of complex issues (r = - 0.26, p <. 01) (Lins de Holanda Coelho et al., 2018). Although the internal consistency coefficients across the validation studies of the various versions are high, the ten-item NCFS has been chosen for administration in this study due to its slightly higher internal consistency coefficients.

Postformal Thought Questionnaire

The PFT questionnaire (See Appendix A) was developed by Sinnott (1998) and is comprised of 10 items scaled on a seven-point Likert format (one = strongly disagree,

seven = strongly agree) with possible composite scores ranging from the lowest sum score of 10 to the highest sum score of 70. Higher scores represent higher levels of postformal thinking. The PFT questionnaire assesses the degree to which adults prefer to use relativistic operations of thought as represented by levels of paradox, multiple methods, parameter setting, problem definition, process/product shift, meta-theory shift, multiple causality, multiple solutions, multiple goals, and pragmatism. The questionnaire encompasses Multiple Elements, Subjective Choice and Underlying Complexities as its subscales. The reliability and validity of scores were previously tested, albeit with a small sample of 302 adult students, using the ten-item PFT questionnaire (Cartwright et al., 2009). Unlike the reliability status of the NCS, the reliability coefficient of PFT was found to be relatively low with an alpha co-efficient of 0.63 (Cartwright et al., 2009). However, coefficient Alpha is known to yield low estimates under violations of tau-equivalence (Brown, 2015). Therefore, the adequacy of the magnitude of factor loadings reflect tenability of the construct and thus provide alternative support for factor-based reliability (see next paragraph).

Despite the low reliability coefficient, the item factor loadings were acceptable with coefficients ranging from 0.48 to 0.76. The subscale of Multiple Elements had item loadings of 0.48, 0.58, 0.65, 0.76, while the subscales Subjective Choice and Underlying Complexities had item loadings of 0.55, 0.63, and 0.71 and 0.6, 0.6, and 0.75, respectively. While loadings of 0.4 do not contribute to a factor substantially, loadings between 0.5 and 0.7 make acceptable, albeit not good, contributions in a factor analysis (Brown, 2015; Kline, 2016). Interestingly, the subscale of Underlying Complexities had the highest factor loadings. Regarding convergent validity, Cartwright et al. (2009) found

a positive, albeit a moderate to low, relationship between the scores of NFC and the scores of the PFT questionnaire.

A previous confirmatory factor analysis by Yan and Arlin (1995) connected multiple assessments of higher order reasoning to the theoretical elements of PFT. In this factor analysis study, the N/R (nonabsolute/relativistic thinking) and PFT factors were used for cross-validation. The analysis also highlighted the lowest loading of the formal reasoning test indicator (.31) on the N/R test factor, whereas the postformal, epistemic view, dialectical reasoning, reflective judgment, problem-finding and relativistic thinking tests were good indicators with loadings ranging from .56 to .85. Based on good model fit results, the confirmatory factor analysis showed the levels of the formal form were distinct from the postformal form within the construct of N/R thinking.

Following Cartwright et al.'s (2009) validation study, only a scarce amount of research using the PFT questionnaire exists. The questionnaire was employed in a recent study to measure the connections between marital satisfaction, relationship styles and PFT by Jory et al., (2018). Based on a sample with 66 female and 43 male respondents (mean age 39.5 years), they reported robust reliability coefficient of .81, which stand in contrast to Cartwright et al.'s reported coefficients of $\alpha = < .80$.

A possible explanation could be related to respondents' age. The respondents in Cartwright et al.'s (2009) and this study were young adults enrolled at a higher education institution whereas Jory et al.'s (2018) study employed with middle-aged adults to examine connections among marital satisfaction and PFT. It is possible that older adults may understand the PFT items better than younger adults. However, this is speculative as the reasons for the varying internal consistencies across studies are unclear.

In spite of the psychometric challenges displayed by the PFT questionnaire, this study used the PFT instrument because no other alternative scale was available that assesses complex or relativistic thinking patterns with higher reliability is available. Given the acceptable factor loadings, the PFT questionnaire has the potential to capture adult students' preferred approaches to thinking about knowledge and problem-solving. Hence, the possibility of failing to provide statistically significant as well as statistically practical results still persists.

Data Collection

Data collection proceeded with the help of faculty and instructors who agree to invite their students to complete questionnaires. Survey questionnaires were distributed through the instructors' emails that contained a link to questionnaires assembled using Qualtrics software Copyright © (Qualtrics, Provo, UT). The body of the email explained the purpose of the study, instruments used and the informed consent (Appendix B). Participation in the study was completely voluntary. Respondents participating were compensated with a digital gift card of the amount of $25. As already explained in the section on Sample and Sampling Procedure, the distribution of surveys via digital or virtual means has no impact on response rates while providing monetary incentives has positive effects on response rates (Czaja & Blair, 2005). In the questionnaire, students were informed that participation in this study would not affect their grade in the course and that the instructor will not be informed about their participation, or a lack thereof.

Ethical Considerations

This study underwent an Institutional Review Board procedure that determined the ethical adequacy of this study at Texas State University. Following adjustments as

requested by IRB and an approval to conduct this research, all participants were provided an informed consent and were invited to participate voluntarily with the option to withdraw from the study. Participants' confidentiality, such as identifiable data in the form of email addresses to match and compensate participants, is stored on a personal password-protected computer.

Potential Threats to Internal Validity

Although there are always potential threats to internal validity in experimental studies, quasi-experimental static-group pretest-posttest design studies are particularly susceptible to internal validity threats (Fraenkel et al., 2012). A study exhibits strong internal validity when the effect of the independent variable (i.e., the intervention – as participation and learning through PBL), and not some other unmeasured or unexplained factors, increased NFC and PFT levels (Fraenkel et al., 2012). To avoid threats to internal validity, several factors were taken into account through measurement.

The first factor relates to previous exposure to the educational PBL approach. For example, students who have taken PBL courses before in their educational career were asked to indicate whether they had taken a PBL course in the past on the first page of the questionnaire to account for previous exposure to the independent variable PBL. Further, the inclusion of a control or comparison group is expected to reduce, if not eliminate, the threat of testing, also called a pre-test "practice effect" (Fraenkel et al., 2012).

Other factors serving as possible threats to the internal validity of the study were also considered. Potential threats to which the study may have been subject are (b) location; (c) history, or an unexpected or unforeseen event, and maturation; (d) mortality or attrition; (e) implementation or the manner in which the PBL group was treated;

(f) subject characteristics and attitude instrumentation (Fraenkel et al., 2012).

Location Threat

Location threat refers to unmeasured but impacting characteristics of a learning environment, which could facilitate the development of higher NFC and PFT due to a relaxed atmosphere as evoked by a pleasant location. In this study, the effects of a learning environment may have been related to the small student size of PBL courses that may provide access to facilitative resources or certain advanced equipment or technology to promote students' PBL-oriented learning. This poses a location-related threat because larger purely lecture-based classes may not have or need resources used in PBL for lecturing and thus, may not create a rich and resourceful learning environment. PBL learners came from two different universities while majoring in the same disciplines to avoid effects from multi-disciplinary characteristics. However, the control group came from one university majoring in the same discipline as the experimental group.

History and Maturation

Given the variety of course-related characteristics, such as instructors, class-room and learning environments and course topics, threats such as history or unforeseen disrupting or facilitative features that may occur over the course of the study, should be counteracted by including different course units from different universities. The threat of maturation means that academic and other life experiences may impact increases or changes in the thinking of adult learners. For instance, they could mature and change their thinking patterns merely due to maturation and life experiences that happened over the course of a semester. Employing a control group is essential to overcome the threats

of maturation as well as the testing effect of the pre-test that could prime participants to have a high NFC or higher postformal thinking patterns (Fraenkel et al., 2012).

Attrition or Mortality

To lower the mortality threat or attrition rate, students were offered a gift card for the completion of each questionnaire. However, attrition still posed a threat to the internal validity of the study because the number of respondents was reduced from 57 at pre-test to 47 at post-test in the experimental PBL group. Because no random sampling and random assignment to groups took place, the threat of subject characteristics may still have persisted. However, it was possible to match participants based on particular characteristics, which are referred to as covariates. Potentially influencing covariates that were measured were discipline majors, past exposure to community-based or problem-based learning, attitudes towards working in teams, age and gender.

Implementation Threat

The implementation threat, which refers to the manner PBL and lecture-based courses are taught, may just simply explain different responses on the questionnaires. With a variety of course units, the implementation of PBL should not be significantly similar across courses and universities. It is important to note that PBL is intentionally designed to be a learner-centered course and the implementation of this learner-centered instruction is not only intentional but it also is expected to promote rich learning experiences and psychological development.

Subject Characteristics and Attitude

These experiential and attitudinal factors may, for example, explain the lack of differences between the PBL and control group if the majority of learners in the control

group already have extensive volunteering experiences in communities where they may have been solving problems in an informal setting and generally enjoy working and have worked extensively in teams in the past. Other subject characteristics concern the age of the participants. For example, non-traditional student participants may have different approaches to learning and problem-solving due to their different level of life experiences compared to traditional students. Using age as a continuous covariate in a statistical analysis controls (adjusts) for differences due to age.

Subject attitudes may have posed a threat to the internal validity in this study because biased responses that may due to social desirability bias may take place unnoticeably. Adult students in the control group may provide higher rating on the NFC or PFT at baseline due to social desirability bias or the PBL learners may provide low ratings of PFT and NFC in the PBL context if they did not enjoy the course or experienced conflicts. To control for positive or negative experiences, participants of the experimental group were required to indicate their perceptions of working in groups pretest and at posttest.

It is important to reiterate that this study was limited to universities in Central Texas and a smaller sample at a given point in time with a student population that may have features not accounted for. Although random selection of adult learners and random assignment to course units would reduce the threat to internal as well as external validity, randomization was not feasible in this study.

Data Preparation

For the data analysis, I used the statistical program SPSS® Statistics Version 25 (SPSS® Inc., Chicago, IL). The Qualtrics platform stores the raw quantitative data sets,

that are subsequently imported into SPSS® Statistics Version 25 (SPSS® Inc., Chicago, IL) for an initial screening of the two groups' mean distribution shapes based on the ordinal scale data. Testing for statistically significant differences between the experimental and control groups proceeded by using One-Way ANOVA and ANCOVA.

Quantitative Data Analysis

Because the score data is based on an ordinal scale of measurement, the bootstrapping technique was used, in addition to ANOVA, for analyzing the means of the two independent study groups. Given the nature of ordinal scores, the non-normal distributions of the dependent variables of NFC and PFT were adjusted using the bootstrapping technique in IBM SPSS Statistics. The test was two-tailed and was set at $p < 0.05$ to allow 5% of the outcomes to be due to chance. Following the significance testing of the main effects of group means, I analyzed potentially significant interactions among covariates to control for the multiple confounding factors in this study using ANCOVA with bootstrapping, where applicable. For example, age was treated as a continuous covariate that could potentially interact with particular score levels of constructs of interest. Other factors for which I controlled included attitude towards group work, gender, discipline and major.

Operational Definitions of Research Variables

Taking the latent nature of both constructs of NFC and PFT into consideration, it is important to define these variables operationally to highlight the overt features that translate into observable operational patterns. Because both variables are latent constructs, observable features and behavioral patterns rely on instrumentation via self-report measures.

Postformal Thought

High scores on the PFT questionnaire imply extensive operational use of reflective thinking, dialectical reasoning and problem finding (Yan & Arlin, 1995). In ambiguous situations with unresolved and open-ended problems, individuals who score high on the questionnaire may abandon formal logical thinking in favor of postformal thinking. The reason for favoring postformal thinking is the use and synthesis of multiple frames of reference (Inhelder & Piaget, 1958). The active integration of these multiple epistemological views and frames of reference allows the individual to understand and synthesize these multiple perspectives during problem finding and solving.

These operational processes of postformal or relativistic thought may be required during PBL, such as community-based or field-based learning, where making sense of an ill-defined problem without a preconceived correct solution encompass problem-finding. In other words, adults may encounter a variety of views and opinions that may lead to the coordination and integration of multiple frames of reference, which are the operations of relativistic dialectical or postformal reasoning.

Need for Cognition

Operationally, NFC translates into the tendency to engage in complex task on a broad level (Cacioppo & Petty, 1982). The term, Need for Cognition, was originally coined by Cohen, Scotland and Wolfe in the 1950's. Based on preliminary experimental findings, Cohen et al. (1955) posited that individuals with a high NFC demonstrate the "need to structure relevant situations in meaningful, integrated ways" as well as the need to "understand and make reasonable the experiential world" (p. 291). While these operational elements of wanting to understand, structure and integrate novel knowledge

appears to relate to relativistic postformal thinking operations, recent empirical work expanded and refined the concept of NFC by adding enjoyment of cognitive stimulation, preference for complexity, commitment of cognitive effort, and a desire for understanding to the definition of NFC (Lord & Putrevu, 2006).

A person who scores high on NFC is expected to demonstrate perseverance during complex tasks, as defined by the commitment and willingness to engage in a complex problem-solving activity that requires prolonged cognitive effort. Empirical work also indicates that NFC is manifested in the types of activities, which high NFC individuals choose to engage in, such as educational activities and exposure to conflicting views by participating in discussions with debates (Dole & Sinatra, 1998). In contrast to high NFC behaviors, operations of low NFC are characterized by the common use of heuristics and refusal to engage in extended elaborations and analyses of issues (Petty et al., 2009).

Taken together, operations of each of each of these constructs relate to differences in thinking approaches during problem-solving and the degrees of interest and desire to engage in a rather complex problem-solving tasks as opposed to a simple and concrete one. While both constructs relate to behaviors associated with reasoning, NFC is a motivational construct that may facilitate the emergence or development of relativistic and dialectical approaches to reasoning that involve the synthesis of conflicting and contradicting issues to make meaning of experience or a situation during PBL.

Procedure for Testing Hypotheses and Answering Research Questions

Combining the quasi-experimental static group design with ANOVA and ANCOVA made it possible to test for significant differences between the group means

and potential interaction effects among the dependent variables and other factors. Testing for these differences between groups answered the question whether a significant increase in the constructs of interest was obtained following exposure to PBL as a learning strategy.

