Assessing Critical Thinking among High School Students: A Systematic Review of Empirical Studies

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Abstract

Critical Thinking is higher-order thinking, it involves some frequently thinking such as problem-solving, decision making. Those thinking skills can help individuals best thinking and better growth. Hence, developing Critical Thinking is necessary recently. Through existing studies, high school students are the more suitable group to develop critical thinking, because they can find their favorite major easily and have an advantage for seeking work if having the ability of Critical Thinking. A way of developing Critical Thinking is also important because of effectiveness, which affects the strength of Critical Thinking. This article checked 825 relevant articles during 2011-2021 and finally kept 23 articles in three rounds of checking. Then, 23 studies were done by coding framework, which discussed their assessment tools, dimensions and types, types of intervention, and years. We found that most articles were published in 2019 and 2020, which means people pay attention to developing Critical Thinking. In the 23 studies, the most studies usually are in STEM classes, some are language classes and literature classes, one of 23 classes is specially designed for developing skills of Critical Thinking. For the assessment tool, 21 out of 23 were written tests including a questionnaire and short essay test; and the rest of the 2 studies were interview and observation combined. Specifically, 14 out of 23 studies used critical thinking assessment tools, developed by predecessors; 7 studies used their assessment tool; one study took combination way, that was an assessment tool their used predecessors and own's designed. Most studies usually included five dimensions: Assumption Identification, Induction education or reasoning, Interpretation, argument, etc. Evaluation and those dimensions can be adjusted based on needs. In 23 studies, we found that California Critical Thinking Scale (CCTDI) was popular in classes. However, people establish more subjects that aim to grow Critical Thinking, which can better observe the skills. Also, we should pay attention to other situations to grow the Critical Thinking of high school students.

Keywords

Critical Thinking; High School Student; Way of Assessment; Empirical Studies.

1. Introduction

People are living in an era of rapid development, they have to develop necessary skills with various aspects to survive. In addition, it is important to have special thinking, that is Critical Thinking (CT), forgoing well in society. Critical Thinking is a comprehensive thinking process and the aim is to help an individual decide the best decision, also helpful for self-assessment to push growing better (as cited in Ennis &Scriven & Paul, 2017). Thus, researchers think that developing critical thinking is one of the key goals in education. They think that students can adapt to the uninterrupted changes of society and solve some ambiguity if students have great Critical Thinking ability (as cited in Brookfield, 2017). Due to the importance of critical thinking, researchers and educators recently view it as a key study object are researched. In their experiments, there were many ways to assess it, which knows the current situation of critical thinking. In this article, we focus on assessment tools of Critical Thinking in high school students, searching 23 empirical studies during three-round checking, and see the current situation of critical thinking in high school students and hope to give some future direction for educators and researchers.

2. Literature Review

2.1. What Is Critical Thinking?

Sternberg (1986) defined that Critical Thinking as a mental process including solving problems, making decisions, and learning concepts. These are big branches in this concept, some specific processes or activities such as interpretation, judgment, hypothesizing and explanation also was contained the concept (Lipman, 1987). Also, Ennis (1989) said Critical Thinking with different dimensionalities adapted used in various subjects because of domain specificity. In education, researchers have to pay attention to measuring students' critical thinking skills (CTS) and critical thinking dispositions (CTD). In measurement, most researchers choose from explanation, interpretation, analysis, and evaluation as the measuring criteria of critical thinking. Because the process needs to experimenter doing active thinking and clear self-recognizing, which is reasoning and reflexivity (as cited in Facione & Simpson & Courtney, 2011, Liu, 2011).

Students spend more time studying different materials in class. Class is the most frequent place used when critical thinking assessment, due to maximum recovery authenticity. To find an appropriate age to grow Critical Thinking, researchers found that the main task of young children is literacy, schools also do not have formal frameworks to teaching critical thinking (Barbara,1996). Barbara (1996) also pointed that the kids were unconscious process and had difficulties with metacognitive. Researchers claimed that junior middle students have started to tend towards critical thinking, they could evaluate their solution but lack analyzing the data (Mutakinati & Anwari & Yoshisuke, 2018). High school students are a transition period for college students, due that they have the basic critical thinking skills by high schools, and they can apply within in their field in college once they continue work (as cited in Ennis & Johanson & Paul & Elder & Sherblom, 2013). Students are disadvantaged if they have not acquired the skills, and they are hard to find satisfactory work because employers need people who have critical thinking skills (Alliance for Excellent Education, 2013).

