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Synthesis of critical thinking research of basic education level students using Meta-analysis in Thailand during 2010 to 2021

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An analysis of critical thinking research during 2010 to 2021 was conducted using effect size criteria; subsequently, a model was proposed for teaching and learning management that promoted critical thinking by students at the basic education level using the Thai digital collection data base. Based on a search of past research quality examination criteria were identified using a research quality check form. Out of 200 studies identified, 173 met all criteria that covered 34 universities across Thailand. The most frequently used concepts (38.7%) were from the Watson and Glaser study, followed by the Ennis and Mill man study (16.8%). For the 173 learning management models, the most effective learning management model involved inquiry-based learning (19.5%), followed by problem-based learning (7.2%). The effect size value of the inquiry-based learning was high (2.32). In addition, critical thinking encouraged students at the high school level (effect size 2.37) and elementary level (effect size 2.77), based on these high levels of effect size.

Key words: Critical thinking, research synthesis, students in basic education level.

INTRODUCTION

The global society is facing challenges from the impact of rapid technological change, involving the use of new innovative technology to replace old-fashioned technology (Denning, 2016), thus enabling organizations to use technology more and more. Consequently, many organizations had to transform to digital technology, which involved incorporating technology and digital strategies into laying foundations, goals, business operations, and changing organizational culture, which resulted in the world changing more rapidly than before (Schwab, 2016). In addition, the outbreak of the coronavirus disease in 2019 caused the global economy to slow down. Regarding future career issues, the World Economic Forum (WEF) recently noted that countries are concerned that robots are replacing humans, especially as COVID-19 has changed lifestyles (World Economic Forum, 2020).

The WEF survey explored the skills that are most in-demand as inputs to prepare for change. The survey found that in addition to technology skills, data management and creativity are key success factors of economic growth. Furthermore, regardless of the country, critical thinking was considered a top priority (World Economic Forum, 2020).

Critical thinking is a decision-making process that involves thinking clearly and reflectively and being able to

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identify the relevance of different information in making a decision or drawing a rational conclusion before believing or doing anything (Ennis, 1985; Bassham et al., 2008). It is also an important skill for the future because it also creates a competitive advantage at work (Murawski, 2014). For this reason, critical thinking is an extremely important skill in a disruptive situation.

If current and future situations become worse than anticipated, it will be necessary to develop a new generation with better critical thinking skills because critical thinking is not a skill that can be developed in the short-term nor using traditional teaching methods in some countries that education is not yet developed thoroughly, especially as academic success does not guarantee students will be able to use critical thinking effectively in all situations (Willingham, 2007).

Therefore, education is important to encourage students to think critically. Fundamental education in Thailand places emphasis on thinking skills that are defined as one of a student's core competencies, because if students can solve problems through analytical thinking, synthesis, creativity, and critical thinking, it will be able to lead to the creation of knowledge for effective living (Ministry of Education, 2010). In addition, to the above changes, the teaching and learning process must be changed. The focus should be on students using their skills for self-directed learning, (Bellanca and Ronald, 2010) because nowadays it's filled with a lot of information that students could learn to further develop their knowledge.

For the above reasons, Thailand has conducted research studies using different teaching methods to encourage students at the basic education level to think more critically. "This considerable corpus of work can be made more useful by applying research synthesis the process of seeking knowledge or answering research questions with the scientific method by collecting data on the problem and analyzing using statistical or qualitative analysis and finally, presenting the information as a systematic summation providing answers to the desired research problems" (Glass, 2015). This may involve meta-analysis by effect sizes using the results of each research study. The outcomes can expand the study so that education personnel can apply the results to further promote critical thinking among students at the basic education level effectively, which will positively affect society in the future.

The purpose of the current research was to synthesize research involving critical thinking variables using meta-analysis. The population group was students at the basic education level (Grade 1–Grade 12). Specific aims were: 1) to study the characteristics of research involving critical thinking during 2010–2021 using research synthesis; 2) to study the effect size of research on critical thinking; and 3) to propose a model of teaching and learning management to promote critical thinking by students at the basic education level.

