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Collaborative Problem Solving in Promoting Students' Critical Thinking a Meta-Analysis Based on Empirical Literature

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Abstract: The research aims to demonstrate the role of collaborative issues in enhancing students' critical thinking by relying on a meta-analysis based on empirical literature. The study relied on previous literature on collaborative issues, as well as the impact on the two components of critical thinking (directional orientation and cognitive skills). How do different moderating variables affect the discrepancies in study results when the results of the various experimental designs of the included research are heterogeneous? This study adhered to the strict guidelines provided by Cooper to evaluate quantitative data from several independent investigations on the same research question on Significant empirical studies published in the global literature on 21st century education was assessed using RevMan 5.4 meta-analysis. In order to assess the accuracy of this meta-analysis, the results were synthesized around the amount of value that general critical thinking education has contributed to college specifically. The critical thinking literature may benefit from a shift in focus to include domain specific critical thinking. Our review of the literature found that there are few studies that have examined critical thinking in a specific subject area and that the core competencies could be further developed. Additional research is needed to investigate this possibility.

Keywords: Collaborative problem solving, Critical Thinking, Meta-analysis

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1. Introduction

While research on critical thinking is not new, researchers and educators have recently focused more on the idea of critical thinking as a vital ability for learners in the twenty-first century [1]. Critical thinking should be at the center of curriculum reform based on core competencies since students who possess it are not only able to comprehend the meaning of knowledge, but also to solve practical issues in real life even after losing the knowledge [2]. Regarding the educational domain [3]. There are differing definitions of critical thinking [4]. Generally speaking, critical thinking is described as an intellectual process that is self-aware and self-regulating.

There's no consensus on the definition of critical thinking (CT). According to several definitions, critical thinking is an attitude, a logical procedure, a deliberate process, and the evolution of a complicated idea. Glaser [5] defined critical thinking in a way that was novel. In his view, it was the use of skills and a logical mindset in circumstances requiring problem-solving. Ennis and Sternberg defined critical thinking as a logical, goal-oriented process that includes competent assessment of assertions and a purposeful, reasoning-based activity [6,7]. According to other research conducted in the 1990s, a person's temperament and conscious thought process influence their ability to think critically [8].

There is a great deal of overlap between these definitions despite their distinctions. Many people consider critical thinking to be responsible, skilled, and intellectually engaged thinking. It encourages the use of assumptions, information, expertise, and the capacity to critically analyze

one's own thought processes in order to make outstanding decisions. Critical thinking skills necessitate reflexivity, self-correction, and assessing the reasoning behind one's ideas. One of the characteristics of critical thinking is the ability for people to take a step back and evaluate the caliber of their reasoning. It speaks of the mental capacity needed to comprehend, interpret, synthesize, reason, and assess data, as w well as the readiness to put these skills to use [9] Teachers have been trying to help students develop critical thinking skills since a number of researches [10,11], for example have substantially supported the idea that critical thinking can be taught and learnt via curricular instruction. According to Ennis [12], there are three different kinds of courses that educate critical thinking in the context of teaching practice. Critical thinking is taught and encouraged in the first curriculum, which is autonomous and does not need knowledge of any particular field; in the second curriculum, which is integrated, critical thinking is included into the teaching of other disciplines as a separate educational objective.

The third choice is a mixed curriculum that incorporates other integrated teacher preparation disciplines with the teaching of critical thinking. Furthermore, scholars and educators have developed a wide range of instruments to assess critical thinking within the framework of instruction. International experts believe standard measuring procedures like the WGCTA, CCTST, CCTT, and CCTDI to be effective and trustworthy, having been verified via several trials [8]. Essentially, definitions of critical thinking offer a complicated normative framework for comprehending, instructing, and evaluating critical thinking. These frameworks include aspects of cognitive capabilities and attitudinal disposition, as well as a variety of course kinds and standardized testing instruments.

One of the most common ways to teach critical thinking in curricula is through problem-based education, which may be the starting point for fostering the growth of critical thinking [13]. Deutsch et al [14] define problem-based learning as progressive active learning that can improve learners' ability to think critically and solve problems in a group setting. According to [15], collaborative problem solving is the natural fusion of problem-based learning and collaborative learning, placing students at the center of the process and beginning with loosely organized issues from actual life scenarios. Pupils acquire the knowledge required to work in a cooperative group to solve issues, come to an understanding of the challenges in the field, and create answers using social collaborative techniques like dialogue.

Because the concept of critical thinking has so many different implications, it can be challenging to define and comprehend [16]. "Prudent judgment and self-management that leads to comprehension, evaluation, interpretation, and decision making," combined with an explanation of the grounds supporting the conclusion, is the basic understanding of critical thinking for our study. There are two ways to define critical thinking: as a skill and as a disposition. Capabilities related to critical thinking including comprehension, forecasting, analysis, and assessment of data. Conversely, a person's inclinations and personality traits linked to critical thinking qualities, such as openness, curiosity, caution when making decisions, and so on, are referred to as predispositions [17].

There are several variables that might impact the relationship between students' critical thinking skills and their academic performance. The historical characteristics of students, such as their racial or ethnic background, have been investigated in critical thinking research; nevertheless, the results are contradictory. According to several research, there are no gender disparities or variations in critical thinking tests across men and women.