2.2. Critical Thinking Assessment

Researchers had chosen various scales or questionnaires to evaluate critical thinking skills in the past decades. Such as Watson-Glaser Critical Thinking Appraisal, Cornell Critical Thinking Tests, Ross Test of Higher Cognitive Processes, and The Ennis-Weir Critical Thinking Essay Test (as cited in Huffiman, 2000). Watson-Glaser Critical Thinking Appraisal includes multiple choices containing induction, assumption, deduction, judging, argument, and evaluation,

adapting for high schools and college students (as cited in Huffiman, 2000). There is also including the same aspects of measurement in Cornell Critical Thinking Tests, but students took different tests based on their age group (as cited in Huffiman, 2000). Ennis-Weir Critical Thinking Essay Test is similar to the Cornell test, but it is the paper format and more suitable for high schools and college students, like Watson-Glaser Critical Thinking Appraisal (as cited in Huffiman, 2000). The last one is the Ross Test of Higher Cognitive Processes, paying attention to the ability of analysis, comprehension, and evaluation (as cited in Huffiman, 2000). Nearly all the assessment tools choose a format of multiple choices, open-ended questions, and essays, to evaluate the opinion of two or more elements and then reflect his life also applying in class (as cited in Huffiman, 2000). In the assessment tool, it is not hard to find their similarities: they have similar dimensionalities: interpretation, evaluation, analysis, explanation, and evaluation. The five dimensionalities were defined by the critical thinking expert panel, and they explained that this was a fully thinking process(Gelerstein & Rio, 2016). Specifically, students explore how to form their thinking (interpretation) and then evaluate their solutions also needing to analyze their mistakes finally explain their mental process (Gelerstein & Rio, 2016). The way is to examine construct validity, representativeness, and coherence (Black, 2012). Surprisingly, some experiments are not limit these traditional assessment tools, the researcher develops their assessment tool because it is closer to a situation they want to, which can produce a good effect of critical thinking fostering. For instance, Giancarlo and Blohm (2004) developed an assessment tool called CM3, targeting middle school students, including four dimensionalities: learning orientation, solving a problem using creative ways, attention focusing, cognitive integrity, and these four was relating to student motivation and grades. It also targeted four aspects of the personality of critical thinking: open-minded, self-regulation, creative thinking, and self-control about studying, which hope to increase their knowledge base using their ability of inference (Giancarlo & Blohm et al, 2004). Oliveras and Marques (2011) made a scale based on another scale consisting of some "element of reasoning" proposed by Paul and Elder (2005), to examine whether middle school students have critical thinking when they read newspaper articles with scientific content. The scale was including six categories as the process in the experiment: identifying the main idea, purpose, hypothesis, and then asking a scientific question, also finding some evidence supported to question and arguing conclusion based on evidence students found (Oliveras & Marques et al, 2011).

2.3. Research Questions

There is evidence to show that critical thinking can be gained in class, teachers give some exercise or problem solving to students; students also can through Socratic questioning to learn critical thinking (as cited in Huffiman, 2000). However, there is a shortcoming here, for example, a test is not so comprehensive if it only contains multiple-choice, some experiments do not have pre-test or post-testing of a control group, a cultural factor is not considered (as cited in Huffiman, 2000). Throughout the whole, there is also a lack of overview for manipulating and measuring for a specific age group, a high school student. Hence, this article aims to collect assess Critical Thinking among high school students in classes in global countries. For the research goal, the article collects existing studies including different aspects of assessment, areas, experiments methods in the last ten years, to show a clear reference about critical thinking assessment for educators and researchers.

3. Method

3.1. Data Resource Main Points

The relevant data and resources were processed through the following phases:

First, literature search. The inclusion criteria consisted of 4 conditions: English, assessment on critical thinking, research design, and K12. 1200 potential articles were split into 3 separate groups consisting of around 400 articles each, with 2 people in charge of each group. These articles would then be assessed using a checklist method to check their relevance, while the irrelevant articles were discarded. As a result, 825 potential articles remained after being deemed relevant by the groups.