Summary

Given the broad nature of Problem-Based Learning, it is possible that quantitative measures may not capture cognitive changes in learners. There may also be insufficient time for learners to develop these changes if measured immediately at the end of PBL. Thus, learners' development of higher order reasoning may have to be stimulated already during the intermediate and advanced stages of PBL. From a research design perspective, relying exclusively on quantitative measures via instrumentation used in this study may thus be a risky choice. Thus, this study's internal validity relied on the inclusion of the control group and accounting for potential confounding factors. In summary, the goal of this non-randomized, quasi-experimental study was to investigate whether PBL affects students' reasoning and thinking skills. To assess such changes in thinking skills, learners in PBL (treatment) and traditional lecture (control) groups were administered the PFT and NFC scales at pre-PBL and post-PBL.

IV. RESULTS

The purpose of this study was to investigate cognitive changes in university students majoring in social work following their participation in a problem-based learning (PBL) course. The first intention was to examine whether exposure to PBL significantly increases the levels of sophisticated reasoning, in particular relativistic reasoning as assessed by the postformal thought (PFT) questionnaire and the NFC scale (See Appendix A) (Cacioppo & Petty, 1982; Sinnott & Johnson, 1997).

The second intention was to investigate interactions among the dependent variables of PFT and NFC and covariates of gender, age, attitude towards group work and previous exposure to PBL based on participation in PBL. Specifically, the interactions between (a) PFT and NFC, (b) PFT and covariates and (c) NFC and covariates were of interest in the analysis. Because the motivation to engage in complex reasoning (NFC) is measured in addition to the ability of complex reasoning itself (PFT), the study also intended to demonstrate that the motivation to engage in complex tasks may facilitate increases in complex reasoning. More importantly, assessing NFC may minimize confounding variables, which are unmeasured, but decisive, variables that explain an existing relationship between variables. This chapter details the (a) analyses executed for this study, beginning with a description of the student participants and recruitment procedure, (b) assumptions necessary that determined the appropriate statistical analyses, (c) process of analysis, and (d) analytic results.

Participants by Group

Upon beginning to collect data for the study, faculty members from social work programs teaching PBL-based and traditional lecture courses across several Central Texas university were contacted to serve as liaison for inviting students to participate in

this study. Faculty members who agreed to support data collection taught at three large public universities in Central Texas. Each faculty member provided their syllabus upon request to ensure that the PBL-based courses taught by participating faculty follow the principles of problem-based learning. All control group students were based at one large university while the PBL students attended the other two public universities in Central Texas.

The PBL group consisted of adult students with a mean age of 27.1 (*SD*= 8.83) enrolled in courses that included a community practice component and were titled *Specialized Social Work Methods: Community Practice* or *Advanced Social Work Methods: Communities and Organizations*. The control group participants, whose mean age was 25.94 (*SD*= 6.93), were enrolled in social work courses following the traditional lecture model and included of 10 graduate students at the Masters degree level. Participating students in both groups received a $25-gift card for each completion of the questionnaires at pre- and posttest phases. Despite the monetary incentive, in the PBL group, 47 out of 57 (82%) of participants provided responses at posttest (See Table 1).

Table 1

Sociodemographic Characteristics of Participants at Baseline

Baseline Characteristic	Control (*N*=52)		PBL (*N*=47)		Total sample	
	n	*%*	*n*	*%*	*n*	*%*
Gender						
Female	47	90.3	45	95.7	92	92.9
Male	5	9.6	2	4.2	7	7.0
Age						
< 25	32	61.5	30	63.8	62	62.6
> 26	20	38.4	17	36.1	37	37.3

Note. $N = 99$. All participants were on average 26.1 years old ($SD = 7.85$; lowest age= 19; highest= 53), and participant age did not differ by condition.

Assumptions

To test for differences among groups, three main assumptions must be fulfilled before a One-way Analysis of Variance (ANOVA) can be performed (Field, 2013). The first assumption is that all dependent variables, which includes participant scores on the PFT and NFC, must be on a continuous scale of measurement. The second assumption requires that there is one independent variable that encompasses two or more categorical, independent groups. The third assumption states that there should be statistical independence of observations within and between the groups. In other words, there should be no systematic relationship between the treatment and control groups participants. Other assumptions specific to all dependent variables include normality of score distributions, absence of outliers and homogeneity of variance (i.e., the variances of each group's dependent variable should be equal in each group of the independent variable).

Regarding the first assumption, item-level responses for the PFT and NFC are on an ordinal scale of measurement. For example, the response scales for these instruments range from 1 to 7 (PFT) and from 1 to 5 (NFC). Non-continuous dependent variables are often non-normally distributed and thus may not be suitable for parametric tests, such as ANOVA or *t*-tests. Specifically, in nonnormal score distributions, the standard errors of parameter estimates (e.g., means or regression coefficients) are inaccurate making statistical tests of significance incorrect. Although the dependent variables at the ordinal scale violated the first assumption in this study, it is possible to adjust for potentially non-

normal distributions stemming from the ordinal or rank-based measurements by using the bootstrapping procedure (Tabachnik & Fidell, 2013).

Bootstrapping

Bootstrapping is a procedure through which statistics are generated by drawing a large number of statistically independent samples from an existing data set. In this study, a total of 1,000 bootstrap samples were drawn from the sample data set cases from the treatment group (n=47) and from the control group (n=52) in this study because the total scores of the dependent variables NFC and PFT were not normally distributed for both groups. Further, each bootstrapped case may be drawn once, more than once, or not at all (i.e. sampling with replacement; Tabachnik & Fidell, 2013). Because the drawing of 1,000 samples normalizes the distribution of the ordinally scaled data, parametric tests with non-continuous dependent variables can be performed. Thus, bootstrapping was performed on several dependent variables (see Tables 3, 4 and 5 for bootstrapped variables) that were not normally distributed, i.e., highly skewed, in this study. To this end, application of bootstrapping provided the correct standard errors of parameter estimates for use in the statistical tests to answer the research questions. The second assumption that calls for a minimum of two independent categorical variables was fulfilled as the PBL group and the control group serve as categorical independent variables in this study. There was also independence (e.g. non-relatedness) between the sample groups, which addresses the third assumption.

The final assumption addresses homogeneity of variance. Statistically, homogeneity of variances implies that by calculating the sample variance for a variable and a specific group of subjects, the error scores from all samples can be used to get the

closest estimate of the population variance (Lansing, 1999). To test for homogenous variances, Levene's test was applied, resulting in homogeneity of variances for NFC (p= .651) and PFT total scores (p= .515). Regarding the ten PFT instrument items, all, but two items, Concrete Answers (p= .031) and Multiple Goals (p= .010), had homogenous variances.

To counteract the heterogeneity in variances of the last two variables, bootstrap replications were used to get the closest estimate of the population variance. Because the bootstrap procedure samples distributions of the estimate of the difference between the population means, the resulting mean difference can be used to make inferences about the difference between the population means (Lansing, 1999).

Data Screening

Prior to running the one-way ANOVA, descriptive statistical analysis was conducted to screen for normality, missing values and internal consistency for each instrument using IBM SPSS Statistics version 25.0. For the dependent variable NFC and one-half (50%) of PFT items were non-normally distributed, i.e., highly skewed. Bootstrapping was performed for those variables that were not normally distributed during statistical analysis (See Table 3). The screening also revealed no missing values in the data set for both groups.

Internal Consistency

Internal consistency reliability (Cronbach's alpha) of scores on the PFT at baseline and posttest for all groups were particularly low at .25 and .46 respectively. Coefficient alpha for the NFC scale was substantially better at pretest (α= .77) and posttest (α = .85). Given the low internal consistency of scores on the PFT questionnaire,

a supplementary factor analysis was performed to assess the adequacy of the instrument's factor structure. The analysis revealed multidimensionality in the set of ten items that are meant to form the unidimensional construct of PFT. As a result, the ten PFT items were modeled/analyzed as distinctly different dependent variables. Analyses proceeded on an item-level basis given the lack of unidimensionality for the 10 items comprising the PFT.

A total of ten univariate extreme outliers as specified by an asterisk in the box plot were detected by IBM SPSS EXPLORE function in the data. One extreme outlier was present for the dependent variable of NFC in the control group. Other extreme outliers were detected for the Multiple Methods item from the PFT questionnaire in the control group. There were four extreme outliers in the Complex Reality item for the treatment (PBL) group as well. The outliers were not deleted in the data set for the analysis because the results were not significantly influenced using bootstrapping.

ANOVA Results

This study intended to answer whether exposure to a PBL-based course in social work disciplines increased college students' complex reasoning, as measure by the PFT and NFC scales, over the course of a semester. To answer these questions, a comparison group design was employed in which the treatment group's scores are compared against the scores of the control group. Baseline data on PFT and NFC were also collected. Thus, total scores that are presented here are difference scores that were created by subtracting the respondents' pretest score from their posttest score. Considering the characteristics of this research design, a One-Way ANOVA and ANCOVA for group comparison were selected as statistical analyses techniques to draw inferences by comparing group means

in IBM SPSS Statistics 25.0. As mentioned previously, the statistical tool bootstrapping was applied to variables that showed a non-normal, i.e., highly skewed, distributions.

Description and Measurement of Covariates

Generally, it is recommended to assess interaction variables, (i.e, covariates), that may potentially explain the changes in the dependent variable following the manipulation of an independent variable (Fraenkel et al., 2012). Potential covariates that were considered to have interacting effects were (a) age of the participants to insinuate the level of maturity, (b) previous exposure to a PBL course in the past, (c) participants' gender and (d) participants' attitude towards group work, as PBL courses involve extensive interaction and collaboration with team members.

Table 2

Descriptive Statistics for Covariates by Study Group.

Measure	Control			PBL		
	M	*SD*	*n*	*M*	*SD*	*n*
Attitude towards Group work[a]	-0.15	1.05	52	-0.23	1.1	47
Age	25.98	6.93	52	26.4	8.83	47
Previous Exposure to PBL[b]	0.8	0.71	52	0.78	0.65	47
Gender	1.09	0.29	52	1.04	0.2	47

Note. An independent samples *t*-test displayed non-significance between the group means on all four covariates.

[a]Attitude towards group work was measured on a scale from Strongly agree (5) to Strongly disagree (1) at pretest and posttest for each participant. Mean scores are based on the total scores per group and represent the difference between the posttest scores and pretest scores.

[b]Past exposure to PBL-based courses included categorical fixed response options of "Yes", "No" and "Not Sure".

Main Effects

A between-subjects ANOVA was conducted using programmatic syntax in SPSS. Results revealed a significant main effect by study group, such that the PBL group respondents (M = 2.08, SD = 5.48) scored significantly higher on the NFCS following exposure to problem-based learning courses at the end of the semester than the control group participants enrolled in traditional-lecture courses (M = -0.3, SD = 6.18), $F(1, 97) = 4.11$, $p = .045$, $\eta^2 = 0.04$. Further, there was no significant main effect for PFT, such that the PBL group (M = 0.36, SD = 4.89) displayed non-significant difference scores when compared to the control group participants (M =0.86, SD =4.52), F (1,97) = 0.28, p= .596, $\eta^2 = 0$. An independent samples t-test on age showed no statistical difference between the treatment (M= 26.4, SD= 8.83) and control group participants' (M= 25.9, SD= 6.93) age; $t(97)$= - 0.26 ,p= .79.

As previously stated, the significantly low internal consistency and the problematic factor structure of the PFT questionnaire required a separate analysis at the item-level in which each item of the instrument is treated as a dependent variable. Therefore, a between-subjects ANOVA was executed for each of the ten items (see Table 2). Items with non-normal distributions were bootstrapped accordingly. Despite the separate item-by-item analysis, only the first two items showed significant between-group effects. Paradox, which implies acceptance of contradictions in an individual's daily life, was significantly higher for the PBL group (M= 0.34, SD=1.04) in comparison to the control group (M= -0.11, SD= 0.83), $F(1,97)$= 5.79, p= .018, η^2= 0.05. The second

item measuring the concept of using Multiple Methods in the context of problem-solving also showed an increased effect in the PBL group (M= -0.53, SD= 0.9) as opposed to the control group (M= -0.11, SD= 0.83), $F(1,97)$= 4.62, p= .034, η^2= 0.04. The other eight items displayed no significant main effects between the group means (See Table 2).

Despite the significant differences between the groups and the dependent variables NFC, Paradox and Multiple Methods, the effect sizes are fairly small (see Table 3). Statistical difference, or the calculated p-value, does not necessarily imply practical significance or practicality in a real-life setting. In other words, the proportions that account for the differences between the groups can be small in the case of significance or moderate to large in the case of non-significance. It is the researcher's task to make a judgment regarding the magnitude of the effects and whether the resulting effect size is of practical value in the studied subject matter (Kirk, 1996). Cohen (1988) established guidelines for eta squared (η^2) effect sizes that are considered small when η^2 = .01, medium when η^2 = .06, and large when η^2 = .14 in ANOVA analyses. Interestingly, only 4% in NFC is explained by exposure to PBL. Paradox and Multiple Methods each account for 5% and 4% in the variance of group differences via PBL.

Table 3

Means, Standard Deviations, and One-Way Analyses of Variance in NFC, PFT and PFT at Item-Level Between Groups.

Measure	Treatment		Control		$F(99)$	η^2
	M	*SD*	*M*	*SD*		
Need for Cognition[a,c]	2.08	5.48	-0.3	6.18	4.11*	0.04
Postformal Thought[a]	0.36	4.89	0.86	4.52	0.28	0
PFT Item-Level[b]						
Paradox	0.34	1.04	-0.11	0.83	5.79*	0.056
Multiple Methods[c]	-0.53	0.9	-0.13	0.92	4.62*	0.045

Table 3. Continued

Complex Reality[c]	-0.12	1.31	-0.05	0.77	0.1	0
Multiple Definitions	0.02	1.71	-0.03	1.65	0	0
Concrete Answers[d]	-0.08	1.29	-0.25	1.85	0.25	0
Different Logics	0.21	1.97	0.82	1.54	2.99	0.03
Multiple Causes[c]	0.21	1.06	0.21	0.8	0	0
Multiple Solutions[c]	0	1.53	0.05	1.24	0.04	0
Multiple Goals[c,d]	0.12	0.99	0.3	1.55	0.46	0
Difficulty Seeing Others' Logics	0.19	1.32	0.05	1.46	0.22	0

*$p < .05$.

[a]Results based on total difference (i.e., post - pre) scores of the specified instrument. For NFC, the difference values ranged from the lowest value of – 23 to the highest of 17 for all participants. For individual items, the lowest difference score was – 5 and the highest was +5 for all participants from both groups.