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According to Scheffler [18], the notion of critical thinking in the context of education is a "programmatic definition." According to his approach, thinking—including its actions and mental processes—is one of the most essential aspects of being human. Some authors have drawn com-

parisons between thinking and breathing. For everyone, it is essential. Through thinking, man discovers the presence of the All-Powerful Creator, the laws governing the cosmos, and the principles of nature. Imam Al-Ghazali once said that thinking is "the key to lights and the principle of insight" because of this. The appropriate and efficient handling of the situations and challenges that come up in our day-to-day lives must be one of the top concerns. What matters most in our life is the caliber of our thinking. Using Sahih al-Bukhari and Muslim as examples, this study aims to define critical thinking as a tool and approach for handling situations and problems in accordance with the Prophet's teachings. The inquiry was suitably conducted by the use of inductive and analytical approaches in the study. By identifying eight key intellectual skills from the chosen hadiths and developing a useful model from them, the study came to a successful conclusion that aids in problem solving and situation management. the procedure for achieving the learning objective. Formulating a critical thinking process with norms and criteria for the kinds of thinking the process could include is significantly more beneficial for this aim than a one sentence formulaic description. The actual goal of education is for students to understand, accept, and follow these guidelines. Developing the knowledge, abilities, and attitudes of a critical thinker are part of adoption and implementation.

Bakour's [19] study highlights the need of incorporating emotion into intellectual and mental discourse based on the sample examined. A person is drawn to thought and emotion. The independent thinker must strike a balance between the need for critical thinking and taking the nation's collective intellect into account in order to correct reality, recognize issues, and find solutions. Every culture has a unique set of beliefs, opinions, and practices that have grown over time and are ingrained in each person's conscience. These practices cannot be abruptly eliminated and must be handled carefully so as for the community to develop into able to achieve a positive attitude change.

The majority of the time, conceptions of critical thinking exclude moral integrity. For instance, Dewey contrasted between the development of social cooperation among students, which he saw as the main moral objective of education, and critical thinking, which he saw as the ultimate intellectual purpose of education. To his prior collection of critical thinking dispositions, Ennes [12] introduced a set of disposition to care for each person's dignity and value. defined this as a "interconnected" disposition, absent whom critical thinking would be less beneficial and perhaps harmful. According to him, the program's objective is to foster critical thinking skills rather than the corresponding disposition to value each individual's dignity and worth [12,17].

Critical thinking has been taught mostly through collaborative problem solving, and several studies have attempted to methodically assess and meta-analyze the empirical literature on critical thinking from various angles. Nonetheless, there hasn't been much discussion of how collaborative problem solving affects critical thinking. Therefore, studying how critical thinking instruction is implemented is the best way to develop and improve critical thinking through collaborative problem solving. Unfortunately, this issue is still unresolved which means that many teachers are unable to teach critical thinking more effectively [11,20].

In order to ascertain whether critical thinking is indeed teachable, for instance, a number of researchers have presented their findings on this subject. One such researcher is [21]. who reported the findings of a meta-analysis of 71 studies on the development of critical thinking in college over various time periods. These authors discovered that critical thinking varies based on factors including topic matter, length of intervention, teaching style, and instructional approaches, and that critical thinking increases dramatically throughout university education. Nevertheless, neither the importance of collaborative problem solving in fostering students' critical thinking nor the existence of statistically significant variations among the components the researcher examined in this study.

It was also presented by Liu et al. [22] conducted a meta-analysis of 31 pieces of educational research to analyze the impact of problem solving on college students' critical thinking. These authors found that problem solving may increase the development of critical thinking among college students, and they called, in a follow up study, for building an appropriate group structure for problem solving to improve students' critical thinking. Moreover, previous empirical investigations have shown ambiguous, if not conflicting, results about whether and to what extent collaborative problem solving enhances or reduces critical thinking skills.

Most research examining the variables affecting the academic performance and perseverance of community college students focuses on attributes such being a first-generation student, socioeconomic position, and previous academic accomplishment. The use of prescriptive measures that evaluate students' cognitive, motivational, and behavioral traits that affect access, retention, and achievement cannot be disregarded, even if it is crucial to identify these crucial components.

Conversely, Yang et al. [23] carried out an experiment in which university students were taught the integrated curriculum through the use of an online networking site bulletin board, with the goal of promoting participants' critical thinking within the framework of cooperative problem solving. The study's findings demonstrated how involvement, debate, inquiry, and reflection on a range of experiences and viewpoints may enhance learners' critical thinking in real-world problem scenarios through collaborative problem solving. Other studies on undergraduate and high school students by Naber and Wyatt [24] and Sendag and Odabasi [25] found that while collaborative problem-solving improved learners' engagement and could increase motivation and interest in learning, it did not significantly improve students' critical thinking when compared to traditional classroom instruction.

It has been said that our world is changing quickly and that human knowledge is expanding in all domains, theoretical and applied. As a result, people are under pressure to demonstrate their worth and aptitude in the face of these waves of sophisticated cognitive schooling, and they are making every attempt to resist them. There are a lot of issues and challenges to be solved, and the only way to do so is for a person to lead a fully cognitive life and to have knowledge as understanding that allows people to gain access to information [26].

The notion of enhancing cognitive capacities and promoting a variety of thought processes gained traction, and the phrase “productive person” spread across school hallways. The ideas that give rise to the living system are the work of this creative individual, who is distinguished not by his brute force but instead by his extraordinary cerebral faculties. Some people adapted this to suit their requirements at the time. It satisfies the needs of the educated person hoping to solve problems and leave his imprint in manufacturing [27].

The writers found that educated Arabs who developed nations that entered this field decade earlier differ greatly, and it comes out that everyone is looking for a solution to improve the mental faculties of those in the educational community.