LITERATURE REVIEW

Critical thinking

According to World Economic Forum (2020), organizations around the world are worried about the impact of rapid technological change as mentioned above; consequently, people with critical thinking abilities are in high demand now and in the future. This is particularly so for the digital native cohort, which is the age group using social media and accessing a lot of information. Therefore, to be able to effectively process fake news, there is a need to support education in this field from a young age, using 21st-century skills that are essential in the transformation age (Boonsathirakul, 2021). This process involves preparing for the future by learning essential skills, such as critical thinking and problem solving, which include reasoning effectively, systems thinking, decision making, and problem solving (Panich, 2017). Critical thinking and problem solving are complementary because the former is essential to achieve the latter (Rahman, 2019). This is supported by data from the National Association of Colleges and Employers (2016) that showed many organizations considered critical thinking as important as problem-solving ability.

Although critical thinking is applied in many contexts, at the core of critical thinking, there is a process that requires knowledge and decision-making skills to take action. It is a reflection before deciding to believe or do anything with assumptions, selecting the theories, principles, or reliable sources (Ennis, 1985; Paul and Elder, 2008). Critical thinking is not a recent concept, but rather one first mentioned in ancient Greek writings. To be able to think critically, a person must discuss and critically reflect on things with their own knowledge, not simply using information transferred from the teacher to the student. In addition, critical thinking helps a person come up with answers or solutions for simple personal problems and also for more complex ones (Thayer-Bacon, 1998). However, it is important to be careful to avoid introducing a lot of subjective bias when analyzing information in order to make informed decisions about information and beliefs (Paul and Elder, 2008). In addition, people who have thought critically are also generous, accept other people's opinions, understand that others seek and choose new information that differs from previous knowledge, and can evaluate the strength of the evidence to support the various reasons for choosing the best example (Bayer, 1983).

Critical thinking and education

As mentioned above, the new generation of digital natives is the generation that uses social media and accesses a lot of information through social media. Their

future will involve many challenges that will require critical thinking skills in life and work. Therefore, if the educational system can encourage pupils to think critically through teaching, the result will be people with critical thinking skills in the future. In addition, Heyman (2008) suggested that it is worth trying to teach children critical thinking skills, even when it is challenging because those who have critical thinking gain a competitive edge in their future work (Murawski, 2014). This is consistent with Thailand's core curriculum that emphasizes thinking skills that are defined as a student's core competency (Ministry of Education, 2010). Therefore, preparing students at both secondary and tertiary levels of education by developing their critical thinking skills will also meet the stated needs of many employers (Sulaiman et al., 2008).

In addition, a disturbing study by Rujivanarom (2016) found that 2,901 Grade 6 students, 2,305 Grade 10 students and 1,029 vocational students from 10 provinces (in Thailand) were evaluated by testing them on an exam similar to the one at PISA.

The test evaluated logical thinking and analytical skills, and learned that the average score was just 36.5%, with just 2.09% of all students passing the exam," Therefore, to develop students to have critical thinking skills, it is necessary to improve teaching process to encourage students to think as critically as possible, especially in the today's impact of rapid technological change with less interactive conversation and increasing use of TV, video games, and the Internet.