[b]Given the multi-dimensional nature of the PFT questionnaire, an ANOVA was conducted at the item-level (Table 5).

[c]Bootstrapping was performed due to non-normal distribution.

[d]Bootstrapping was performed due to heterogeneity of variances.

According to Cohen's (1988) guidelines, the proportions presented above are rather small with $\eta^2 < .06$ whereas the dependent variables Multiple Methods and Multiple Causes demonstrated moderate effect sizes of .09 and .12 respectively when Previous Exposure was taken into account. Precisely, Multiple Causes and Multiple Methods each showed a main effect of 0 and .04 respectively. However, when Previous Exposure was considered by study group, a significantly larger effect size of .12 for Multiple Causes

and .09 for Multiple Methods emerged. Although these effect sizes were not displayed as significant differences, they were larger than smaller effect sizes that resulted in significant differences (see Tables 3 and 6). To this end, they may make a more substantial contribution of 12% and 9% to the variances in Multiple Causes and Multiple Methods explained by PBL via Previous Exposure than the statistically significant outcome variables of NFC and Paradox alone. In light of Cohen's (1988) principles for effect sizes, these variances are moderate at the higher end of the guidelines.

Table 4

Interaction Effects Between Need for Cognition and PFT Items by Study Group.

Measure	SS	df	MS	*F*(99)	η^2
Need for Cognition[a] PFT Total Scores	0.652	1	0.652	0.019	0.02
Need for Cognition[a] Paradox	30.541	1	30.541	0.888	0.05
Need for Cognition[a] Multiple Methods	22.587	1	22.587	0.655	0.04
Need for Cognition[a] Complex Reality	24.18	1	24.18	0.702	0.04
Need for Cognition[a] Mutliple Definitions	4.38	1	4.38	0.126	0.04
Need for Cognition[a] Concrete Answers	110.926	1	110.926	3.305	0.07
Need for Cognition[a] Different Logics	1.002	1	1.002	0.029	0.04
Need for Cognition[a] Multiple Causes	40.525	1	40.525	1.182	0.05
Need for Cognition[a] Multiple Solutions	11.288	1	11.288	0.326	0.04
Need for Cognition[a]					

Table 4. Continued

Need for Cognition[a] Multiple Goals	6.242	1	6.242	0.18	0.04
Need for Cognition[a] Difficulty Seeing in Others	9.349	1	9.349	0.27	0.04

*$p < .05$.

[a]Based on total difference sores of the instrument (Post-Pre).

Table 5

Interaction Effects Between Covariates and NFC by Study Group.

Measure	*SS*	*df*	*MS*	*F*(1, 97)	η^2
NFC[a]					
Previous Exposure	168.48	2.00	84.24	2.56	0.12
Gender	12.43	1.00	12.43	0.37	0.08
Age	33.97	1.00	33.97	0.99	0.05
Attitude towards Group work	17.47	1.00	17.47	0.51	0.04

*$p < .05$.

[a]Bootstrapping was performed due to non-normal distribution.

Interaction Effects

A one-way ANCOVA displayed no statistically significant interaction between PFT (total score and item-level) and NFC. Although there is no statistically significant interaction between NFC and PFT items, a closer look at the effect sizes for Paradox, Multiple Causes and Concrete Answers shows moderate effect sizes of 0.05 and 0.07. with 5% and 7% of the variances explained (See Table 4). Despite the non-significant statistical effect (p= 0.072) in the interaction between NFC and Concrete Answers, it is interesting to see a negative trend in the association between NFC levels (M= 2.08; SD= 1.29) and Concrete Answers (M= -0.08; SD= 5.48) in the PBL group. The control group shows a slightly similar pattern but to a much lesser extent with M= -.25 and SD= 1.85

for Concrete Answers and *M*= -0.30 with *SD*= 6.18 for NFC. Bootstrapping was applied in the analysis for Concrete Answers. This pattern in the PBL group implies that following participation in PBL, those who have developed the need to think about and engage in complex tasks started to show lower preferences for concrete answers in finding a solution to a complex problem. To take this interpretation a step further, higher levels NFC may mediate a dislike of concrete answers and solutions during complex problem-solving. Nonetheless, a statistically significant interaction between PFT as the ability to reason and NFC as the motivation to reason in complex problem-solving was not displayed in the analysis.

A further analysis of the interaction between the covariates described above and NFC or PFT by study group was performed with one-way ANCOVA using syntax in IBM SPSS Statistics. Analyses focusing on the dependent variable of PFT were based on each PFT item from the PFT instrument, in addition to the total score of the PFT questionnaire. There were no interaction effects for NFC (See Table 4). However, two statistically significant interaction effects were detected at the item level for PFT. Table 5 shows a significant interaction effect between Concrete Answers, exposure to PBL and attitude towards group work, $F(1, 96)= 5.652$, $p= .019$, $\eta^2= .05$. The statistical difference in Concrete Answers scores between the PBL and control group was dependent on the students' liking, or a lack thereof, for group work. Exposure to PBL and group work attitude accounted for 5% of the variance in Concrete Answers.

Another significant interaction was detected between Multiple Solutions and the study groups when accounting for gender. Gender moderates the scores on Multiple

Solutions between the treatment and control groups ($F(1,95) = 8.817$, $p = .004$, $\eta^2 = .08$). Gender and exposure to PBL explained 8% of the variance in Multiple Solutions.

Table 6

Interaction Effects Between Covariates and PFT at Item-level by Study Group.

Measure	*SS*	*df*	*MS*	$F(1, 96)$	η^2
Paradox					
Previous Exposure to PBL	1.24	2	0.62	0.68	0.07
Gender[a]	0.31	1.00	0.31	0.35	0.06
Age[a]	0.73	1.00	0.73	0.83	0.06
Attitude towards Group work	0.07	1.00	0.07	0.08	0.05
Multiple Methods					
Previous Exposure to PBL	3.39	2.00	1.70	2.04	0.09
Gender[a]	0.14	1.00	0.14	0.17	0.05
Age[a]	0.02	1.00	0.02	0.02	0.04
Attitude towards Group work	0.31	1.00	0.31	0.37	0.04
Complex Reality					
Previous Exposure to PBL	1.35	2.00	0.68	0.60	0.04
Gender[a]	1.68	1.00	1.68	1.48	0.02
Age[a]	1.24	1.00	1.24	1.09	0.01
Attitude towards Group work	1.10	1.00	1.10	0.97	0.01
Multiple Definitions					
Previous Exposure to PBL	6.06	2.00	3.03	1.05	0.02
Gender[a]	0.00	1.00	0.00	0.00	0
Age[a]	0.31	1.00	0.31	0.11	0
Attitude towards Group work	0.15	1.00	0.15	0.05	0
Concrete Answers[b]					
Previous Exposure to PBL	3.78	2.00	1.89	0.73	0.05
Gender[a]	0.65	1.00	0.65	0.25	0
Age[a]	1.26	1.00	1.26	0.48	0
Attitude towards Group work	14.09	1.00	14.09	5.652*	0.05
Different Logics					
Previous Exposure to PBL	0.16	2.00	0.08	0.03	0.03
Gender[a]	7.90	1.00	7.90	2.56	0.05
Age[a]	4.52	1.00	4.52	1.46	0.04
Attitude towards Group work	0.00	1.00	0.08	0.03	0.03

Table 6. Continued

Multiple Causes					
Previous Exposure to PBL	4.49	2.00	2.24	2.82	0.12
Gender[a]	0.57	1.00	0.57	0.65	0.01
Age[a]	0.46	1.00	0.46	0.53	0
Attitude towards Group work	1.74	1.00	1.74	2.02	0.02
Multiple Solutions					
Previous Exposure to PBL	3.35	2.00	1.67	0.87	0.04
Gender[a]	15.85	1.00	15.85	8.817*	0.08
Age[a]	0.93	1.00	0.93	0.48	0
Attitude towards Group work	1.62	1.00	1.62	0.84	0
Multiple Goals[b]					
Previous Exposure to PBL	1.57	2.00	0.79	0.44	0.02
Gender[a]	3.03	1.00	3.03	1.74	0.02
Age[a]	2.66	1.00	2.66	1.54	0.02
Attitude towards Group work	4.62	1.00	4.62	2.71	0.03
Difficulty Seeing Others' Logics					
Previous Exposure to PBL	0.84	2.00	0.42	0.21	0.03
Gender[a]	1.27	1.00	1.27	0.65	0.03
Age[a]	0.00	1.00	0.00	0.00	0
Attitude towards Group work	0.79	1.00	0.79	0.40	0

*$p < .05$.

[a]Bootstrapping was performed due to non-normal distribution.

[b]Bootstrapping was performed due to heterogeneity.

Summary

This chapter presented a parametric One-Way ANOVA and ANCOVA analyses that were used to test for differences and interaction effects among the PBL and control groups and several covariates. In addition to the demographic information about student participants, the reasons for the procedure and steps chosen were provided in detail. Significant main effects were observed between the groups on NFC levels; students exposed to PBL scored higher at the end of the semester on the NFC scales when compared to the control group that was exposed to traditional-lecture after accounting for

participants' age, gender, attitude towards group work and previous exposure to PBL-based courses in the past. There were no significant differences on the total scores of the PFT questionnaire between the groups. However, an item-level analysis revealed significant differences on Paradox and Multiple Methods between the groups after accounting for the covariates presented in Table 5. The PFT items Concrete Answers and Multiple Solutions interacted with attitude towards group work and gender respectively.

V. DISCUSSION

The study examined whether exposure to PBL significantly increases the levels of sophisticated reasoning, in particular relativistic reasoning as assessed by the postformal thought (PFT) questionnaire and the NFC scale (NFCS) (Cacioppo & Petty, 1982; Sinnott & Johnson, 1997). Furthermore, this study addressed interactions among the dependent variables of PFT and NFC and covariates of gender, age, attitude towards group work and previous exposure. The premise of the study proposed that complex cognitive reasoning skills are a crucial part of adult development and are in high demand in the rapidly changing workplace environment (Hart Research Associates, 2015, p. 6). On several occasions the major employer and innovative entrepreneur Elon Musk went even as far as to say that he does not consider university degrees as important; he prefers candidates who had solved complex problems in the past and can transfer their hands-on problem-solving skills into his company environment (Matousek, 2020). Furthermore, the literature reveals an increase in metacognitive and critical thinking among young adult learners in higher education contexts following participation in PBL-based courses in a variety of disciplines (Downing et al., 2011; Wynn et al., 2014). In this study, two constructs (PFT and NFC) that contribute to complex reasoning following exposure to PBL, were of interest.

Considering existing literature on the effect of PBL as an educational approach to learning, this study aimed at answering two research questions:

(1) Does exposure to PBL strategies increase PFT in adult learners?

(2) Does exposure to PBL strategies increase the NFC in adult learners following participation in PBL?

The hypothesis associated with the research questions tested for significance of the group means of the PFT and NFC levels of the PBL group and the control group at post-test measure. To test the hypotheses associated with the research questions, a static-group comparison pretest-posttest design was employed. Upon collecting pretest and posttest responses from the experimental (n=47) and the control group (n=52), a One-Way ANOVA and ANCOVA in IBM SPSS Statistics 25.0 were performed to test for main and interaction effects between the study groups. The first hypothesis centering on PFT was rejected due to non-significant group means at posttest (p= .596). The second hypothesis testing for mean differences between groups in NFC levels was not rejected. Adult learners in the PBL group scored significantly higher on the NFC scale when compared to traditional lecture adult students at posttest (p= .045). According to data screening analysis, the NFC scale had a high internal reliability while the PFT showed a substantially low internal consistency as indicated by Crohnbach's alpha.

The PFT's low internal consistency warranted a factor analysis to assess its factor structure, which showed the PFT's multidimensional nature. When a questionnaire is multidimensional, its items tend to represent separate dimensions due to high eigenvalues. Due to the PFT's multiple dimensions, each item was treated as a separate outcome variable. Results showed significant main effects for Paradox (p= .018), a high tolerance towards contradictions occurring in daily life, and Multiple Methods (p= .034), the preference to apply multitude of methods during problem solving, for the PBL group. Other items did not display significant main effects possibly because the PFT's low internal consistency and inadequate item structure consisting of long or two statements per item, making it difficult for respondents to understand what the item measures.

Because this study did not make use of randomized assignment to groups, four factors that may account for differences between groups were measured. These four factors are (1) participants' age and (2) gender, (3) their past exposure to courses that follow the model of PBL and (4) their attitude towards group work assessed on a scale from 1 for least enjoying group work to 5 highly enjoy working in groups. The latter two of these factors were assessed under the assumption that a positive attitude towards group work may facilitate cognitive changes, or vice versa. Adult learners who feel comfortable working in groups may be significantly less inhibited to develop and employ complex reasoning skills. Being familiar with PBL-based courses, i.e., previous exposure to PBL, may make young adult students more susceptible to cognitive changes, a phenomenon that is referred to as practice effects (Leary, 2012).

To test for interaction effects of these four factors, an ANCOVA was selected and revealed significant interaction effects for Concrete Answers with 5% of variance via attitude towards group and Multiple Solutions with 8% of variance via Gender accounted for group differences attributable to PBL. Based on the differences between pretests and posttest scores, participants' attitudes towards group work (M= -0.23; SD= 1.10) moderated levels of Concrete Answers (M= -0.08; SD= 1.29) in the PBL group while there were no significant mean differences for the control group (p= 0.257).

Interpretation of Results

Discussion of Results on Postformal Thought

Regarding the first hypothesis centering on increased scores of the PFT questionnaire following exposure to PBL, there were no significant differences in the PFT scores between the groups. This finding stands in contrast with Wynn et al.'s (2014)

study that showed higher education learners' increased PFT scores post-PBL in a history course. Although there were no pretest measures in Wynn et al.'s (2014) study, his qualitative data analysis highlighted students' motivation to understand contradicting perspectives before evaluating them. Other qualitative responses verified that students learned how context influences decision-making in PBL courses. The PBL group's responses revealed students' ability to grasp content and increased awareness of two conflicting sides.