Numerous research that are covered in this study indicate that there is inconsistent evidence about the benefits of collaborative problem solving for developing students' critical thinking. Therefore, in order to ascertain if and to what extent collaborative problem solving may promote or inhibit critical thinking, a thorough and reliable assessment is required. A quantitative analytical method for assessing quantitative information from several studies on a single research issue is meta-analysis. In an effort to lessen the uncertainty created by separate research and produce more reliable results, this method evaluates impact performance by aggregating the influence sizes of many qualitative investigations [28].

In order to add to research and practice, this study employed the meta-analysis approach and carried out a meta-analysis to assess the value of collaborative problem solving in fostering students' critical thinking. This meta-analysis examined the following research questions:

1. What is the overall impact of collaborative problem solving on improving critical thinking in students, as well as the influence on the two components of critical thinking (attitude tendency and cognitive skills)?
2. How do various moderating variables effect discrepancies in study findings when the outcomes of the included research's varied experimental designs are heterogeneous?

2. Methods

This study adhered to the stringent guidelines provided by Cooper [29] for assessing quantitative data from many independent investigations on the same research question.

(e.g., data searching, proof of identity, screening, eligibility, merging, deleting redundant information, and analyzing the results of included studies). Important empirical studies that were published in the worldwide literature on 21st-century education were assessed using the Rev-Man 5.4 meta-analysis. In order to assess the accuracy of this meta-analysis, researchers independently verified the consistency of the data acquired using Cohen's Kappa coefficient. They also conducted publication bias and heterogeneity tests on the sample data.

2.1. Criteria for Literature Search and Inclusion

The study process began with a thorough selection of papers on success and critical thinking. The researcher accomplished this by using a range of search methods to locate all pertinent studies. The researcher chose a broad variety of terms since researcher might not explicitly define or characterize critical thinking. One or more of the following three search terms must appear in at least one of the papers that are found: population, achievement and persistence outcomes, and predictors of critical thinking.

The researchers searched and validated studies for the years 2005 to 2023 using the material that followed electronic database and complete transcripts of academic journal articles from original journal articles of the web of Science Core Collection. In addition to the Jordanian university libraries where a manual search was done.

The research topic was "Pedagogical educational research." "TS = (("Critical Thinking" OR "ct" AND "Pretest" OR "Posttest") OR ("Critical Thinking" OR "ct" AND "Control" group" OR "quasi-experiment" OR "experiment") AND ("collaboration" OR "cooperative learning" OR "CSCL") AND ("problem solving" OR "problem-based learning" OR "PBL") AND ("collaboration" OR "cooperative learning" OR "CSCL".

Out of the studies that researcher looked up in the previously specified sources, 56 studies the researcher trusted. Based on all of the above terms, the search string was created: SU = ("Critical Thinking"*"Collaboration" + "Critical Thinking"*"-Collaborative Learning" + 'Critical Thinking'*'CSCL' + 'Critical Thinking'*'Problem Solving' + 'Critical

Thinking'*'Critical Thinking'*'PBL' + 'Problem-Based Learning'*'Solution-Oriented Problems') AND FT is equal to ('pilot study' + 'pre-test' + 'post-test' + 'quasiexperiment')'. A total of 56 studies the researcher found throughout the search period, and all surveys and duplicates the researcher eliminated from the databases prior to managing and converting bibliographic references.

Second, the researcher chose papers that satisfied the inclusion and exclusion criteria for the meta-analysis after going over the titles and abstracts of the articles that the researcher gathered.

Third, the researcher meticulously assessed the whole content of every included article based on the inclusion and exclusion criteria. To guarantee thorough coverage of research articles, a snowball search was carried out utilizing included article references and citations. In the end, thirty-six research publications the researcher kept.

The mean and standard deviations of the critical thinking values at various points during the college career the researcher used to categorize each research. All cross sectional and longitudinal designs with enough data to calculate the standard mean difference between two or more time periods or study years the researcher included (the researcher used the approach of evaluating present undergraduates to seniors). Critical thinking exercises unique to a given domain the researcher excluded. Measures that the researcher re excluded the researcher essays produced in non-native English and critical thinking tests given to psychology students [30]. Additionally, the researcher excluded a time referred to by [31] as it focused more on support than educational experiences.

Furthermore, studies that reported increases on three of the five different subscales of the Watson-Glaser Critical Thinking Assessment [32] but excluded data on the remaining two subscales and overall score gains the researcher eliminated. These studies only offered partial change data from the sample. This restriction was implemented to limit the possibility of impact size estimates being skewed higher by analyzing only economically significant changes from certain studies.

Studies that reported just the outcomes of experimental therapies aimed at enhancing critical thinking, or that solely depended on modifications in critical thinking, were excluded from the

meta-analysis sample. However, experimental study control groups the researcher included since it was evident that no attempt was made to impart critical thinking skills to these control groups.

The main exception to the general lack of targeted interventions was research on academic students. The NLN expressly includes critical thinking instruction in its accreditation requirements, even if some courses that are primarily focused on teaching pupils critical thinking are nevertheless forbidden. The remarkably high number of articles that use samples is indicative of academic programs' considerable interest in critical thinking instruction.

Hence, academic students can be examined independently to address possible contamination issues (i.e., benefits from teaching critical thinking instead of the typical college knowledge) and as a comparative group helpful in showcasing the potential of explicitly teaching critical thinking throughout a course of study. education in a university.