Second, the data were sorted and transferred to an excel document to undergo further evaluation. A researcher would analyze the data and determine whether an article was correctly and equally evaluated by comparing the checklists of the same article across the ratings given by all 3 groups. If an article was given a check-in at least 1 of the 4 criteria listed above (English, k12, assessment on CT, research design) by all 3 groups, it was deemed relevant, otherwise, it was discarded. This process left behind a sample consisting of 200 articles which were then further evaluated in detail by everyone.

3.2. Coding Framework

Observe students' content knowledge through literature review papers, the influence of school curricula on students' critical thinking, the teacher's influence on students' critical thinking, and self-efficacy:

1 Determine the author, journal, publication year, skills, country and region, and student grade (k12, junior high school, high school).

2 Students' skills and knowledge, ability to judge and solve problems, critical thinking, cooperative ability, student emotions and attitudes (challenging tasks, multiple perspectives, voices of doubt, student negotiation, non-determinism)

3 Independent variables, dependent variables, intervention

4 Hypothesis, analysis, evaluation

3.3. Reliability Among Raters

To evaluate the reliability of the grader's coding of the quality of the paper, select several papers as samples, and evaluate the credibility. 10 (50%) articles are independently coded by two graders.

4. Result

4.1. Descriptive Analysis

The researcher's analysis of the assessment of adolescents' critical thinking in the classroom from the year of publication, distribution, descriptive statistics of assessment tools, types of intervention, and dimensions and types.

4.1.1. Publication Year

Figure 1 shows that the distribution of 23 articles during from 2011 to 2021. Between 2011 and 2021, the number of articles published in the SSCI on empirical research on critical thinking assessment of adolescents in the classroom area fluctuated significantly, with several turning points in 2012, 2015, 2017, and 2020. Among them, the largest number of articles is 7, and the smallest is 0, respectively in 2020 and 2019. While there were four articles published in 2017 on critical thinking assessment in the adolescent classroom area, there were only two in 2018 and almost none in 2019. Overall, the distribution of articles showed a more positive trend.
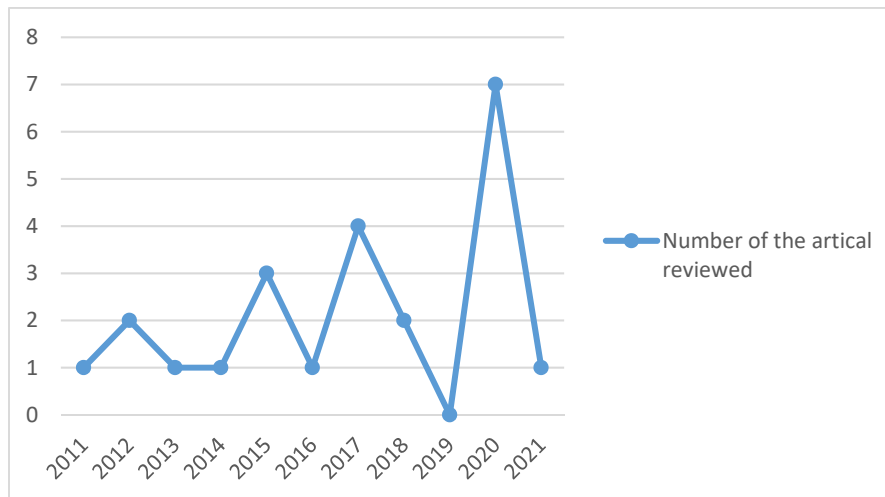
Figure 1. The Distribution of Reviewed Articles From 2011 to 2021

4.1.2. Distribution

According to statistics, most of the studies were conducted in Taiwan, China, followed by Hong Kong, China, while few studies were completed in other countries and regions. As shown in Figure 2, all the participants in these studies were high school students from K9 to K12, and most of the participants were from K10, followed by K12. In our survey, we found that there was also a wide range of subjects that assessed the classroom areas of adolescent critical thinking. Most of these subjects are science subjects such as physics, mathematics, engineering design, biology, and science. Of the remaining subjects, English language study accounts for the majority. We speculate that high school may be a critical time for students to develop critical thinking.