Wynn et al.'s (2014) findings on cognitive effects of wanting to understand contradicting views and context-dependent decision making relate to the results in this study. A person's tolerance towards contradictions in daily life as measured by the PFT item Paradox was significantly higher in the PBL group compared to the traditional lecture group at the end of the semester. Given that the PFT items Multiple Methods and Multiple Solutions also displayed increased scores post-PBL in the experimental group in this study, Wynn et al.'s (2014) qualitative finding of context-driven decision-making could explain students' willingness to generate multiple methods and multiple solutions in complex contexts of problem-solving. To date only this study and the study by Wynn (2014) tested the effects of PBL on PFT levels among adult learners in higher education. No other studies have combined PBL and PFT in learning contexts. Because of this gap in the literature, the review of existing literature in Chapter 2 evaluates group-comparison studies producing significant effects of PBL as a learning approach on metacognitive and critical thinking skills among adult students (Hung et al., 2015; Kuvac & Koc, 2019).

While these reasoning approaches are conceptually interrelated, the instruments for each reasoning construct are too distinct to draw direct connections among PFT,

metacognition and critical thinking. Because metacognition is the ability to be aware of one's own thinking patterns and the way one's assumptions and values influence these patterns, it can be argued that, to an extent, metacognition promotes the ability to be aware of the limitations of one's thinking and perspectives. This heightened awareness of one's thinking and reasoning structures may facilitate tolerance towards contradictions of views and the use of a multitude of viable methods for problem-solving by acknowledging one's limitations and imperfections in reasoning.

Because the questionnaire's internal reliability and factor structure are not robust (see Chapter 4), a supplemental analysis of the instrument's factor structure displayed that several items had high eigenvalues (λ >1) that point to distinct dimensions comprised of individual items (i.e., not a unidimensional scale or instrument). As previously mentioned, the instrument's low internal consistency and a multidimensional factor structure required a separate analysis in which each PFT item was treated as its own dependent variable. This type of analysis revealed two statistically significant main effects of the first two PFT items Paradox and Multiple Methods.

Like the effect size for NFC, Paradox and Multiple Methods displayed small but statistically significant effect sizes. Paradox and Multiple Methods each account for 5% and 4% in the variance of group differences stemming from exposure to PBL. Significant effects of these items indicate that PBL learners demonstrate an increasing tolerance towards contradictions in daily life as compared to participants learning through traditional-lecture methods. Regarding the statistical significance of the second PFT item Multiple Methods, PBL participants showed a higher preference to apply a variety of methods during problem-solving than learners of the traditional-lecture group. Both

significant main effects remained after accounting for gender, age, past participation in PBL and group work attitude.

Discussion of Results on Need for Cognition

The second hypothesis focused on determining if an increase existed on NFC following participation in PBL. The results of the analysis confirmed a statistically significant, albeit small, difference ($\eta^2 = .04$) in the NFC scores between the PBL group and control group. This significant difference between group means of NFC persisted even after accounting for gender, age, previous exposure to PBL and attitude towards working in groups. While previous research has demonstrated similar results that point to associations between high NFC and complex problem-solving skills (Coutinho, 2006; Rudolph et al., 2018) as well as creative problem-solving skills (Watts et al., 2017), it has mainly been associational in nature, not manipulating independent variables to examine interventional effects on adult learners' NFC levels. For example, Coutinho's (2006) study predicts that NFC increases engagement in complex-problem-solving.

Rudolph et al.'s (2018) associational study used model fit indicators to assess links among NFC with a sample of seventh-graders, duration or length of time spent exploring problems during problem-solving tasks, reasoning ability and complex problem-solving (CPS). Combinations of the constructs produced higher variances explained than NFC exploration time alone, for example. NFC and exploration time together accounted for 41% of the variance in CPS while NFC alone explained only 6% of the variance in CPS exploration time. Upon combining exploration time, NFC and reasoning ability together, an SEM analysis explained 59% of the variance in CPS. Although the study' sample consisted of young teenagers, the robust sample size of 474

young learners and the established empirically meaningful links might be transferable to an adult sample.

Taking into consideration that Rudolph et al.'s study produced a variance of 6% accounted for by NFC in CPS, the variance of 4% explained by exposure to PBL in NFC in this study very closely aligns with the identified variance in Rudolph et al. (2018). Given the correlational nature of the described studies on NFC above, this study presents PBL as the precursor to increases in NFC; engagement in complex problem-solving precedes increases NFC levels among adult learners in higher education. As pointed out in the framework section, this finding is also in alignment with the assumption that NFC is a malleable trait that can change when exposed to complex problem-solving contexts.

Discussion of Interaction Factors

To test for interaction effects, an ANCOVA revealed significant interaction effects for Concrete Answers with 5% of variance via attitude towards group work and Multiple Solutions with 8% of variance via Gender accounted for group differences attributable to PBL. Based on the differences between pretests and posttest scores, participants' attitudes towards group work (M= -0.23; SD= 1.10) moderated levels of Concrete Answers (M= -0.08; SD= 1.29) in the PBL group while there were no significant mean differences for the control group (p= 0.257).

Taking the means into account, participants in the PBL group may prefer concrete answers while showing an aversion towards working in groups. This is an interesting finding because learners who prefer straight-forward and rather simple answers to problems do not like working in groups, an approach that may require mental effort and patience to attend to a variety of views among group members. Preferring simple and

concrete answers may thus be considered as opposing or conflicting with the PBL learner's attitude towards group work. Bootstrapped interaction effects in the PBL group between Multiple Solutions (M= .00; SD= 1.53) and gender (M= 1.04; SD= 0.20) also showed a trend of female participants' bias against using Multiple Solutions during problem-solving. There were no such interactions in the control group (p= 0.162).

Interestingly, interaction effects for Multiple Methods and Multiple Causes via Previous Exposure to PBL displayed larger effect sizes, yet non-significant statistical results. The PFT item of Multiple Methods accounts for 9% of the variance of group differences while the item Multiple Causes explains a total of 12% of the variance in differences between the group means via past PBL participation. Another such case is evident in the interaction effects of higher NFC (M= 2.08; SD= 1.29) and lower values for Concrete Answers (M= -0.08; SD= 5.48) with a moderate η^2 of 0.07. It is thus advised to interpret the statistically significant results of the main and interaction effects considering small effect sizes (η^2<.06) critically (Kirk, 1996). Such critical examination would consider moderate effect sizes that were statistically not significant as they may show a substantial practical contribution to the dependent variable.

Implications for Theory

The results of this study provide insightful evidence relative to learning theory in the field of adult education, higher education and educational psychology. As has been stated in the section on conceptual framework, NFC as a motivational construct precedes the skill of complex reasoning PFT. This distinction makes sense because in this study PBL student participants scored higher on NFC post PBL while the PFT scores showed no significant differences at posttest compared to the control group. Despite the PFT's

problematic structure, this non-significant difference may also be the result of insufficient time to develop PFT reasoning skills during the three months of PBL courses. Although the study by Wynn et al. (2014) is the only study to date that tested the influence of PBL on PFT among higher education learners, their mixed-methods methodology provides implications on the relationships among the various higher order reasoning skills. For example, their qualitative data shows statements indicating metacognitive ways of thinking about a complex subject matter.

Further, learners' descriptions showed tendencies towards critical thinking and other meaningful insights adult students have gained from PBL compared to learners in the control group. By triangulating the data, a direct and reasonable connection can be established between metacognitive statements, critical thinking and increased PFT in their study. As far as critical thinking is concerned, Hung, Tang, and Ko (2015) obtained reflections on the benefits nursing students gained from a PBL nursing course. Emerging themes that relate to PFT and NFC results in this study included thinking through a diversity of perspectives, systematic thinking skills to improve or adjust performance, application of knowledge on real-world problems and brainstorming approaches to problem solving (Hung et al., 2015).

This study in particular highlights the connections among the theoretical constructs of metacognition, critical thinking, NFC and Postformal Thinking and establishes the connection between exposure to PBL and increased tolerance towards contradictions, the use of a multitude of methods in problem-solving and NFC empirically. Considering these conceptual and preliminary empirical connections among the reasoning styles, a statistical modelling approach, such as structural equation

modelling, is suitable to assess the reasoning skills contributions - as indicated by the loadings of each of these skills- to the quality of complex problem-solving in higher education.

An important point to consider is that experimental research tends to produce less variance than nonexperimental studies because researchers have less control over people's behavior than nature in daily life. For example, social science research (including education) typically display smaller effects than sociology, economics, and physiological psychology where associational, such as correlational, research design is the norm (Tabachnik & Fidell, 2013). Given the nature of experimental research, there is a chance that learners in this study may have benefitted from PBL in cognitive as well as other dimensions that were not accounted for in this study. For example, changes in attitudes towards complex social problems may have occurred but were not assessed in this study (i.e., unmeasured variables may exist). Learners may be more confident and less anxious when facing a complex problem that relies on their skills and competence. Taking these aspects into account, a variety of questions remain - addressing not only the connections between PBL and NFC and PFT but learning interventions and cognitive development in general.

Implications for Adult Higher Education Practice

The current higher education models in Westernized nations tend to be predominantly standardized and rigid, inhibiting teachers and students to engage in discourse on the intricacies of 21st century problems (Hursh 2005). For instructors in the US, such rigid models and theory-driven didactics create pressure to adhere to narrow curriculum standards, raise student test scores, and follow predetermined lessons

(Taubman, 2009). Similarly, learners who study under such theory-driven curricula experience immense pressure to prepare for tests and understand learned content in abstract terms. This may inhibit critical thinking and the capacity to participate in discourse on social problems (Hursh, 2005). The observation that rigid learning structures do not allow for critical reasoning to improve nursing practice was evident in the qualitative component in Gholami et al.'s (2016) study as well.

Given these issues in current higher education, this study extends the scope of adult higher education practice by showing that problem-based and community-based learning models are a valuable addition to higher education. Such learning approaches do not only replace seclusion with collaboration (Ritchie 2012; Ronfeldt et al. 2015) but they also have the potential to foster higher order reasoning skills, as this study has shown.

To extend the scope of practice slightly further, the primary focus on predominantly theoretical teaching and learning approaches should shift towards efforts of closing the gap between theory and practice in academic disciplines and create spaces for engaging in discourse and problem-solving processes (Morrison, 2018). PBL offers learners the opportunity to apply previously learned theory in real-life contexts. In this study, it is possible that the way a learner has reasoned theoretically about quandaries based on preexisting values prior to engaging in PBL may have changed in a variety of real-life contexts filled with intricate problems. In other words, it is possible that increased NFC, tolerance towards contradiction in life (Paradox) and the preference to apply a multitude of methods to solve one problem (Multiple Methods) in this study were fostered by not only PBL alone but by the synthesis of learned theory and practice implemented by PBL in the context of higher education. According to PBL advocate

David Boud, changes in thinking occur through genuine profound reflective activities. Such reflections are provoked by tangible problems with which the learners are confronted and experience actively. Thus, profound changes in adult learners' reasoning are brought on by the connection between theoretical knowledge and the application of such knowledge in a real-life situation (Boud & Feletti, 1997).

Taking into account the connection between theory and practice enabled by PBL, embedding problem-based and community-based learning approaches into higher education may change the way instructors and learners experience learning in higher education. While PBL models offer opportunities for application of theoretical knowledge and collaboration with active participation in critical discourse in adult higher education practice, this study has presented cognitive outcomes of PBL-based learning approaches in the form of increased higher-order reasoning.

Potential Outcomes of Adult Education Fostering Postformal Thought

In an interview, the adult educator David Boud proposed that during PBL, learners create a shift in knowledge and the way they understand certain issues. This shift in viewing and perceiving occurs also through application and re-application of one's knowledge and techniques (Norman, 2012). Although participants in this study developed a shift towards higher tolerance towards contradictions (i.e, Paradox), higher interest in working with complex problems (NFC) and a preference for using a variety of methods (i.e., Multiple Methods), the question regarding why such reasoning skills are important on a holistic level, i.e., in different dimensions of life, remains. Questions addressing the extent to which these ways of reasoning are important and the impact these reasoning

approaches have on an adult's daily life have been addressed extensively in the literature on PFT and its theory.

In Morgan's in-depth analysis of PFT, PFT is considered a sophisticated or higher order reasoning that relies on "[…] ever-deepening experience of *being-in-the-world* and more adequate modes of *being and knowing*" (emphasis in original) (2006, p. 341). He further argued that promoting the development of post-formal thinking is beneficial for two main reasons: (1) it is the kind of thinking which is seen to be necessary to combat 21st century key challenges encompassing environmental decay, intercultural issues, the search for spiritual fulfilment; and (2) postformal thinking is the highest order of reasoning a human can reach in the personal and societal domains. Interestingly, Morgan points to social activities in which the opportunity "offered by a social group to distribute and co-ordinate or share perspectives amongst itself suggests that post-formal thinking and the development of wisdom is much facilitated through dialogic argumentation" (p. 346). Thus, the development of PFT skills is less likely to occur in isolation and is a social matter relying on hands-on problem-solving experiences.

Other proponents of reasoning following the PFT model argue that analyses of issues that have complex dynamics, such as terrorism, corruption, poverty, and other societal challenges are facilitated by reasoning at the metasystematic stage to comprehend "how multiple metasystems must change to alleviate conditions that give rise to such challenges" (Commons & Ross, 2008, p. 327). They further argue that postformal reasoning allows the individual to view each person as a system with multiple perspectives rather than objects "of others' strategic plans" (p. 327). This shift in perspective stimulates "preferences for genuine interest and inquiry in others' points of

view" (p. 327). Commons and Ross (2008) further posit that such features of PFT help progress the fields of humanities, mathematics and science because dilemmas and intricate issues are addressed within broader, de-personalized contexts to co-create practical and viable solutions.

To advance the fields of adult and community education, reasoning beyond formal and logical terms is likely necessary due to the intricate challenges and conflicts that prevail in the adult world. PFT synthesizes conflicting needs and contradicting views as "The struggle for independence and dependence is integrated into a more functional interdependence in which contributions to the needs and preferences of others is a normal part of non-strategic interaction" (Commons & Ross, 2008, p. 328). Within the stages of adult development, the highest order of relating to others is state of interdependence as it allows for a synthesis of conflicting views. When PFT is employed as a reasoning mechanism, the accompanying process of balancing conflicting needs and views plays a crucial role in adult education practice whose focus is on implementing just social policies and practices. The results of this study show that PBL stimulated increases in NFC and increases in a few of the PFT items, such as acceptance of paradox and the use of multiple methods. Although effect sizes of the variables were small, the increases may have meaningful impacts on adult students' choices and actions that reflect postformal principles.