After our preliminary investigation, the researcher eliminated 88 publications that the researcher thought would be appropriate for inclusion. The frequency of the various causes for study rejection, as previously mentioned, is summarized in Table 1. Even though some studies could be lacking in several areas, the researcher explain the primary rationale behind rejecting every study. The most frequent grounds for exclusion the researcher reporting just gains in critical thinking after the intervention (21.6%), reporting only improvements in critical thinking (21.6%), and only doing a single critical thinking assessment (30.7%). employing a non-university population (11.4%) and neglecting to include other crucial data needed to determine the impact magnitude (11.4%). Following the application of our exclusion criteria, 36 articles the researcher left for further examination.

Table 1. Frequencies of exclusion criteria applied to prescreened studies.

Exclusion criterion	No. of studies	% Excluded studies
Does not measure critical thinking at multiple time points	27	30.7
Only reports gains after an interventiona	19	21.6
Non college sample	10	11.4
Missing vital information	10	11.4
No data (research proposals, qualitative studies)	6	6.8
Only uses a domain-specific critical thinking measure	6	6.8
Not related to critical thinking	4	4.5
Self-report data only	3	3.4
Time frame too short (less than one term)	2	2.3
Only reports statistically significant sub-scale gains	1	1.1
Total	88	100.0

[1]ncludes logic/reasoning courses.

2.2. Calculating the Size of an Effect

Cohen's function was computed to take into consideration how critical thinking evolves with time. SD units of this effect magnitude are used to quantify the variation between two means. Standardized effect sizes can, however, be assessed on a range of metrics, contingent upon the information that is accessible and the study's objectives. Morris and Dishion presented two measures in this scenario: a level of change measure and a primary outcome measure; to calculate the raw score value *d*, the variation in average scores between two time points is divided by the pooled standard deviation (SD), using the SD of the change scores rather than the mean SD of reported scores for the denominator, which better suits the degree of change measure due to its larger effect sizes; although the critical thinking literature has not provided the SD for change scores, under certain circumstances, raw result effect sizes can be converted to change outcome effect sizes using a conversion formula developed by Morris and Dishion, which also helps in ascertaining the link between pretest and posttest results in each study, and this meta-analytic assessment of the relationship can be utilized to convert to cross-sectional effect sizes, however, this tactic

is not advised if significant differences exist between the pre- and post-test correlations across studies [33].The researcher performed an exploratory meta-analysis of pretest and posttest correlations from other longitudinal studies in the population to assess the viability of utilizing a change score measure. When a correlation's population value increases, its sampling variance also changes, particularly for any value that receives a score of greater than 50 [34].

Therefore, the researcher used Fisher's r to z transformation to normalize the sample variances before to doing the analysis. As the original correlation approaches one, Fisher's normalized r approaches infinity, which is why the two correlation estimates decreased from 1 to.99, the next highest number in our sample. After that, the researcher performed an uncontrolled meta-analysis using the time frame as a moderator, and the researcher converted the findings back to the original association measure.

These raw data did not provide a valid estimate of the degree of change. Significant residual heterogeneity persisted after adjusting for the (non-significant) impact of time frame, Q (27) = 1022.6326, p.0001. In studies where there is insufficient data to explicitly quantify a connection, it would be incorrect to use the meta-analytic mean as a proxy due to the residual heterogeneity in effect sizes in the research sample. Cohen's function was thus computed using the more common primary outcome method.

In many of the studies that the researcher relied upon in the study sample, the researcher had to attribute specific variables in order to evaluate the extent of the effect. When only the SD was provided for the pretest, it was replaced with the SD for the posttest. Estimates the researcher obtained from comparable samples with high sample sizes where standard deviation values were not available. Table 2 lists the samples to which this procedure was applied, as well as the source of the calculated SDs. A sensitivity analysis was performed to see if our results the researcher affected by changes in the imputed data.

After taking into consideration all impact sizes, the researcher modified the estimations of unreliability in the measures that the researcher employed. Effect size estimates are consistently impacted by measurement error, which causes an overestimation of the actual population effect size [35]. One way to counteract this biasing impact is to divide the effect size by the linked measure's square root of dependability [36]. Where feasible, the researcher employed study-specific internal consistency reliability measures (e.g., split-half, coefficient alpha, KuderRichardson-20, and Kuder-Richardson-21) to account for attenuation resulting from measurement error. The researcher used estimations based on test evidence where reliability statistics the researcher unavailable. The most conservative (i.e., biggest) estimations that the researcher available under these conditions the researcher selected in order to prevent overcorrection.

2.3. Meta-Analysis

A multivariate mixed-effects meta-analysis, which combines effect size data from several primary studies and examines various rates into a single hierarchical model, was carried out by the researcher using R's METAFOR package [37]. Since the capacity to examine various effect estimates derived from nested samples is the primary attribute of multivariate meta-analysis. It computes the study value independently the first time (say, the initial calendar year) and every time after that when a minimum of two or several years of study are included in a single document. The resultant effect sizes' errors in sampling are no more independent as they share a pretest set [29]. The independence presumptions of the majority of meta-analytic techniques run counter to this.

Dependent effect sizes and researcher-adjusted variances are taken into consideration in multivariate meta-analysis. This is accomplished by creating a variance-covariance matrix, which the researcher will use as the foundation for effect size estimations, and which contains the expected sample deviations for each value of d. Given the size of the sample and study design, the researcher first estimated variation in samples for each study. For both cross-sectional and longitudinal designs, sample variances were estimated using Morris and Dishion's [33] Equation 22. Estimates of sample variance for each effect magnitude are shown in Table 2.