Figure 2. Nationals/regions distribution of articles

4.2. Aspect of Assessment

In the high school education stage, based on the literature, the researchers sorted out the evaluation aspects in the literature from the aspects of evaluation types and the frequency of

occurrence in different articles, as shown in Table 1. The evaluation dimensions of critical thinking are summarized from the literature, most of which mainly includes five dimensions: Assumption Identification, Induction education or reasoning, Interpretation, argument, etc. Evaluation. Another is to evaluate critical thinking from the four dimensions of students' language ability, logical ability, cultural background, and social environment. Given the critical thinking of students majoring in evaluation, more students are evaluated from the dimension of professional application. Data collection methods include self-reported measurements, classroom observations, and artificial model-based methods. The types of assessment include diagnostic assessment, formative assessment, and summative assessment. The data collection methods are used in assessing the various aspects and whether formative or summative assessments are used.
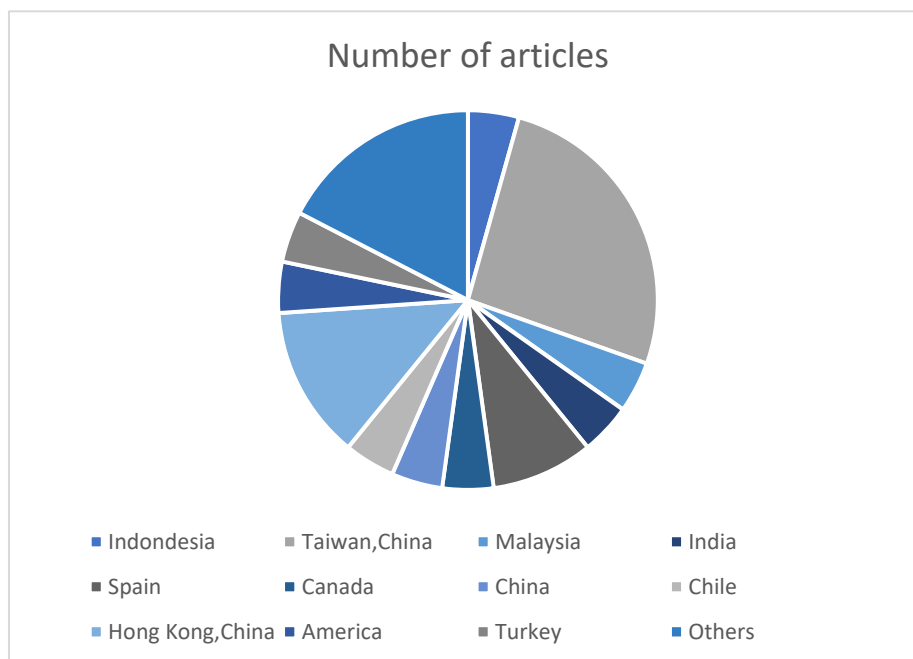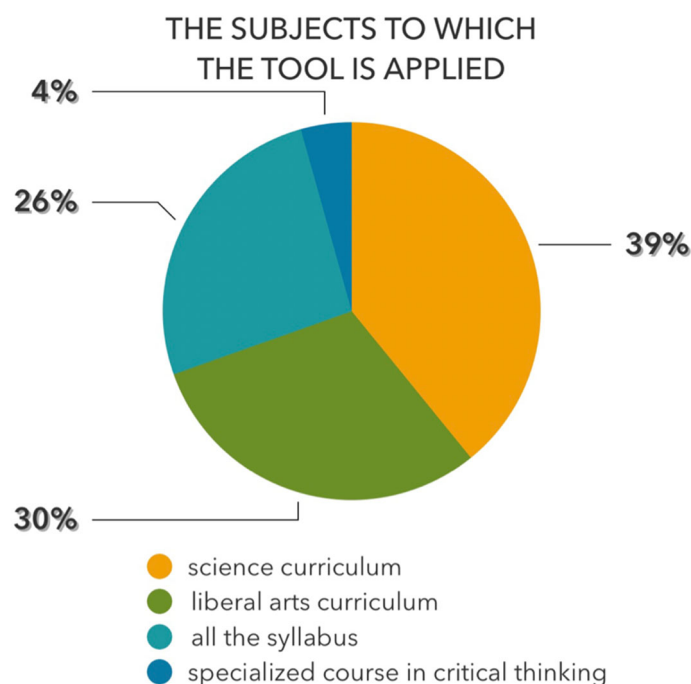
Table 1. Dimensions of 23 studies