Given the benefits associated with postformal reasoning patterns during complex issues in a variety of life domains, it is possible that the practical significance of the increased levels in NFC and PFT items may be more insightful than the statistically calculated significance. Based on this argument, educators, education administrators and

other stakeholders should advocate for learning approaches that operationalize the characteristics of PFT required to work with and manage complex problems.

Implications for University Policy

Given the results of this study, there is tentative support that learning through problem-based and community-based learning approaches employing societal real-life problem scenarios is an essential component to developing higher-order reasoning skills and problem-solving skills. Although this study's results are limited to social work majors, the review on existing literature in Chapter 2 describes similar results post-PBL in a variety of other disciplines, such as nursing, history, business and engineering. The diversity of study settings proves that PBL-based learning models are suitable for courses focusing on practice and field experience. Irrespective of the discipline, the university plays a major role in the implementation of such learning approaches. Providing empirical evidence of the benefits PBL provides in higher education contexts may be an important factor from a university policy perspective. This study identifies several benefits at the cognitive level as characterized by higher-order reasoning among adult learners. Although increases in these complex ways of reasoning seem promising, statistical significance does not necessarily imply an important practical effect in practice. Therefore, researchers in social and behavioral sciences are obligated to evaluate results beyond hypothesis testing and *p*-values and make a judgment(s) about the proportion of variance (e.g., how using PBL explains changes in cognition) stemming from the causal (predictor) variable and its contribution to the variance in the outcome variables (Kirk, 1996).

In light of this view, it appears that the item Multiple Causes, for example, makes a better contribution of 12% of variance accounted (i.e., greater explanatory power) for via previous exposure to the variances between group scores than the item Concrete Answers via group work attitude, which explains only 5% of the variance. However, despite small main effect sizes of NFC, Paradox and Multiple Methods, the increases in the dependent variables may still make a difference if learners benefit from such increases in the long run. It's possible that small increases or contributions in the mentioned dependent variables may also stimulate further increases in the mentioned constructs of reasoning once the adult learner has developed the tendency to employ these reasoning skills. Taking this possibility into account, PBL as an approach to learning should be considered a viable learning approach in higher education to accompany curricula that predominantly use traditional-lecture models.

Delimitations

The research design in this study provides delimitations. Having a control group is an essential delimitation that should part of every experimental study. In addition to a control group, assessments on a construct of interest at pretest and posttest are crucial to determining differences not only between but within the groups. Without a pretest, the researcher has no way of knowing whether the experimental group was scoring high on an instrument at pretest already. In addition to the design characteristics, this study's sample size exceeded the minimum required sample of 39 participants and increased by 18% for the PBL and 25% for the control group.

Further, a few factors that may explain certain effects were accounted for. These include demographic aspects, such as gender and age, and psychological dimensions,

such as attitude towards group work and past exposure to the independent variable. Aspects specific to this study also involve the examination of course syllabi for PBL principles, keeping the majors of adult students equal by including only adult students of social work majors. Instead of being limited to one higher education institution, student participants came from three different large public universities in Central Texas.

Limitations

A major limitation is this study is the use of a quasi-experimental design that includes the use of static groups without random assignment. Having static groups in a study makes it difficult to ascertain whether certain group characteristics influenced the results. However, true experimental designs are difficult to implement in the context of education due to ethical reasons (e.g., withholding treatment or exposure to novel or innovative interventions), making quasi-experimental designs the norm in the social sciences (Fraenkel et al., 2012). Another major limitation of this study relates to the unequal sample sizes of the genders represented in the sample with only 7% making up the male sample. Having a predominantly female sample makes it more difficult to apply the results beyond female adult learner populations.

Another design issue revolves around the use of sound and robust instruments. Having administered the PFT questionnaire is a critical limitation due to the low internal consistency and the absence of its unidimensional factor structure. The consequences of using a structurally unstable instrument not only threatens internal validity but it may also not measure complex reasoning as defined by PFT. A solution to this problem involved an item-by-item analysis to address the multidimensionality of the PFT questionnaire.

Another limitation in the present study relates to the fact that it is a case study because the findings are limited to social work adult students enrolled at three large public Central Texas Universities who were exposed to PBL during the Fall Semester of 2019. In order to interpret the findings beyond adult learners who are studying social work at universities in Central Texas, this study must be replicated multiple times with different student populations at different points in time. It is important to mention that the review on existing literature in Chapter 2 has already shown positive results post-PBL in a variety of other disciplinary settings, such as nursing, history, business and engineering. Such diversity of study settings implies that effects from PBL-based learning models are extendable to other disciplinary courses as long as they focus on solving complex problems such as in practice and field experience.

Recommendations for Future Research

Future research should explore other benefits associated with the PBL approach to learning. This study highlights a small amount of explained variance in the dependent variables ranging from 4% to 12%. It would be insightful to identify variables responsible for the unaccounted variance explained in the present analyses. For example, future research could explore other cognitive and behavioral changes, such as self-efficacy, confidence as well as competence in problem-solving, perceived competence in working with teams, relationship-building skills and other outcomes that logically connect to the principles of the PBL learning approach. A good example is the associational study by Rudolph et al. (2018) using structural equation modeling (SEM) to assess interactions among several interrelated constructs of NFC, problem exploration time, reasoning ability and complex problem-solving. When using the SEM approach with multiple

factors, the variances explaining CPS were much higher at 41% compared to 6% when using only one of the predicting factors to explain the variance in CPS (Rudolph et al., 2018).

While the topics provide substantial insight into the effects associated with PBL, choosing the appropriate research design is equally important. As has been recommended in the previous chapters evaluating previous research on PBL, a mixed-methods design of any kind could offer relevant themes and in-depth results via triangulation. A qualitative component can serve as a guide to researchers who may select the appropriate instrument based on qualitative findings. Qualitative findings will also complement or explain quantitative findings that are based on fixed responses in the questionnaires. Regarding the nature of the research design is concerned, experimental or correlational methods are appropriate. However, because the majority of research on PBL is experimental or intervention-based, correlational or associational research being explanatory (and possibly causal via structural equation modeling) could include a variety of factors to explain how and why the variables relate to each other. To obtain an accurate picture of PBL, associational research is appropriate as it allows for sophisticated model building with accurate error terms to pinpoint substantial or trivial effects of PBL (Tabachnick & Fidell, 2013).

Conclusion

This study investigated whether PBL increases college students' certain thinking approaches, such as complex reasoning and the motivation to engage in complex problem-solving. Adult students recruited from three universities in central Texas completed the scales of PFT and NFC that served as indicators of complex cognitive

changes resulting from exposure to PBL. Only NFC increased in the PBL group while the PFT scores were shown as non-significant between the PBL and the control group. Upon conducting an item-level analysis, significant increases in tolerating contradictions in daily life as well as the preference for employing multiple methods during problem-solving emerged. Because skills, such as complex problem-solving, are increasingly in high demand in many areas of daily life, learners in higher education contexts should be involved in practice-oriented learning interventions that foster such hands-on skills. As demonstrated by this study, the PBL approach to disciplinary learning is suitable to foster complex reasoning styles. Taking such outcomes into account, the PBL approach should be implemented to complement theory-driven traditional lecture instructional approaches in higher education.

APPENDIX SECTION

APPENDIX A: PFT AND NFC INSTRUMENTS-PRETEST AND POSTTEST

PFT (Sinnott, 1998) Questionnaire (Complete 10-item Questionnaire) and NFC Scale Shortened 10-item version (Chiesi, Morsanyi, Donati, & Primi, 2018)

Start of Block: PFT and NFC Scales - Pretest

Q1 Please enter your university e-mail address.

_____

Q2 What is your age?

_____

Q3 To which gender identity do you most identify?
- o Female (1)
- o Male (2)
- o Nonbinary (3)
- o Prefer not to answer (4)

Q4 What is your major?

_____

Q5 To which degree do you agree with the following statement?

I enjoy working in groups on projects.
- o Strongly agree (1)
- o Somewhat agree (2)
- o Neither agree nor disagree (3)
- o Somewhat disagree (4)
- o Strongly disagree (5)

Q6 Have you taken a problem-based or community-based learning course before?

For clarification, a problem-, community-based or service-learning course is a course in which you spent a great deal of time identifying and defining an unresolved problem with your group members before crafting a solution during a full semester. You may have also engaged in self-directed learning and research activities frequently to understand the problem and contribute to the solution before suggesting to and discussing it with your group and class. Your teacher or professor spent also less time lecturing as you used that time for working in groups and researching.
- o Yes (1)
- o No (2)
- o Not Sure (3)

o Other (4) _____

Skip To: PFT If = No

Q6.1 Have you taken such a course in

▢ High School (1)

▢ College (2)

PFT

The next 10 statements assess your view about the nature of problems. Please indicate the extent to which you agree or disagree with the following statements.

Strongly agree (1) Agree (2) Somewhat agree (3) Neither agree nor disagree (4) Somewhat disagree (5) Disagree (6) Strongly disagree (7)

1. I see the contradictions in life.
2. I see more than one method that can be used to reach a goal.
3. I know that reality is really multi-level and more complicated.
4. There are many ‘‘right’’ ways to define any life experience; I must make a final decision on how I define the problems of life.
5. I think that ‘‘succeeding’’ in the everyday world means finding a concrete answer to one of life’s problems.
6. Almost all problems can be solved by logic, but this may require different types of ‘‘logics’’.
7. I tend to see several causes connected with any event.
8. I see that a given dilemma always has several good solutions.
9. I realize that I often have several goals in mind, or that life seems to have several goals in mind for me. So I go toward more than one in following my path in life.
10. I have difficulty seeing the hidden logic in others’ solutions to the problem of life when I disagree with their solutions.

NFC

For each of the statements below, please indicate whether or not the statement is characteristic of you or of what you believe. For example, if the statement is extremely uncharacteristic of you or of what you believe about yourself (not at all like you) please place a "1" on the line to the left of the statement. If the statement is extremely characteristic of you or of what you believe about yourself (very much like you) please

place a "5" on the line to the left of the statement. You should use the following scale as you rate each of the statements below.
Extremely uncharacteristic of me (1) Somewhat uncharacteristic of me (2)Uncertain (3)Somewhat characteristic of me (4) Extremely characteristic of me (5)

1. I would prefer complex to simple problems.

2. I like to have the responsibility of handling a situation that re- quires a lot of thinking.

3. Thinking is not my idea of fun.

4.I would rather do something that requires little thought than something that is sure to challenge my thinking abilities.

5.I try to anticipate and avoid situations where there is likely a chance I will have to think in depth about something.

6. I find satisfaction in deliberating hard and for long hours.

7. The idea of relying on thought to make my way to the top appeals to me.

8. I really enjoy a task that involves coming up with new solutions to problems.
9. I prefer my life to be filled with puzzles that I must solve.

10. I would prefer a task that is intellectual, difficult, and impor- tant to one that is somewhat important but does not require much thought.

End of Block: PFT and NFC Scales - Pretest

PFT and NFC Scales - Posttest

with the following posttest items

Q1 Please enter your university e-mail address.

_____

* Q2 How satisfied were you with group dynamics in your PBL group?
o Extremely satisfied (1)
o Somewhat satisfied (2)
o Neither satisfied nor dissatisfied (3)
o Somewhat dissatisfied (4)
o Extremely dissatisfied (5)

*Q2 Item exclusively for experimental group. Control group will only answer Q1.

Following the items above, PFT and NFC Scales will be administered as in the pretest.

APPENDIX B: INFORMED CONSENT

Angelina Lapina, a graduate student at Texas State University, is conducting a research study on problem-based learning. You are being asked to complete this survey because you are enrolled in a problem-based learning course.

Participation is voluntary. The survey will take approximately 15 minutes or less to complete. You must be at least 18 years old to take this survey.

This study involves no foreseeable serious risks. We ask that you try to answer all questions; however, if you are uncertain about an item's statement and meaning, choose "neutral" on the scale as your response. Your responses are anonymous or confidential.

Possible benefits from this study are

The value of, or a lack thereof, Problem-based Learning as a learning approach used in higher education to enhance learning.

Reasonable efforts will be made to keep the personal information in your research record private and confidential. Any identifiable information obtained in connection with this study will remain confidential and will be disclosed only with your permission or as required by law. The members of the research team, the funding agency (remove funding agency if study is not funded), and the Texas State University Office of Research Compliance (ORC) may access the data. The ORC monitors research studies to protect the rights and welfare of research participants.

Your name will not be used in any written reports or publications which result from this research.
Data will be kept for three years (per federal regulations) after the study is completed and then destroyed.

You will receive a link where you can get your Amazon gift card digitally ($25 value) upon the completion of the survey.

If you have any questions or concerns feel free to contact me or my chair Dr. Joellen Coryell:

Angelina Lapina, Doctoral Student

Department of Counseling, Adult Education, Leadership and School Psychology
512-905-0678
a_l489@texasstate.edu

Dr. Joellen Coryell, Professor
Department of Counseling, Adult Education, Leadership and School Psychology
512.245.1856
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This project [insert IRB Reference Number or Exemption Number] was approved by the Texas State IRB on [insert IRB approval date or date of Exemption]. Pertinent questions or concerns about the research, research participants' rights, and/or research-related injuries to participants should be directed to the IRB chair, Dr. Denise Gobert 512-716-2652 – (dgobert@txstate.edu) or to Monica Gonzales, IRB Regulatory Manager 512-245-2334 - (meg201@txstate.edu).

If you would prefer not to participate, please do not fill out a survey.

If you consent to participate, please complete the survey.

APPENDIX C: RECRUITMENT AND INVITATION TO PARTICIPATE DOCUMENTS

Invitation E-Mail for PBL Participants (Experimental Group)

Subject Line: Invitation to Complete a Survey and Receive $25 Gift Card

Dear student,

My name is Angie, and I am a doctoral student from the Adult Education program at Texas State University. I am writing to invite you to participate in my research study about problem-based learning. You're eligible to be in this study because you are enrolled in a problem-based learning (PBL) course. Your participation will help answer whether participation in PBL adds value to your problem-solving experience.
If you decide to participate in this study, you will also be compensated with a $25 Amazon gift card.
Your participation involves the completion of a 10-minute questionnaire on Qualtrics.

To participate, please click on the link below that will take you to the Qualtrics survey. You may complete the survey using a computer or your mobile device. Please fill out the questionnaire as accurately as possible. After you have completed the survey, I will send you a link through which you will be able to retrieve your gift card.

[*Insert Link to Qualtrics Questionnaire*]

Remember, this is completely voluntary. You can choose to be in the study or not. Your participation will not impact your course grade and your instructor will not be informed about your decision to participate. If you have any questions about the study, please email or contact me at a_l489@txstate.edu.