The variations are based on the recalculated dependent effect sizes by the researcher. Two key equations are presented by Glaeser and Olkin [38]to estimate these covariances. Firstly, the variance in effect sizes that a researcher encounters in several treatment trials with a shared control group is taken into consideration by Equation 19.19. The variance resulting from a common primary test set (or, in cross-sectional research, a common comparison set) was taken into account using this equation. Secondly, Equation 19.27 may be used to a single sample whenever multiple outcome measures are employed. Data from two different critical thinking tests that were given to a single sample in the current study were reported [39]. The calculated covariance's for each of the dependent effect sizes are shown in the following table.

As an extra precaution against homogenous effect sizes, the researcher defined a data hierarchy with sizes of effects pooled among trials. Even if derived from nonoverlapping samples, different estimates of effect size from a single study could be more homogenous than would be predicted by chance. Study of origin can be used as a classification variable to provide greater similarity throughout effect sizes resulting from the same source.

Based on Table 2's criteria, the majority of the studies were included in the meta-analysis. The investigator categorized 124 effect sizes from these studies in total. The researcher separated critical thinking abilities from personality traits for all analyses due to evidence that they are independent variables which interact significantly with contextual correlates [10].

Since both longitudinal and cross-sectional studies are included in this analysis, the study technique will determine how the number of samples of a given study is interpreted. In cross-sectional study, for instance, 100 participants yield an average of 50 data points.

Table 2. Summary of Studies in the meta-analysis

Study	Effect size(d)	σ 2d	Pre n	Post n	Publication type	Grade	Time frame years	Design	Nursing yes/no	Measure
Adams, stover and whitlow (1999)	0	.00498	203	203	Journal	So-sr	2.5	L	Y	Watson-glaser
Arburn and Bethel (1999)	0.32	.03082	37	37	Conference paper	n/a	0.5	L	N	CCTST
Bartlett and cox (CCTDI)	0.67	.04916	28	28	Journal	So	1	L	N	CCTDI
Beckie et al. (2001) cohort 2 years	0.05	.01901	55	55	Journal	Jr-Sr	2	L	Y	CCTST
Beckie et al. (2001) cohort 1 years	0.07	.01896	55	55	Journal	Jr-Sr	1	L	Y	CCTST
Beckie et al. (2001) cohort 2 years	0.14	.01916	55	55	Journal	Jr-Sr	2	L	Y	CCTST
Beckie et al. (2001) cohort 1 years	-0.33	.01524	73	73	Journal	Jr-Sr	1	L	Y	CCTST
Beckie et al. (2001)	-0.65	.01847	73	73	Journal	Jr-Sr	2	L	Y	CCTST

cohort 1 years										
Berger (1984)	0.41	.00816	137	137	Jour-nal	So-Sr	3	L	Y	Wat-son-glaser
Blaich and wise (2008)	0.11	.00033	3,081	3,081	Re-search report	Fr-So	1	L	N	Wat-son-glaser CAAP-CT
Blaich and wise (2011)	0.44	.00051	2,200	2,200	Re-search report	Fr-Sr	4	L	N	CAAP-CT
Brigham (1989) 1year	0.6	.07842	28	28	Dis-serta-tion	Fr-So	1	C	Y	Wat-son-Glaser
Brigham (1989) 2year	0.5	.07567	28	29	Dis-serta-tion	Fr-Jr	2	C	Y	Wat-son-Glaser
Brigham (1989) 3year	0.74	.07907	28	29	Dis-serta-tion	Fr-Sr	3	C	Y	Wat-son-Glaser
Burgess (2003)	0.45	.02025	59	59	Dis-serta-tion	Jr-Sr	2	L	Y	Critical Think-ing As-sess-ment
Colbert (1987)	-0.41	.00768	146	146	Dis-serta-tion	N/A	0.5	L	N	Wat-son-Glaser
Coluc-ciello (1997) CCTDI	0.18	.01750	129	105	Jour-nal	Jr-Sr	1	C	Y	CCTDI
Coluc-ciello (1997) CCTST	0.14	.01749	129	105	Jour-nal	Jr-Sr	1	C	Y	CCTST
Criner (1992)	0.27	.05268	22	22	Dis-serta-tion	N/A	0.5	L	N	New Jersy Test Rea-soning Skills
Dale, Ballotti, Handa, and Zych (1997)	-0.08	.02718	39	39	Jour-nal	Fr	0.5	L	N	Wat-son-Glaser
Daly (2001)	0.03	.02444	43	43	Jour-nal	Fr-So	1.5	L	Y	Wat-son-Glaser
Drouin (1992)	0.2	.01691	120	120	Dis-serta-tion	So-Sr	2	C	N	Wat-son-Glaser
Erickson (1999)	0.09	.05621	20	20	Dis-serta-tion	Fr	0.5	L	N	Wat-son-Glaser
Ewen (2001) 1 year	-0.04	.02261	74	113	Dis-serta-tion	Fr-So	1	L	Y	Wat-son-Glaser
Ewen (2001) 2 year	-0.2	.02299	74	110	Dis-serta-tion	Fr-Sr	2	L	Y	Wat-son-Glaser
Ewen (2001) 3.5 year	-0/19	.02256	74	115	Dis-serta-tion	Fr-Sr	3.5	L	Y	Wat-son-Glaser
N.C. Facione	0.42	.00653	216	570	Book	Fr-So	1	C	Y	CCTDI

and facione (1997), CCTDI,1 Year										

3. Results

This Using a mixed-effects meta-analysis, the researcher examined the impact of four moderating variables: sample 3 (non-academic = 0, academic = 1), study design (cross sectional = 0, longitudinal = 1), and time frame (0.5–4 years). and the publishing year. To make the year of publication variable easier to comprehend and give the model more time to converge, the researcher removed the first year from all values in the research sample. In theory, this indicates that the first year of the sample selection years corresponds to the value of zero for the year of publication. In order to test for nonlinear changes in critical thinking over time (e.g., larger gains for the researcher throughout college), the researcher additionally inserted a quadratic term for the time period. What one may anticipate when impact sizes from a single semester are rescaled.