Year	Articles	The dimensions covered
2021	The effects of digital storyte	1.assumption identification 2.inductiond eduction 3.interpretation 4. argument evaluation
2020	Structural Relationships an	/
2020	Reflexivity in multilingual a	Language ability, cultural background, society
2020	Using Concept Mapping Ac	interpretation analysis, evaluation, and inference, explanation
2020	T/E design based learning: a	Description, professional application, logic
2020	Critical Thinking Dispositio	scientific creativity
2020	Effect of Scientific Argumer	interpretation , analysis, evaluation, and inference, explanation
2020	An adaptation of the Critica	Rational thinking, intuitive thinking, inverse thinking
2018	Critical Thinking of Young C	/
2018	Fostering the skills of critic	skill of argumentation
2018	The Mediating Effects of Cri	/
2017	Effect of problem-based lea	1.Basic Clarification 2.Bases for a Decision 3.Inference 4.Advanced Clarification
2017	The pedagogical impacts on	Cognitive development
2017	Exploring the effects of clas	1.Personal Relevance 2.Uncertainty 3.Skeptical Voice 4.Shared Control 5.Student Negotiation
2016	The Development and Valid	interpretation , analysis, evaluation, and inference, explanation
2015	An exploratory study on th	1. Systematic knowledge of communication technology; (2) Theoretical knowledge of communication technology; (3) The impact of communication
2015	Investigating the synergy o	Graphic and linguistic fluency, flexibility, originality
2015	Comparison of Secondary E	thinking skills, self-expression skills, test taking skills
2014	Group work and the learnin	Debate and discussion, lecture, integration, conclusion, application
2013	The Use of Newspaper Artic	1.assumption identification 2.inductiond eduction 3.interpretation 4. argument evaluation
2012	Digital storytelling for enha	Critical thinking modelling activity, Application of critical-thinking model, Debate and discussion, Presentation, Consolidation and conclusion
2012	Fostering Critical Thinking,	1.assumption identification 2.inductiond eduction 3.interpretation 4. argument evaluation
2011	Pedagogy for developing cr	Reasoning, argumentation analysis, hypothesis testing, and decision-making performance

4.3. Course Subjects to Which the Tool Is Applied

22 of the 23 studies were conducted in the regular school curriculum, and 9 of the 22 studies were conducted in the science curriculum, including Mathematics (Marin & Halpern, 2011), Engineering Design (Bilge & Meral,2015) Biology (Yu, Lin & Fan,2015), Science (Tee, Leong & Abdul Rahim,2017; Cheng & Wan,2017), Mechanism(Qiang et al.,2020), Physics (Giri & Paily,2020; Qiang et al.,2020). Seven studies were conducted in the liberal arts curriculum, including English (Yu, Lin &Fan, 2015 Mundilarto & Ismoyo,2017 Fung,2017 Solihati & Hikmat,2018) and Turkish Literature (Yu, Wu&Fan,2020).In addition, 6 studies were carried out in all the regular courses in the syllabus of students (Chang et al.,2015). One of the studies took place in the critical thinking elective course, which is an unconventional course specially designed for improving students' critical thinking levels (Giri & Paily,2020).

Figure 3. The subjects to which the tool is applied

4.4. Type of the Assessment Tools

According to the statistical analysis of the tool types used in 23 studies, 21 of them adopted written tests, and 2 of them combined interview and observation (Bilge & Meral, 2015; Wu,2020).

For the 21 studies, the written instrument can be divided into two forms: questionnaire and short essay test. Among them, 11 questionnaires used the Richter scoring method to evaluate critical thinking level (Yang & Wu, 2012; Oliveras, Marquez & Sanmarti, 2013; Fung & Howe,2014, etc.), and 8 questionnaires used the answer scoring method to evaluate critical thinking level, which was independently developed by researchers (Sasson, Yehuda & Malkinson, 2017; Yu, Wu & Fan, 2020, etc.). Two studies used short-essay items (written questions composed of items from different essay types) to provide reading context to assess students' critical thinking level (Mundilarto & Ismoyo,2017; Tseng,2020).