Lastly, you will receive an email with an invitation to complete the same questionnaire upon the completion of the course at the end of the semester. You will be compensated with an additional $25 Amazon gift card after completing the questionnaire a second time.

Thank you very much.

Sincerely,
Angelina Lapina
Doctoral Student in Adult Education
Doctoral Research Assistant (DRA) in the Department of Counseling,
Leadership Adult Education and School Improvement (CLAS)
Texas State University
512.905.0678

Recruitment E-mail Attachments

- Informed Consent
- IRB approval

Reminder E-mail Following five days after the invitation E-mail

Dear student,

this is a reminder to participate in my problem-based learning study. Please participate by completing a questionnaire (see link below), which takes approximately 10 minutes. The dead line is [*insert date here*]. As stated previously, you will receive a link through which you will be able to redeem a $25-Amazon gift card upon completion of the questionnaire.

Link to the survey [*insert link here*]

Thank you very much. Your participation is appreciated.

Angelina Lapina
Doctoral Student in Adult Education
Doctoral Research Assistant (DRA) in the Department of Counseling,
Leadership Adult Education and School Improvement (CLAS)
Texas State University
512.905.0678

Comments:

The standard line "I obtained your contact information from your instructor [*insert name*]." may not be included if the faculty decides to distribute the invitation to their students. If the project will be funded, the line "This study received funding from [*insert funding source*]." will be included in the E-Mail invitation.

Posttest E-mail

Dear student,
My name is Angie, and I am a doctoral student from the Adult Education program at Texas State University. I am writing you regarding a PBL study in which you had participated at the beginning of this Fall semester and I would like to invite you to participate one more time. To answer whether participation in PBL has added value to your problem-solving experience, completing the same questionnaire at the end of the semester is crucial.
If you decide to complete the 10-minute questionnaire in the next 10 days, you will be compensated with another $25 Amazon gift card.
To participate, please click on the link below that will take you to the Qualtrics survey. You may complete the survey using a computer or your mobile device. Please fill out the questionnaire as accurately as possible. After you have completed the survey, I will send you a link through which you will be able to retrieve your gift card.

[*Insert Link to Qualtrics Questionnaire*]

Remember, this is completely voluntary. You can choose not to participate in the study. Your participation will not impact your course grade and your instructor will not be informed about your decision to participate. If you have any questions about the study, please email or contact me at a_l489@txstate.edu.

Thank you very much. Your participation is appreciated.

Angelina Lapina
Doctoral Student in Adult Education
Doctoral Research Assistant (DRA) in the Department of Counseling,
Leadership Adult Education and School Improvement (CLAS)
Texas State University
512.905.0678

Invitation E-Mail for Traditional-lecture Participants (Control Group)

Dear student,
My name is Angie, and I am a doctoral student from the Adult Education program at Texas State University. I am writing to invite you to participate in my research study about your learning experience in the [*insert course name here*].
If you decide to participate in this study, you will also be compensated with a $25 Amazon gift card.
Your participation involves the completion of a 10-minute questionnaire on Qualtrics.

To participate, please click on the link below that will take you to the Qualtrics survey. You may complete the survey using a computer or your mobile device. Please fill out the questionnaire as accurately as possible. After you have completed the survey, I will send you a link through which you will be able to retrieve your gift card.

[*Insert Link to Qualtrics Questionnaire*]

Remember, this is completely voluntary. You can choose not to participate in the study. Your participation will not impact your course grade and your instructor will not be informed about your decision to participate. If you have any questions about the study, please email or contact me at a_l489@txstate.edu.
Lastly, you will receive an email with an invitation to complete the same questionnaire upon the completion of the course at the end of the semester. You will be compensated with an additional $25 Amazon gift card after completing the questionnaire a second time.

Thank you very much.

Sincerely,

Angelina Lapina
Doctoral Student in Adult Education
Doctoral Research Assistant (DRA) in the Department of Counseling,
Leadership Adult Education and School Improvement (CLAS)
Texas State University
512.905.0678

Recruitment E-mail Attachments

- Informed Consent
- IRB approval

Reminder E-mail Following five days after the invitation E-mail

Dear student,

this is a reminder to participate in dissertation study on your experience in the [insert course name here]. Please participate by completing a questionnaire (see link below), which takes approximately 10 minutes. The dead line is [*insert date here*]. As stated previously, you will receive a link through which you will be able to redeem a $25-Amazon gift card upon completion of the questionnaire.

Link to the survey [*insert link here*]

Thank you very much. Your participation is appreciated.

Angelina Lapina
Doctoral Student in Adult Education
Doctoral Research Assistant (DRA) in the Department of Counseling,
Leadership Adult Education and School Improvement (CLAS)
Texas State University
512.905.0678

Comments:

The standard line "I obtained your contact information from your instructor [insert name]." may not be included if the faculty decides to distribute the invitation to their students.

If the project will be funded, the line "This study received funding from [insert funding source]." will be included in the E-Mail invitation.

Posttest E-mail

Dear student,

My name is Angie, and I am a doctoral student from the Adult Education program at Texas State University. I am writing you regarding a PBL study in which you had participated at the beginning of this Fall semester and I would like to invite you to participate one more time. To answer whether the [*insert course name here*] has added value to your learning experience, completing the same questionnaire at the end of the semester is crucial.

If you decide to complete the 10-minute questionnaire in the next 10 days, you will be compensated with another $25 Amazon gift card.

To participate, please click on the link below that will take you to the Qualtrics survey. You may complete the survey using a computer or your mobile device. Please fill out the questionnaire as accurately as possible. After you have completed the survey, I will send you a link through which you will be able to retrieve your gift card.

[*Insert Link to Qualtrics Questionnaire*]

Remember, this is completely voluntary. You can choose not to participate in the study. Your participation will not impact your course grade and your instructor will not be informed about your decision to participate. If you have any questions about the study, please email or contact me at a_l489@txstate.edu.

Thank you very much. Your participation is appreciated.

Angelina Lapina
Doctoral Student in Adult Education
Doctoral Research Assistant (DRA) in the Department of Counseling,
Leadership Adult Education and School Improvement (CLAS)
Texas State University
512.905.0678

Recruitment E-mail for Faculty Across Central Texas Higher Education Institution (Private and Public) – PBL-teaching Faculty

Dr. [insert name here],

my name is Angie and I am a doctoral candidate in Adult, Professional and Community Education at Texas State University.
My dissertation study focuses on Problem-based Learning and the cognitive effects associated with this learning approach. To conduct my study, I will need student participants who will be enrolled in a PBL course this Fall semester.

Will you be teaching a course that follows any variation of PBL (e.g., community-based learning, project-based learning) in Fall 2019, or do you happen to know any other faculty members or instructors who may be teaching a course following a PBL format this Fall? I would be grateful if you allowed me to invite students enrolled in your course to participate in my study.

Details about the study:

Participating students will be asked via e-mail to complete a 10-minute questionnaire consisting of 20 items rated on a Likert-scale format via Qualtrics. Upon completion of the questionnaire, each student will receive a $25 Amazon gift card. test response of a questionnaire.
This study will follow a quasi-experimental design to capture changes in students' reasoning before and after PBL. This means that students will also be invited to complete the same questionnaire at the end of the semester for which they will be compensated with another $25 Amazon gift card.

Because I need a minimum of 55 students in total who will be taking a problem-based learning course, I would also appreciate referrals to other faculty members who may be teaching PBL in the Fall 2019.

I would greatly appreciate your help!!!

Thank you,

Angelina Lapina
Doctoral Student in Adult Education
Doctoral Research Assistant (DRA) in the Department of Counseling,

Leadership Adult Education and School Improvement (CLAS)
Texas State University
512.905.0678

Recruitment E-mail for Faculty Across Central Texas Higher Education Institution (Private and Public) – Traditional-lecture Teaching Faculty

Dr. [insert name here],

my name is Angie and I am a doctoral candidate in Adult, Professional and Community Education at Texas State University.
I am contacting you because I need control group participants enrolled in [insert major or course type here] at the undergraduate level this Fall semester. My dissertation study focuses on Problem-based Learning and the cognitive effects associated with this learning approach. To conduct my study, I will need students who will not be participating in a PBL-course to be able to draw a sound comparison.

I would be grateful if you allowed me to invite students enrolled in your course to participate in my study.

Details about the study:

Participating students will be asked via e-mail to complete a 10-minute questionnaire consisting of 20 items rated on a Likert-scale format via Qualtrics. Upon completion of the questionnaire, each student will receive a $25 Amazon gift card. test response of a questionnaire.
This study will follow a quasi-experimental design to capture changes in students' reasoning before and after PBL. This means that students will also be invited to complete the same questionnaire at the end of the semester for which they will be compensated with another $25 Amazon gift card.

Because I need a minimum of 55 students in total who will be taking a problem-based learning course, I would also appreciate referrals to other faculty members who may be teaching PBL in the Fall 2019.

I would greatly appreciate your help!!!

Thank you,

Angelina Lapina
Doctoral Student in Adult Education
Doctoral Research Assistant (DRA) in the Department of Counseling,
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REFERENCES

Acar, Ö. & Patton, B. (2016). Examination of learning equity among prospective science teachers who are concrete, formal and postformal reasoners after an argumentation-based inquiry course. *Australian Journal of Teacher Education, 41*(2), 69-90.

Addae, J. I., Wilson, J. I., & Carrington, C. (2012). Students' perception of a modified form of PBL using concept mapping. *Medical Teacher, 34*(11), 756-762.

Albanese, M. A., & Mitchell, S. (1993). Problem-based learning: A review of literature on its outcomes and implementation issues. *Academic Medicine, 68*(1), 52–81. https://doi.org/10.1097/00001888-199301000-00012

Aliyu, M. M., Fung, Y. M., Abdullah, M. H., & Hoon, T. B. (2016). Developing undergraduates' awareness of metacognitive knowledge in writing through problem-based learning. *International Journal of Applied Linguistics & English Literature, 5*(7), 233-240.

American Sociological Association (2003). *The importance of collecting data and doing social scientific research on race.* American Sociological Association.

Arslan, S. (2015). Investigating predictive role of critical thinking on metacognition with structural equation modeling. *Malaysian Online Journal of Educational Sciences, 3*(2), 1-10.

Akpur, U. (2017). The predictive degree of university students' levels of Metacognition and NFC on their academic achievement. *European Journal of Foreign Language Teaching, 2*(2), 52-63.

Association for American Colleges and Universities (2007). *College learning for the new global century: A report from the National Leadership Council for Liberal Education and America's Promise.* AACU. https://www.aacu.org/sites/default/files/files/LEAP/GlobalCentury_final.pdf

Basseches, M. A. (1984). Dialectic thinking as a metasystematic form of cognitive organization. In M. L. Commons, F. A. Richards, & C. Armon (Eds.), *Beyond formal operations: Late adolescent and adult cognitive development* (pp. 216-238). Praeger.

Bassett, C. (2011). Wisdom and its development: Learning to become wise(r). In C. Hoare (Ed.), *Oxford handbook of reciprocal adult development and learning* (pp. 302-317). Oxford University Press.

Bassett, M. H. (2016). Teaching critical thinking without (much) writing: Multiple-choice and metacognition. *Teaching Theology & Religion, 19*(1), 20-40.

Baumeister, R. F., Campbell, J. D., Krueger, J. I., & Vohs, K. D. (2005). Exploding the self-esteem myth. *Scientific American, 292*(1), 70–77.

Bell, P., & Volckmann, D. (2011). Knowledge surveys in general chemistry: Confidence, overconfidence, and performance. *Journal of Chemical Education, 88*(11), 1469-1476.

Belsky, J. (1999). The psychology of aging: Theory, research, and interventions (3rd Ed). Brooks\Cole Pub. Co.

Berzonsky, M. D., & Sullivan, C. (1992). Social-cognitive aspects of identity style: Need for cognition, experiential openness, and introspection. *Journal of Adolescent Research, 7*, 140–155.

Bijsmans, P., & Schakel, A. H. (2018). The impact of attendance on first-year study success in problem-based learning. *Higher Education*, 1–17.

Bloomberg Next. (2018). *Building tomorrow's talent: Collaboration can close emerging skills gap* [PDF]. Bloomberg BNA. Retrieved October 16, 2018 from https://www.bna.com/uploadedFiles/BNA_V2/Micro_Sites/2018/Future_of_Work/Workday%20Bloomberg%20Build-Tomorrow-Talent_FINAL.pdf

Boud D., & Feletti G. (Eds.). (1997). *The challenge of problem-based learning* (2nd ed.). Routledge.

Brown, T. A. (2015). *Confirmatory factor analysis for applied research* (2nd ed.). Guilford Publications.

Butler, A. B., Scherer, L. L., & Reiter-Palmon, R. (2003). Effects of solution elicitation aids and NFC on the generation of solutions to ill-structured problems. *Creativity Research Journal, 15*(2–3), 235–244.

Cacioppo, J. T., & Petty, R. E. (1982). The NFC. *Journal of Personality and Social Psychology, 42*, 116–131.

Cacioppo, J. T., Petty, R. E., Feinstein, J. A., & Jarvis, W. B. G. (1996). Dispositional differences in cognitive motivation: The life and times of individuals varying in NFC. *Psychological Bulletin, 119*(2), 197–253.

Campbell, C. L., & Kresyman, S. (2015). Aligning business and education: 21st century skill preparation. *E-Journal of Business Education & Scholarship of Teaching, 9*(2), 13-27.

Campo, K., Escorcia, D., Moreno, M., & Palacio, J. (2016). Metacognición, escritura y rendimiento académico en universitarios de Colombia y Francia. (Metacognition, writing and academic performance in Colombian and French college students.) *Avances en Psicología Latinoamericana, 34*(2), 233-252.

Cao, L. & Nietfeld, J. L. (2007). College students' metacognitive awareness of difficulties in learning the class content does not automatically lead to adjustment of study strategies. *Australian Journal of Educational & Developmental Psychology, 7,* 31-46.

Cartwright, K., Galupo, M., Tyree, S., & Jennings, J. (2009). Reliability and validity of the complex PFT questionnaire: Assessing adults' cognitive development. *Journal of Adult Development, 16*(3), 183-189.

Casey, G. (2012). Thinking critically about critical thinking. In M. F. Shaughnessy (Ed.), *Critical thinking and higher order thinking: A current perspective* (pp. 23-40). Nova Science Publishers, Inc.