Additionally, the moderator of the experiment was removed from the model by the researcher in accordance with the preliminary investigations. A better match was shown by the researcher's evaluation of the Aikake and Bayesian information criteria values. The researcher displayed the reduced model's results for ease of understanding.

The effects of modifications to supervisors' critical thinking skills are displayed in the table. substantial residual heterogeneity, Q (105) = 716.1532, p.0001, and substantial moderating effects, Q (4) = 9325.1340, p.0001, were also shown to be present. It makes sense that researcher gains increase with longer time periods. According to the researcher's perspective, only the squared impact of time frame achieved statistical significance. According to this study, improvements in critical thinking skills during college are not linear.

Over longer times, the rate of change picks up speed. When evaluating this result, it is important to keep in mind that many of the research's time periods cannot be linked to specific college years. Research on gains across a semester, for instance, aggregate data from first-year, sophomore, junior, and senior students enrolled in those particular courses. Therefore, a significant squared term does not provide compelling evidence that critical thinking abilities develop as students advance through college.

To illustrate, Freshman = 1. The researcher looked at a subset of certain impact variables for which the researcher could code a particular starting year in order to further explore this theory.

The original model, the model with the starting year added as an extra mediator, and the starting year added model with the quadratic time frame component removed were all compared by the researcher using the subgroup. The purpose of this was to see if it accounts for the variance in effect sizes that may be linked to the starting year. The coefficients from the three models are displayed in the following table. Models 2 and 3 did not find any significance for the effect of beginning year, indicating that there might not be any differences in benefits across college years.

Across the sample, the researcher also took into account the distinctions between cross sectional and longitudinal study. The findings also showed that effect size estimations are significantly influenced by research design. Selecting a longitudinal design over a cross-sectional one was linked to a 0.27 SD decrease in predicted gains in critical thinking skills after adjusting for possible moderators.

In order to more accurately capture the combined impacts of time frame and study methodology, the researcher generated model projected values for various degrees of each moderator, using the year of publishing as the sample mean. Longer time span cross-sectional studies showed significantly greater benefits, as Table 7 demonstrates. Additionally, the researcher calculated estimates of impact for a hypothetical mixed sample that had the same proportion of longitudinal and cross-sectional studies. The outcome of this inquiry was Estimated 4-year increase of 0.59 SD, as opposed to 0.46 for longitudinal designs and 0.73 for cross-sectional studies.

Throughout the course of the study sample period, data gathering enabled the researcher to examine how improvements in critical thinking progress over time. In order to test the claim that critical thinking instruction in colleges has grown less effective, the researcher employed the year of publication as a mediator. Our moderator analysis supports this idea. According to current research, impact sizes are significantly reduced when controlling for additional moderators. If cross-sectional and longitudinal studies are equally mixed, the projected 4-year improvement for the 1963 study (80% CI [0.75, 1.68]) is 1.22 standard deviations, while for the study (80% CI [0.11, 1.68]]) 0.78]) it is only 0.33.

Only a small number of studies that measured the inclination toward critical thinking using the CCTDI were found using our search. The researcher attempted more straightforward moderator analyses that did not include sample type or year of publication due to the small size of the meta-analysis sample. The basic model with just the linear impact of time window produced the best fit at longer times, and the researcher reconnected with bigger effect sizes, as predicted, Q (1) = 22.8770, p.0001, using the Aikake and the Bayesian information criterion as criteria. The investigator verified that a considerable degree of residual heterogeneity persisted even after taking this impact into account, Q (12) = 52.1465, p.0001. The predicted values for various time periods were displayed in the tables‹ Over the course of four years, the researcher anticipates a 0.55 SD rise in critical thinking disposition.

As previously stated, the investigator computed standard deviations from alternative samples for several studies for which no standard deviations were supplied. It's probable that the particular sources of the imputed data we selected had an impact on the study's overall outcomes. The researcher used several imputed values in a sensitivity study to tackle this issue. In particular, the researcher evaluated the pretest mean and standard deviation from the meta -analysis sample and generated fresh imputed values using N. The Watson-Glaser California Critical Thinking Skills Test (CCTST) and the CCTDI have three additional imputed values as a consequence. In several instances, the researcher substituted these new values with the ones we originally imputed.

After that, the researcher used the revised effect sizes and sample variances to rerun the mixed-effects meta-analyses of critical thinking aptitudes and dispositions. Our overall results seem to be resilient to changes in the computed standard deviation rates because the updated values had no impact on our choices for which models to use or the magnitude of the moderated coefficients.

4. Discussion

Our research indicates that during college, students significantly improve their critical thinking skills. The total impact of college on critical thinking ability is estimated by the researcher at 0.59 standard deviation, which is somewhat higher than the estimations made [40] and Pascarella and Trenzini [41]. The researcher attested to the fact that our findings are typically consistent with earlier studies. For the one- and two-year impact sizes, the researcher falls within the 80% confidence zones, according to Arum and Roksa's [40] estimate of a gain of 0.18 standard deviation over three semesters. Their 4-year estimate of the standard deviation, 0.47, is strikingly close to our 4-year longitudinal study estimate of 0.46.