In addition, 2 items were non-written. Bilge & Meral (2015) design a 15-45 minute interview, during the interviews, questions were asked to the participants with the researcher taking great care to avoid directing participants while also encouraging them to explain their thoughts in detail by giving more examples. Wu (2020) used in-depth interviews, discourse analysis, document analysis, participant observation, visual methods, and online observation to assess students' critical thinking skills

It is worth mentioning that observation can often be combined with written tests or interviews. For example, Fung (2017) adopted the combination of the Richter scoring questionnaire and observation method, Mundilarto & Ismoyo (2017) adopted the combination of the short essay test and observation method, and Bilge & Meral (2015) adopted the combination of interview and observation method.

4.5. Resource of the Assessment Tools

Statistics on assessment tools for 23 studies showed that in 13 of the studies, critical thinking assessment tools developed by predecessors were used to assess students' critical thinking levels. Among them, 3 studies (Fung & Howe, 2014; Fung, 2017; Qiang, Han, Guo & Bai, 2020) measured students' critical thinking using the California Critical Thinking Propensity Scale

(CCTDI). The 2020 study in China used the Chinese version of the Critical Thinking Propensity Scale (CTDI-CV; Peng et al., 2004), and other studies used the original CCTDI scale for measurement. Two studies adopted The Critical Thinking test-level I (CTT-I) scale (Yang & Wu, 2012; Chang et al.,2015), 1 study adopted Level II (CTT-II) of the critical thinking test developed by Yeh (2005) (Chen & Chuang,2021). Other studies used different assessment tools, such as Paul and Elder (2005) Scale to Rank Critical Reasoning (Oliveras, Marquez & Sanmarti,2013), Motivated Strategies Learning Questionnaire, 5 projects related to critical thinking level in MSLQ (Artino 2005) (Ismoyo,2017), Watson-Glaser Critical Thinking Assessment Form (Giri & Paily,2020).

Table 2. Tools for measuring critical thinking in high school students from 2011 to 2021

Title	Published year	Critical thinking assessment tool	Developed by predecessors	Developed by the researchers
Pedagogy for developing …	2011	Halpern Critical Thinking Assessment (Halpern, 2010)	√	
Digital storytelling for …	2012	CTT-I	√	
Fostering Critical Thinking…	2012	analyze the case study of "Ashley X"		√
The use of newspaper …	2013	Paul and Elder (2005) Critical Thinking scale	√	
Group work and the learning…	2014	TCTS-PS;California Critical Thinking Tendency Inventory (CCTDI)	√	
Investigating the synergy…	2015	CTT-I	√	
Comparison of Secondary …	2015	Questionnaire designed by the current researcher(IBO);Interview		√
An exploratory study on the application…	2015	Questionnaire designed by the current researcher		√
The Development and Validation …	2016	Questionnaire designed by the current researcher (MCTS)		√
Effect of problem-based learning…	2017	Hake(2008) Formulas ;Critical thinking skills tests, and observation tables of achievement in learning activities designed by the current researcher	√	√
The Mediating Effects of…	2017	MSLQ	√	
Exploring the effects of…	2017	CLES	√	
The pedagogical impacts…	2017	California Critical Thinking Tendency Inventory (CCTDI)	√	√
Fostering the skills of critical thinking…	2018	Questionnaire designed by the current researcher		√
Critical Thinking of Young Citizens …	2018	Questionnaire designed by the current researcher		√
An adaptation of the Critical Thinking …	2020	Spanish version of the Critical Thinking Disposition Scale	√	
Structural Relationships among…	2020	Questionnaire designed by the current researcher		√
Effect of Scientific Argumentation …	2020	Scale developed by Watson-Glaser	√	
Reflexivity in multilingual and intercultural education…	2020	Scale developed by Brewer (2000)	√	
Using Concept Mapping Activities…	2020	Scale developed by Jie et al. (2015)	√	
Critical Thinking Disposition and Scientific Creativity…	2020	California Critical Thinking Tendency Inventory (CCTDI) Chinese version	√	
T/E design based learning…	2020	Docktor (2009) Critical Thinking scale	√	
The effects of digital…	2021	CTT-II	√	

In 7 studies, researchers used self-developed tests to measure students' critical thinking levels. The self-developed tests in this part are in various forms, including the self-developed Critical Thinking Scale for students (example, Yu, et, al., Mechanical Critical Thinking Scale

(MCTS),2016), and an interview by an expert assessment panel (example, Bilge & Meral,2015), analyzed special cases and tested students' critical thinking level (for example, Analyze the case study of 'Ashley X', Chowning et al.,2012).