Casner-Lotto, J. & Barrington, L. (2006). *Are they really ready to work? Employers' perspectives on the basic knowledge and applied skills of new entrants to the 21st century U.S. workforce.* Alexandria, VA: Society for Human Resource Management.

Cavanaugh, J. C., Kramer, D. A., Sinnott, J. D., Camp, C. J., & Markley, R. P. (1985). On missing links and such: Interfaces between cognitive research and everyday problem-solving. *Human Development, 28*(3), 146-168.

Cazan, A., & Indreica, S. E. (2014). NFC and approaches to learning among university student. *Procedia – Social and Behavioral Sciences, 127*, 134–138.

Chiesi, F., Morsanyi, K., Donati, M. A., & Primi, C. (2018). Applying Item Response Theory to develop a shortened version of the NFC Scale. *Advances in Cognitive Psychology, 14*(3), 75–86.

Chiou, W. B. (2008). College students' role models, learning style preferences, and academic achievement in collaborative teaching: Absolute versus relativistic thinking. *Adolescence, 43*(169), 129-142.

Choi, E., Lindquist, R., & Song, Y. (2014). Effects of problem-based learning vs. traditional lecture on Korean nursing students' critical thinking, problem-solving, and self-directed learning. *Nurse Education Today, 34*(1), 52-56.

Choi, H. (2004). The effects of PBL (Problem-Based Learning) on the metacognition, critical thinking, and problem solving process of nursing students. *Journal Korean Academic Nursing, 34*(5), 712-721.

Czaja, R. & Blair, J. (2005). *Designing surveys: A guide to decisions and procedures.* Pine Forge Press.

National Research Council. (2012). Committee on defining deeper learning and 21st century skills. In J. W. Pellegrino & M. L. Hilton (Eds.), *Education for life and work: Developing transferable knowledge and skills in the 21st century* (pp. 52-83). The National Academies Press.

Commons, M. L., Gane-McCalla, R. Barker, C. D. & Li, E. Y. (2014). The model of hierarchical complexity as a measurement system. *Behavioral Development Bulletin. 19*, 9-14.

Corliss, S. D. (2005). *The effects of reflective prompts and collaborative learning in hypermedia problem-based learning environments on problem solving and metacognitive skills* (Publication No. 3187842) [Doctoral Dissertation, University of Texas at Austin]. ProQuest Dissertations Publishing.

Cummings, C. (2015). Engaging new college students in metacognition for critical thinking: A developmental education perspective. *Research & Teaching in Developmental Education, 32*(1), 64-67.

Choy, S. (2002). *Findings from the condition of education 2002: Nontraditional Undergraduates* [PDF]. National Center for Education Statistics. https://nces.ed.gov/pubs2002/2002012.pdf

Cohen, A.. Stotland, E,, & Wolfe, D. (1955). An experimental investigation of NFC. *Journal of Abnormal and Social Psychology, 51*, 291-294.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Routledge.

Commons, M., L. & Ross, S. N. (2008). What PFT is, and why it matters. *World Futures: The Journal of General Evolution, 64*(5–7), 321.

Coutinho, S. A. (2006). The relationship between the NFC, metacognition, and intellectual task performance. *Educational Research and Reviews, 1*(5), 162-164.

Creswell, J. W. (2014). *Research design: Qualitative, quantitative and mixed-methods approaches* (4th ed.). Sage.

Davidson, J. E., Deuser, R. & Sternberg, R. E. (1994). The role of metacognition in problem solving. In J. Metcalfe & A. Shimamura (Eds.), *Metacognition: Knowing about knowing* (pp. 207–226). MIT Press.

Day, E. A., Espejo, J., Kowollik, V., Boatman, P. R. & McEntire, L. E. (2007). Modeling the links between NFC and the acquisition of a complex skill. *Personality and Individual Differences, 42,* 201-212.

Demetriou, A. (1990). Structural and developmental relations between formal and postformal capacities: Towards a comprehensive theory of adolescent and adult cognitive development. In M. L. Commons, C. Armon, L. Kohlberg, F. A. Richards, T. A. Grotzer, & J. D. Sinnott (Eds.), *Adult development, Vol. 2: Models and methods in the study of adolescent and adult thought* (pp. 147-173). Praeger.

Dixon, J., Belnap, C., Albrecht, C., & Lee, K. (2010). *The importance of soft skills. Corporate Finance Review, 14*(6), 35–38.

Dole, J. A., & Sinatra, G. M. (1998). Reconceptualizing change in the cognitive construction of knowledge. *Educational Psychologist, 33*(2–3), 109–128.

Downing, K., Kwong, T., Chan, S. W., Lam, T. F., & Downing, W. K. (2009). Problem-based learning and the development of metacognition. *Higher Education, 57*(5), 609-621. doi:10.1007/s10734-008-9165-x

Downing, K., Ning, F., & Shin, K. (2011). Impact of problem-based learning on student experience and metacognitive development. *Multicultural Education & Technology Journal, 5*(1), 55-69.

Eccott, L., Greig, A., Hall, W., Lee, M., Newton, C., & Wood, V. (2012). Evaluating students' perceptions of an interprofessional problem-based pilot learning project. *Journal of Allied Health, 41*(4), 185-189.

Efron, B. & Tibshirani, R. (1993). *An introduction to the bootstrap*. Chapman and Hall/CRC.

EL-Shaer, A. & Gaber, H. (2014). Impact of problem-based learning on students' critical thinking dispositions, knowledge acquisition and retention. *Journal of Education and Practice, 5*(14), 74-85.

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175–191.

Field, A. (2013). *Discovering statistics using IBM SPSS statistics*. London: Sage.

Flavell, J. (1979). Metacognition and cognitive monitoring: A new area of cognitive-developmental inquiry. *American Psychologist, 34*(9), 906-911.

Fleischhauer, M., Enge, S., Brocke, B., Strobel, A., Strobel, A., & Ullrich, J. (2010). Same or different? Clarifying the relationship of NFC to personality and intelligence. *Personality and Social Psychology Bulletin, 36*(1), 82–96.

Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2012). *How to design and evaluate research in education* (8th ed.). McGraw-Hill.

Getzels, J. W. (1979). Problem finding: A theoretical note. *Cognitive Science, 3*(2), 167-172.

Gholami, M., Moghadam, P. K., Mohammadipoor, F., Tarahi, M. J., Sak, M., Toulabi, T., & Pour, A. H. (2016). Comparing the effects of problem-based learning and the traditional lecture method on critical thinking skills and metacognitive awareness in nursing students in a critical care nursing course. *Nurse Education Today, 45*, 16-21.

Glaser, E. M. (1942). Experiment in the development of critical thinking. *Teachers College Record, 43*, 409–410.

Goh, K. (2014). What good teachers do to promote effective student learning in a problem-based learning environment. *Australian Journal of Educational & Developmental Psychology, 14*, 159–166.

Grass, J., Strobel, A. & Strobel, A. (2017). Cognitive investments in academic success: The role of NFC at university. *Frontiers in Psychology, 8*, 1-9.

Griffin, P. (2014). Performance assessment of higher order thinking. *Journal of Applied Measurement, 15*(1), 53–68.

Griffin, P., & Care, E. (2015). The ATC21S method. In P. Griffin & E. Care (Eds.), *Assessment and teaching of 21st century skills* (pp. 3–33). Springer.

Grossmann, I., Na, J., Varnum, M., Kitayama, S., & Nisbett, R. (2008). Not smarter, but wiser: Dialectical reasoning across lifespan. *International Journal of Psychology, 43*(34), 239-240.

Hart Research Associates. (2015). *Falling short? College learning and career success* [PDF]. Association of American Colleges and Universities. https://www.aacu.org/sites/default/files/files/LEAP/2015employerstudentsurvey.pdl

Hargrove, R. A., & Nietfeld, J. L. (2015). The impact of metacognitive instruction on creative problem solving. *Journal of Experimental Education, 83*(3), 291–318.

Henry, H. R., Tawfik, A. A., Jonassen, D. H., Winholtz, R. A., & Khanna, S. (2012). 'I know this is supposed to be more like the real world, but . . .': Student perceptions of a PBL implementation in an undergraduate materials science course. *The Interdisciplinary Journal of Problem-Based Learning, 6*(1), 43-81.

Hmelo, C. E., Gotterer, G. S., & Bransford, J. W. (1997). A theory-driven approach to assessing the cognitive effects of PBL. *Instructional Science, 25*(6), 387-408.

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review, 16*(3), 235-266.

Hincapié Parra, D. A., Ramos Monobe, A., & Chrino-Barceló, V. (2018). Problem based learning as an active learning strategy and its impact on academic performance and critical thinking of medical students. *Revista Complutense de Educacion, 29*(3), 665–681.

Hitchcock, D. (2018). Critical thinking. In *The Stanford Encyclopedia of Philosophy* (Fall 2018 Edition). Metaphysics Research Lab. Retrieved May 15, 2019, from https://plato.stanford.edu/entries/critical-thinking/

Hofer, B. K., & Sinatra, G. M. (2010). Epistemology, Metacognition, and Self-Regulation: Musings on an Emerging Field. *Metacognition and Learning, 5*(1), 113–120.

Hung, D. (2002). Situated cognition and problem-based learning: Implications for learning and instruction with technology. *Journal of Interactive Learning Research, 13*(4), 393-415.

Hung, T., Tang, L., & Ko, C. (2015). How mental health nurses improve their critical thinking through problem-based learning. *Journal for Nurses in Professional Development, 31*(3), 170-175.

Hung, W. (2013). Problem-based learning: A learning environment for enhancing learning transfer. *New Directions for Adult & Continuing Education, 2013*(137), 27-38.

Hung, W. (2016). All PBL starts here: The problem. *Interdisciplinary Journal of Problem-Based Learning, 10*(2), 2–10.

Huijser, H., Kek, M. Y. C. A, & Terwijn, R. (2015). Enhancing Inquiry-Based Learning Environments with the Power of Problem-Based Learning to Teach 21st Century Learning and Skills. In P. Blessinger & J. M. Carfora (Eds.), *Innovations in Higher Education teaching and learning, Vol. 4: Inquiry-based learning for science, technology, engineering, and math (Stem) programs: A conceptual and practical resource for educators* (pp. 301 - 320). Emerald Group Publishing Limited.

Hursh, D. (2005). The growth of high-stakes testing in the USA: Accountability, markets and the decline in educational equality. *British Educational Research Journal, 31*(5), 605.

IBM Corp. (2017*). IBM SPSS Statistics for Mac* (Version 25.0). IBM Corp. https://www.ibm.com/support/pages/downloading-ibm-spss-statistics-25

Inhelder, B. & Piaget, J. (1958). *Growth of logical thinking from childhood to adolescence.* Basic Books.

Isaacson, R. M., & Fujita, F. (2006). Metacognitive knowledge monitoring and self-regulated learning: Academic success and reflections on learning. *Journal of Scholarship of Teaching and Learning, 6*(1), 39-55.

Isgör, I. Y. (2016). Metacognitive skills, academic success and exam anxiety as the predictors of psychological well-being. *Journal of Education and Training Studies, 4*(9), 35-42.

Iwaoka, W. T., Li, Y., & Rhee, W. Y. (2010). Measuring gains in critical thinking in food science and human nutrition courses: The Cornell critical thinking test, problem-based learning activities, and student journal entries. *Journal of Food Science Education, 9*(3), 68-75.

Jollands, M., Jolly, L., & Molyneaux, T. (2012). Project-based learning as a contributing factor to graduates work readiness. *European Journal of Engineering Education, 37*(2), 143–154.

Jory, K., Trammell, J., & Miller-Perrin, C. (2018). Marital satisfaction: The role of PFT and partner blame. *Psi Chi Journal of Psychological Research, 23*(4), 282–292.

Jumari N.F., Mohd-Yusof K., & Phang F.A. (2018). Metacognitive development in engineering students through cooperative problem based learning (CPBL). In M. E. Auer & K. S. Kim (Eds.), *Engineering education for a smart society: World engineering education forum and global engineering deans council,* 627 (pp. 107-120). Springer Verlag.

Keegan, L. C., Losardo, A., & McCullough, K. C. (2017). Problem-based learning and civic engagement in undergraduate education. *Communication Disorders Quarterly, 39*(1), 312-319.

Kegan, R. (1994). *In over our heads: The mental demands of modern life.* Harvard University Press.

Kegan, R., & Laskow Lahey, L. (2009). *Immunity to change: How to overcome it and unlock potential in yourself and your organization.* Harvard Business Press.

Khan, M. A. A., & Sobani, Z. A. (2012). Influence of gender and ethnicity on problem-based learning. *Journal of Pakistan Medical Students, 2*(3), 122–125.

Kline, Rex B. (2016). *Principles And Practice of Structural Equation Modeling*. Guilford Press.

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development.* Prentice Hall.

Kong, L. N., Qin, B., Zhou, Y., Mou, S., & Gao, H. M. (2014). The effectiveness of problem-based learning on development of nursing students' critical thinking: A systematic review and meta-analysis. *International Journal of Nursing Studies, 51*(3), 458–469.

Kramer, D. A. (1983, November 17-22). *A Developmental Investigation of Relativistic and Dialectical Thought.* Paper presented at the 36th Annual Scientific Meeting of the Gerontological Society, San Francisco, CA. https://files.eric.ed.gov/fulltext/ED243017.pdf

Kramer, D. & Bacelar, W. T. (1994). The educated adult in todays world: Wisdom and the mature learner. In J. Sinnott (Ed.), *Interdisciplinary handbook of adult lifespan learning* (pp. 31-50). Greenwood Press.

Kramer, D. & Woodruff, D. (1986). Relativistic and dialectical thought in three adult age-groups. *Human Development, 29*(5), 280-290.

Kuvac, M., & Koc, I. (2019). The effect of problem-based learning on the metacognitive awareness of pre-service science teachers. *Educational Studies, 45*(5), 646–666.

Leary, M. (2012). *Introduction to behavioral research methods* (6th edition). Pearson Education, Inc.

Lai, E. R. & Viering, M. (2012, April). *Assessing 21st century skills: Integrating research findings.* Paper presented at the National Council on Measurement in Education, Vancouver, B.C. https://pdfs.semanticscholar.org/d0a6/4ed0dcbd7ea9c88d8f7148189094e5340c02.pdf

Lave, J. (1988). *Cognition in practice: Mind, mathematics and culture in everyday life*. Cambridge University Press.