Comparably, the mixed-design estimate of 0.59 and Pascarella and Trinzini's [41] overall estimate of 0.50 standard deviations from a variety of longitudinal and cross -sectional studies are comparable (especially considering that our effect size estimates were adjusted for unreliability while theirs were not). It is important to remember that a person starting at the 50th percentile would move to the 69th percentile with an increase of 0.50 SD, which would not qualify as a small improvement.

Additional information on nonlinear patterns in growth rate is provided by the researcher's investigation of the time frame as a moderator, as opposed to combining all time frames into a single estimate. Our quadratic study of the time frame moderator indicates that as time goes on, critical thinking abilities grow at a faster pace. This result suggests that rescaling and compressing impact sizes from various time periods might not be suitable. Nevertheless, further analyses were unable to link this influence to certain college years. Therefore, the acceleration effect—which

holds that critical thinking skills increase more quickly in the last years of college—was not conclusively supported by the researcher's findings.

A further benefit of this study's analysis is that it addresses cross-sectional designs, which were either ignored or included in conjunction with longitudinal research in other assessments. These designs make up a significant amount of the literature, thus it is vital to take them into consideration. It also shown that cross-sectional studies had significantly bigger impact sizes than longitudinal studies, indicating that categorizing it as akin to longitudinal designs may result in inaccurate results. This result shows that while examining critical thinking, researchers should carefully consider how their study design will affect the end product. If students who perform better on critical thinking tests are far more inclined to pursue further education, cross-sectional research might be an excellent study design.

This uncertainty is likely due to the fact that critical thinking is associated to college performance [10]. However, longitudinal research encounters a comparable issue with self-selection. When collecting and analyzing data, longitudinal samples are frequently restricted to students who remain enrolled in college. As a result, range limitations—a statistical fallout from artificially reduced variation in the outcome of interest—may lead to impact size estimations that are not true for the researcher. Furthermore, compared to their colleagues with higher ability, kids who start off with lower critical thinking scores can have greater opportunity for improvement. The area of focus for the investigation determines how problematized something is. Another alarming discovery is that, in spite of growing interest in honing critical thinking skills, apparent development in critical thinking seems to have gotten worse over time. There are other reasonable explanations for the observed result, therefore these statistics do not provide conclusive proof of a reduction in the caliber of university education. First, it is important to note that there was a significant amount of residual variance in the impact sizes even when moderators were taken into account. As a result, the year of publication might be used as a stand-in for some traits that have evolved throughout time but are still lacking. Improvements in critical thinking may be influenced by this variable either directly or indirectly. Modifications to the course of study or the conduct of students, for instance, might make the institution less successful.

However, modifications to research methodology or study quality may have an impact on observed effect sizes that are not taken into account by the single design supervisor. These variations could just be side effects rather than significant adjustments to the researcher's critical thinking skills. It's important to remember that a 4.2-standard deviation improvement is anticipated in 4 years. This big impact size raises potential red flags and suggests that the standards for study design and execution are being lowered.

The fact that students are currently less equipped to develop critical thinking skills in college is another reason. This might be due in part to students developing their critical thinking skills before enrolling in college. There should be a decrease in overall growth scores if a greater number of students possess the skills taught in college. On the other hand, the number of students attending college has grown throughout time, and many of these newcomers might not be ready for the demands of higher-level thinking. Another possibility is that students' motivation or capacity to develop critical thinking skills has waned over time. Right now, they are merely conjectures. To determine the precise causes of this phenomenon, more research is required.

5. Implications and Limitations

5.1. Implications

While university education may not keep up with other disciplines, it is debatable if greater resources, including time and money, should be allocated to public critical thinking instruction. For a subset of individuals with pre-existing above-average cognitive skills, a gain of 0.59 standard deviations over theoretical general ability is pretty significant (equal to going from the 50th percentile to the 72nd percentile). The impact of college on critical thinking is comparable to the effect of learning disposition (0.61 SD; Hattie, 1992) and greater than the average impact of educational

qualities on academic performance (0.40 SD). Put another way, students who attend college seem to become more engaged learners and critical thinkers.

Additionally, critical thinking is more positively viewed in college. Compared to the critical thinking talent, the critical thinking disposition may be less teachable as a behavioral notion. According to the researcher's assessment, attending university seems to have a big influence. Our estimated 4-year growth of 0.55 standard deviation is comparable to Pascarella and Trinzini's [42] estimate of 0.50. This discovery holds significance as the inclination towards critical thinking could be the sole domain general kind of critical thinking where the readiness to scrutinize and offer feedback is evidently applicable in various contexts. In this overall trend, an average rise of greater than half a standard deviation is deemed positive.

The worth of educational efforts in relation to other possible spending should be a major consideration for researchers evaluating them. It takes longer to teach critical thinking than other disciplines, such as reading, writing, numeracy, and job information. The same should be true for areas where apparent improvements are equivalent to the advantages of critical thinking, if our efforts to foster critical thinking are insufficient. Similar to our estimates of growth in critical thinking, Pascarella and Triazine [42] estimate 4-year gains in the fields of science, English, and math at 0.77 standard deviations, 0.62 standard deviations, and 0.55 standard deviations, respectively. Additionally, there is obviously space for improvement in these fundamental skills.

In reading and science, American students achieve approximately average compared to other OECD members; in mathematics, they perform below average. The scarcity of skills in the workforce necessitates a thorough assessment of the researcher's educational resource allocation. It's doubtful that more funding for critical thinking in public will address our issues. Students did not outperform their counterparts in terms of improvement, according to our analysis of the samples, which did not reveal any long-term benefits to the NLN critical thinking requirements. While critical thinking therapies had an average effect size of 0.34 for Abrami et al [17].