Two studies used a combination of previous development tools and independent development tools for measurement. Specifically, Dennis Fung (2017) used the California Critical Thinking Propensity Scale (CCTDI) combined with focus group interviews to comprehensively consider students' critical thinking ability. Mundilarto et al. (2017) independently designed a critical thinking skills test and a learning activity achievement observation table based on the calculation of short-form test items using the formula developed by Hake(2008).

One study adapted the tools developed by the predecessors. Specifically, Shanta et al. (2020) designed the classification scale, which was adapted from the scoring criteria developed by Docktor (2009). The classification scale is used to measure key student competencies (SAs). The evaluation tools are shown in Table 2.

5. Discussion

5.1. Using Various Measurement Ways for Developing CT

A review of 23 studies using critical thinking assessment tools in classroom areas found that traditional measurement tools, such as the CCTDI called California Critical Thinking Scale contains 75 items including seven aspects (Inquisitiveness, Open-mindedness, Systematicity, Analyticity, Truth-seeking, CT Self-confidence, and Maturity) (Facione, 1995). It is a way of measuring critical thinking for most high school students because CCTDI is testing one's intellectual curiosity and desire for learning (Facione, 1995). In addition to these traditional scales, many researchers have made innovations in assessment tools and produced some new forms, such as assessing students' critical thinking through writing, case analysis, or interview.

In addition, the classification of critical thinking dimensions is becoming more diversified. Critical thinking has been continuously studied in the past 10 years, with researchers constantly optimizing critical thinking itself based on theory and practice. The division of critical thinking dimensions has also developed from the early five dimensions (hypothesis identification, induction, deduction, explanation, and argument evaluation), which consists of the core of Ennis' critical thinking, and those are usually used in many critical thinking curricula (Moore, 2007). Also, it may be applied in a different situation, (Moore, 2007), for example, four dimensions (explanation, analysis, evaluation, reasoning) in Taiwan, China, 2020, and six dimensions, in Spain, 2013.

Critical thinking helps develop students' higher-order way of thinking and abilities' about 'to decide what to believe and to do (Moore, 2007). Researchers think of various suitable ways for developing critical thinking. Educators and scholars also recommend that CT skills should be taught in the K-12 schools and encourage students to use the skills in the future (Facione, 1995).

6. Research Advantages and Recommendations

The 23 studies reviewed in this paper covered high school students in the Americas, Europe, Asia, and Africa, and the findings have implications for the global context. In addition, Ennis viewed critical thinking as an independent cognitive ability, so it can be added and taught on any topic (Moore, 2007). 9 of 23 studies took science classrooms as the background, 7 of them took liberal arts classrooms as the background, 6 of them took general subjects as the background, and 1 of them took new-type subjects as the background, which covered all disciplines of senior high school students and had universality. In this paper, a coding framework was established to screen 849 articles for three rounds and carry out a consistency test, which met the scientific research standards.

7. Research Limitations and Prospects

7.1. Focus Only on the Classroom Area

This study only focuses on the measurement tools of critical thinking in the classroom of senior high school students, because they stay a long time in schools and classes. Thus, it shows that Critical thinking is paid attention to in the school community (Kuhn, 1999). In most of the 23 studies, it divided more than one round to measure Critical thinking, due that Critical Thinking needs to become concrete realities from an abstract term originally (Kuhn, 1999). Unfortunately, its application value is relatively small, because of a single setting.

In future research, on the one hand, the age group of the study can be expanded, for example, the study of junior high school and primary school students can be added; On other hand, the field of study can be expanded by, for example, adding the non-classroom environment of the home environment or school.

7.2. Carry out Research on Innovative Subjects

Creative subjects refer to those specifically designed to improve students' critical thinking skills. Through the review of previous studies, we found that only 2 of the 23 final retained studies were related to the study of innovative subjects, indicating that this is an area rarely covered by researchers. Therefore, research on this subject can be carried out in the future to enhance the application value of research.

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