Lawson, A. E. (1978). The development and validation of a classroom test of formal reasoning, *Journal of Research in Science Teaching, 15*(11), 11-24.

Lawson, A. E., Banks, D. L., & Logvin, M. (2007). Self-efficacy, reasoning ability, and achievement in college biology. *Journal of Research in Science Teaching, 44*(5), 706-724.

Leddington Wright, S., Duncan, M. J., & Savin-Baden, M. (2015). Student perceptions and experiences of problem-based learning in first year undergraduate sports therapy. *Journal of Hospitality, Leisure, Sport & Tourism Education, 17*, 39-49.

Lefrançois, G. R. (1972). *Psychological theories and human learning: Kongor's report.* Brooks/Cole Publishing Co.

Lins de Holanda Coelho, G., Hanel, P. H. P., & Wolf, L. J. (2018). The very efficient assessment of NFC: Developing a six-item version. *Assessment.* [Online First]. https://doi.org/10.1177/1073191118793208

Liu, S., & Liu, M. (2020). The impact of learner metacognition and goal orientation on problem-solving in a serious game environment. *Computers in Human Behavior, 102*, 151–165.

Lopez Brown, P. (2017). Theme: The 21st century adult learner. *Educational Research and Reviews, 12*(8), 540–548.

Lord, K. R., & Putrevu, S. (2006). Exploring the dimensionality of the NFC scale. *Psychology & Marketing, 23*, 11–34.

Lowe, J. I. & Reisch, M. (1998). Bringing the community into the classroom: Applying the experiences of social work education to service-learning courses in sociology. *Teaching Sociology, 26(*4), 292-298.

Loyens, S. M., Jones, S. H., Mikkers, J., & van Gog, T. (2015). Problem-based learning as a facilitator of conceptual change. *Learning and Instruction, 38*, 34-42.

Lucas, M. G. (2015). Re-viewing Self and societal development from a postformal perspective: An artistic de-concealiation, reconciliation and trans-formation. *Integral Review, 11*(3), 6-29.

Magno, C. (2010). The role of metacognitive skills in developing critical thinking. *Metacognition & Learning*, *5*(2), 137–156.

Malterud, K. (2001). Qualitative research: Standards, challenges and guidelines. *The Lancet. 358*(9280), 483-488.

Markoulis, D. (1989). Postformal and postconventional reasoning in educationally advanced adults. *Journal of Genetic Psychology, 150*(4), 427.

Matousek, M. (2020, March 24). *Elon Musk says you still don't need a college degree to work at Tesla. Here's what he looks for in job applicants instead.* Business Insider. https://www.businessinsider.com/elon-musk-no-college-degree-needed-to-work-at-tesla-2019-12

May, T. & Perry, B. (2011). *Social research & Reflexivity: Content, consequences and context.* SAGE Publications, Ltd.

McInerney, D. M., Cheng, R. W. Y., Mok, M. M. C., & Lam, A. K. H. (2012). Academic self-concept and learning strategies: Direction of effect on student academic achievement. *Journal of Advanced Academics, 23*, 248–268.

Morgan, A. (2006). Developing geographical wisdom: Post-formal thinking about, and relating to, the world. *International Research in Geographical & Environmental Education, 15*(4), 336–352.

Morrison, S. A. (2018). Reframing Westernized culture: Insights from a Critical Friends Group on EcoJustice education. *Environmental Education Research, 24*(1), 111–128.

Nargundkar, S., Samaddar, S., & Mukhopadhyay, S. (2014). A guided problem-based learning (PBL) approach: Impact on critical thinking. *Decision Sciences Journal of Innovative Education*, 12(2), 91-108.

National Council for the Social Studies (NCSS). (2010). *National curriculum standards for social studies: A framework for teaching, learning, and assessment.* NCSS.

Netshandama, V. O., & Farrell, S. P. (2006). Deconstructing the methods and synergies in Problem-Based Learning, Community-Based Project-Organized Education: Perspectives at the University of Venda, South Africa. *Journal of Higher Education Outreach and Engagement, 11*(2), 57–72.

Norman, H. (2012). Australian Indigenous tertiary studies: A discussion with professor David Boud on experience-based learning and the transformation of university courses. *The Australian Journal of Indigenous Education, 41*(1), 34-39.

Onyekuru, B. U., & Njoku, J. (2017). Metacognition, intelligence, motivation and students' academic achievement: A theoretical review. *Journal of Educational Review, 10*(1/2), 79-88.

O*NET. (n.d.). Skills — Complex Problem Solving Skills. In *O*NET database*. Retrieved September 26, 2018, from https://www.onetonline.org/find/descriptor/browse/Skills/2.B.2/

Pepper, C. (2010). "There's a lot of learning going on but NOT much teaching!": Student perceptions of Problem-Based Learning in science. *Higher Education Research and Development, 29*(6), 693-707.

Petty, R. E., Briñol, P., Loersch, C., & McCaslin, M. J. (2009). The NFC. In M. Leary & R. H. Hoyle (Eds.), *Handbook of individual differences in social behavior,* (pp. 318-329). The Guilford Press.

Prast, H. A., & Viegut, D. J. (2015). *Community-based learning: Awakening the mission of public schools.* Corwin.

Qualtrics (2019*). Qualtrics Software Copyright* © (2019). https://www.qualtrics.com

Reinhard, M. A., & Dickhäuser, O. (2009). NFC, task difficulty, and the formation of performance expectancies. *Journal of Personality and Social Psychology, 96,* 1062–1076.

Ritchie, S. (2012). Incubating and sustaining: How teacher networks enable and support social justice education. *Journal of Teacher Education 63*(2), 120–131.

Robles, M. M. (2012). Executive perceptions of the top 10 soft skills needed in today's workplace. *Business Communication Quarterly*, *75*(4), 453–465.

Ronfeldt, M., Owens Farmer, S., McQueen, K., & Grissom, J. A. (2015). Teacher collaboration in instructional teams and student achievement. *American Educational Research Journal, 52*(3), 475–514.

Rué, J., Font, A., & Cebrián, G. (2013). Towards high-quality reflective learning amongst law undergraduate students: Analysing students' reflective journals during a problem-based learning course. *Quality in Higher Education*, *19*(2), 191-209.

Rudestam, K. E., & Newton, R. R. (2014). *Surviving your dissertation: A comprehensive guide to content and process.* Sage Publications.

Rudolph, J., Greiff, S. Strobel, A., & Preckel, F. (2018). Understanding the link between NFC and complex problem solving. *Contemporary Educational Psychology*, *55*, 53–62.

Sart, G. (2014). The effects of the development of metacognition on project-based learning. *Procedia - Soc. Behav. Sci. 152*, 131–136.

Savery, J. R. (2006). Overview of problem-based learning: Definitions and distinctions. *The Interdisciplinary Journal of Problem-based Learning, 1*(1), 9–20.

Savery, J. R., & Duffy, T. M. (2001). *Problem based learning: An instructional model and its constructivist framework.* Center for Research on Learning and Technology (Report No. 16–01), Bloomington: Indiana University.

Shoop, G. H. (2014). *The effects of using concept mapping as an artifact to engender metacognitive thinking in first-year medical students' problem-based learning discussions: A mixed-methods investigation* (Publication No. 2015-99150-594) [Doctoral Dissertation, Pennsylvania State University]. ProQuest Dissertations Publishing.

Shrader, D. E. (2003). Moral metacognition in adolescence and adulthood. In J. Demick & C. Andreoletti (Eds.), *Handbook of adult development* (pp. 301–327). Kluwer Academic/Plenum Publishers.

Schraw, G. & Moshman, D. (1995). Metacognitive Theories. *Educational Psychology Review, 7(*4), 351-371.

Sinnott, J. D. (1994). The relationship of PFT, adult learning, and lifespan development. In J. D. Sinnott (Ed.), *Interdisciplinary handbook of adult lifespan learning* (pp. 105-119). Greenwood Press.

Sinnott, J. D. (1998). *The development of logic in adulthood: PFT and its applications.* Plenum Press.

Sinnott, J. D. (2011). Constructing the self in the face of aging and death: Complex thought and learning. In C. Hoare (Ed.), *Oxford handbook of reciprocal adult development and learning* (pp. 248-264). Oxford University Press.

Sinnott, J. D., & Johnson, L. (1997). Brief report: Complex PFT in skilled administrators. *Journal of Adult Development, 4*(1), 45-53.

Sonnleitner, Keller, Martin, & Brunner. (2013). Students' complex problem-solving abilities: Their structure and relations to reasoning ability and educational success. *Intelligence, 41*(5), 289-305.

Soubelet, A., & Salthouse, T. A. (2017). Does NFC have the same meaning at different ages? *Assessment, 24*, 987–998.

Soufi, S., Damirchi, E. S., Sedghi, N., & Sabayan, B. (2014). Development of structural model for prediction of academic achievement by global self-esteem, academic self-concept, self-regulated learning strategies and autonomous academic motivation. *Procedia -Social and Behavioral Sciences, 114*, 26–35.

Stadler, M. J., Becker, N., Greiff, S., & Spinath, F. M. (2016). The complex route to success: Complex problem-solving skills in the prediction of university success. *Higher Education Research and Development, 35*(2), 365-379.

Stedman, N. L. P., Irani, T. A, Friedel, C., Rhoades, E. B., & Ricketts, J. C. (2009). Relationships between critical thinking disposition and Need for Cognition among undergraduate students enrolled in leadership courses. *North American Colleges and Teachers of Agriculture Journal, 53*(3), 62-70.

Sternberg, R. J. (1984). Higher order reasoning in postformal operational thought. In M. L. Commons, F. A. Richards & C. Armon (Eds.), *Beyond formal operations: Late adolescent and adult cognitive development* (pp. 74-91). Praeger.

Strobel, J., & van Barneveld, A. (2009). When is PBL more effective? A meta-synthesis of meta-analyses comparing PBL to conventional classrooms. *Interdisciplinary Journal of Problem-Based Learning, 3*(1), 44-58.

Tabachnick, B. G. & Fidell, L. S. (2013). *Using multivariate statistics* (6th ed.). Pearson Education Inc.

Tarricone, P. (2011). *The taxonomy of metacognition*. New York, NY: Psychology Press.

Taubman, P. (2009). *Teaching by numbers: Deconstructing the discourse of standards and accountability in education.* Routledge.

Torbert, W. R. (1994). Cultivating postformal adult development: Higher stages and contrasting interventions. In M. E. Miller & S. R. Cook-Greuter (Eds.), *Transcendence and mature thought in adulthood: The further reaches of adult development* (pp. 181-203). Rowman & Littlefield.

Tosun, C. & Senocak, E. (2013). The effects of problem-based learning on metacognitive awareness and attitudes toward chemistry of prospective teachers with different academic backgrounds. *Australian Journal of Teacher Education, 38*(3), 61-73.

Uzuntiryaki-Kondakci, E., & Capa-Aydin, Y. (2013). Predicting critical thinking skills of university students through metacognitive self-regulation skills and chemistry self-efficacy. *Educational Sciences: Theory and Practice, 13*(1), 666-670.

van Breukelen, G. P. (2006). ANCOVA versus change from baseline: More power in randomized studies, more bias in nonrandomized studies. *Journal of Clinical Epidemiology, 59*(9), 920-925.

Visschers-Pleijers A. J., Dolmans, D. H., de Grave, W. S., Wolfhagen, I. H., Jacobs J. A.,van der Vleuten, C. P. (2006). Student perceptions about the characteristics of an effective discussion during the reporting phase in problem-based learning. *Medical Education, 40*(9), 924–931.

Vadhan, V., & Stander, P. (1994). Metacognitive ability and test performance among college students. *Journal of Psychology, 128*(3), 307-310.

Vogler, J. S., Thompson, P., Davis, D. W., Mayfield, B. E., Finley, P. M., & Yasseri, D. (2018). The hard work of soft skills: Augmenting the project-based learning experience with interdisciplinary teamwork. *Instructional Science, 46*(3), 457–488.

Wang, J. S., Pascarella, E. T., Laird, T. F. N., & Ribera, A. K. (2010). How clear and organized classroom instruction and deep approaches to learning affect growth in critical thinking and NFC. *Studies in Higher Education, 40*(10), 1786–1807.

Watts, L. L., Steele, L. M., & Song, H. (2017). Re-examining the relationship between NFC and creativity: Predicting creative problem across multiple domains. *Creativity Research Journal, 29*(1), 21–28.

Weary, G., & Edwards, J. A. (1994). Individual differences in causal uncertainty. *Journal of Personality and Social Psychology, 67*, 308-318.

Weidner, J. B., Stone, R. C., Latimer-Cheung, A. E., & Tomasone, J. R. (2018). Comparing experiences and vocational benefits of service-learning and community service volunteering in a community-based exercise program. *Partnerships, 9*(2), 66–86.

Wolter, A. (2011). Schwierige Übergänge: Vom Beruf in die Hochschule. Zur Durchlässigkeit des Hochschulzugangs [Difficult transitions: from a professional career into a HE institution. On the permeability of HE access]. *Hessische Blätter für Volksbildung, 3*, 206–216.

Wynn, C. T. (2015). A cognitive rationale for a problem-based U.S. history survey. *Teaching History: A Journal of Methods, 40*(1), 28-42.

Wynn, C. T., Mosholder, R. S., & Larsen, C. A. (2014). Measuring the effects of problem-based learning on the development of postformal thinking skills and engagement of first-year learning community students. Learning Communities: *Research & Practice, 2*(2), 1-33.

Wynn, C. T., & Okie, W. T. (2017). Problem-Based learning and the training of secondary social studies teachers: A case study of candidate perceptions during their field experience. *International Journal for the Scholarship of Teaching & Learning*, *11*(2), 1-14.

Yan, B., & Arlin, P. K. (1995). Nonabsolute/relativistic thinking: A common factor underlying models of postformal reasoning? *Journal of Adult Development, 2*(4), 223–240.

Yoshioka, T., Suganuma, T., Tang, A. C., Matsushita, S., Manno, S., & Kozu, T. (2005). Facilitation of problem finding among first year medical school students undergoing problem-based learning. *Teaching and Learning in Medicine, 17*(2), 136-141.

Zlotkowski, E. (1998). A new model of excellence. In E. Zlotkowski (Ed.), *Successful service-learning programs. New models of excellence in higher education* (pp. 1–14). Anker Publishing.