5.2. Limitations and Prospects

A major weakness in the literature that the researcher assembled is the inability to establish strong causal conclusions. This is problematic in two ways. First, as is common in this area of research, the reviewed studies do not differentiate between maturity effects attributable to the researcher and college and those unrelated to the latter. According to certain studies, the kidney is mostly to blame for the consequences that have been recorded. College had a considerable impact, according to evidence evaluated by Pascarella and Trin A major weakness in the literature that the researcher assembled is the inability to establish strong causal conclusions. This is problematic in two ways. First, as is common in this area of research, the reviewed studies do not differentiate between maturity effects attributable to the researcher and college and those unrelated to the latter. According to certain studies, the kidney is mostly to blame for the consequences that have been recorded. College had a considerable impact, according to evidence evaluated by Pascarella and Trinzini [42], who also looked at research that controlled for other variables such as maturity. The study demonstrates that some discernible gains in critical thinking can happen without a college degree and that critical thinking can develop organically with age.

The focus on critical thinking that separates academic researchers from those in other fields is another difference. Disparities in the way academic students or academic schools develop critical thinking skills might be caused by other factors. Curricular variety may have an unclear effect if some component of academic programs that has not been studied before inhibits critical thinking. Stated differently, a greater focus on critical thinking within the context of academic education might potentially mitigate the resulting relative deficit. Therefore, the researcher cannot completely rule out the chance that using a critical thinking method may ultimately result in more advantages. Our work at the very least shows that, despite the large body of literature dedicated to making such advances, they are not easily evident, assuming they exist at all.

As was previously indicated, it is not very feasible to assign people at random to a long term critical thinking program. Therefore, the best data available at the moment is presumably from studies of non-equivalent comparator groups.

Results from scholarly samples cast doubt on the precise contribution of general critical thinking education in higher education. A change in emphasis to incorporate domain specific critical thinking would be beneficial for the literature on critical thinking. Upon reviewing the literature, we discovered that the researcher contrasted general and specialized measures and only found a small number of studies that assessed critical thinking in a particular topic area. What the researcher found most interesting were tests of critical thinking in psychology or academic fields. Without significant study on critical thinking in other areas, a researcher cannot make generalizable findings on how to develop critical thinking abilities. If the logical questions on the Watson-Glaser exam and other standardized assessments just represented one of several domains, then one may engage in critical thought.

The amount of value generated by the explicit instruction of broad critical thinking in college is called into doubt by data from academic samples. A change in emphasis to incorporate domain-specific critical thinking would be beneficial for the literature on critical thinking. Few studies that looked at critical thinking in a particular topic area were found in our search of the literature; one study even contrasted specialized and general measures. Most of these researches discovered that the psychologist or academic area repeats critical thinking tests. In the lack of substantial study on critical thinking in other domains, the researcher is unable to make generalizable conclusions about changes in critical thinking ability. If the Watson-Glaser test's and other standardized exams' reasoning questions only addressed one topic out of many that one could think about critically.

Domain-specific evaluations may show higher rates of college enrollment and more accurate monitoring of important outcomes. [43] for instance, looked at gains made in both domain-specific and general critical thinking tasks following a short intervention. Readers of a personality theory chapter were assigned to the experimental and control groups of students. Next, the control group responds to the researcher's basic recall questions in red, whereas the experimental group poses critical thinking questions regarding the content. The experimental group's members did not improve in domain general critical thinking, but they did in domain-specific critical thinking. According to a different research, psychology students' performance on a psychological critical thinking exam increased dramatically when the course included a critical thinking exercise.

The investigator attested to the fact that neither the experimental nor the control groups made appreciable advancements in Watson Glaser. Students taking an educational psychology course demonstrated more significant growth in psychological critical thinking than in general critical thinking, Students with higher course marks also fared better on the subject-specific exam. This study raises the possibility that modifications to domain-specific critical thinking are linked to domain mastery.

The failure of academic programs to explicitly encourage students to think critically at higher levels may also be explained by domain specialization theory. The critical thinking that permeates contemporary academic programs could not be sufficiently reflected by traditional metrics. While general critical thinking inventories evaluate the application of a certain set of logical concepts, they are not always applied to critically evaluate a patient's condition or the appropriateness of a course of therapy. While critical thinking criteria are beneficial for nurses, they are not good for improving Watson-Glaser scores, and this is often the emphasis of academic courses. On the other hand, academic training might not be sufficient to help students retain the knowledge and abilities covered in a general critical thinking course.

Since practice makes perfect, skills are more likely to stick with you. It's unlikely that academic education on a regular basis will provide you much practice identifying subsequent errors or employing deceptive methods. The domain specificity hypothesis states that it is unlikely for critical thinking skills acquired in one area (like formal reasoning) to properly transfer to another. Academic students would be anticipated, in accordance with this concept, to be unable to apply (and so retain) the capacity to assess formal arguments.

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6. Conclusions

Preliminary research findings show that general critical thinking training is not receiving enough time or funding. While developing skills that can be assessed by Critical Thinking tests is important, investing more time in them comes at the expense of other important abilities. According to research, there may be an even greater demand for the development of fundamental skills like reading and math beyond what is now being shown. Additionally, compared to the kind of critical thinking recommended by generic domain evaluations, critical thinking in pertinent key domains could be a more achievable educational aim. However, more study is required to explore this potential.

However, it is not appropriate to extrapolate the researcher's conclusions on how critical thinking would develop in higher education. Conversely, the results of the current study demonstrate that critical thinking skills are really quite well developed in college, freeing up resources to meet other learning objectives.

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