Therefore, teaching students to think more critically becomes more difficult and challenging (Mendelman, 2007) and instructors must consider the changing global context and develop teaching styles that can encourage students to think more critically. Subsequently, efforts have been made to encourage teachers to empower their students to develop the skills needed to differentiate the complexities of an ever-changing society (Hayes and Devitt, 2008). Currently, there are many studies on developing teaching processes to promote critical thinking among students. Generally, the process consists of 1) inductive thinking; 2) credibility of sources and observation; 3) deductive thinking; and 4) assumption identification. This process is an important element of teaching to encourage students to think critically and is also a key in the well-known critical thinking model, the Cornell Critical Thinking Test Level X (Hager and Kaye, 2006). For example, a study by Changwong et al. (2018) developed the PUSCU teaching model consisting of the components: 1) preparation for learning management; 2) understanding and practice; 3) cooperative solutions; 4) sharing new knowledge; and 5) creation of new knowledge in addition, there are other international research studies on how teaching processes can improve a student's ability to think more critically, such as Zhou et al. (2013) who studied critical thinking using learning management by task-based activities approach in

chemistry. Their experimental design was divided into 2 groups, the control group taught using normal methods and the experimental group taught using a task-based approach, there were 119 participants, aged 17 to 9 years. Their results showed that based on the dimensions of the analysis, there were significant (p <0.05) differences in the task-based activities approach and using normal methods. Therefore, the collation of studies involving the design of different teaching processes to promote critical thinking among students at the basic education level would be of great benefit to the education industry.

Research synthesis

Research synthesis is the integration of many research conclusions, where 2 or more factors combine to create something new or a new phenomenon (Glass, 2015). Its purpose is to bring all the results of the research to a common conclusion on the topics studied, which will build on the original research (Cooper, 2016). While, using scientific methodological techniques and statistical or qualitative analysis to present information in a systematic way for general answers or overall guidelines (Light and Pillermer, 1984). Research synthesis can be divided into 1) qualitative synthesis, which is the synthesis of content using a synthetic method with a descriptive method to obtain a summary, where the findings of the synthesized research papers may retain the subject matter of individual studies (Gilson, 2014); and 2) quantitative synthesis, which refers to the use of statistical methods, presenting the results of all research performed in the same standard unit, integrating the results of all synthesized research papers, and demonstrating the correlation between the research characteristics (Sukjaroen and Yoonisil, 2015).The most popular quantitative synthesis method is meta-analysis, which is a type of quantitative research synthesis in which researchers study and analyze the same research problems using statistical methods and synthesize conclusions that are broader and more profound than the initial research findings in each subject (Glass, 2015). The data for the meta-analysis consists of research findings in terms of effect size and research characteristics. The uniqueness of meta-analysis is the statistical analysis to aggregate the findings from various empirical studies in terms of effect size and to compare how the size of the effect from each study differs according to research characteristics (Glass and Smith, 1979). Researchers typically use Cohen's d = 0.20, 0.50, and 0.80 to interpret observed effect sizes as small, medium, or large, respectively (Brydges, 2019).

Research synthesis process

Synthesis of research using the analytical method

consists of: (1) formulating research problems; (2) studying related research papers and research; and 3) conducting research synthesis. The key to research synthesis is based on the selected research studies. Glass (2015) divides the research sources to be analyzed into 2 categories: (1) primary sources, which are those where the researcher collects direct research data, such as a full-text research, published journals, or theses; and (2) higher sources, which refers to data sources from which the researcher has not directly gathered research results but rather, the data on the research results are collected from summary reports and journals for which the selection methods can be divided into: selecting anything, random methods, or selection method.

However, Light and Pillemer (1984) made the following observations on these methods: (1) selecting anything is the easiest method because it is a compilation of all the available search results, both published or non-published in theses or research reports available from various organizations and avoids choosing study topics or deciding why some subjects are selected; and (2) choosing only published works excludes conference research papers that are not available in libraries but is restricted to works that can be found almost anywhere so that it is possible to invest time and budget to check the quality of the research. However, Rosenthal (1978) noted that most of the research cited in journals would be accepted and contained valid findings that were statistically significant and as a result, the results will be higher than the actual results. Glass and Smith (1979) suggested that selecting only published research papers would result in inaccurate conclusions. Therefore, it is worth considering other unpublished research papers because the collection of research from various sources, without unpublished research papers would implicitly bias the conclusions obtained from the study. However, in the choice of research, no matter which method the researcher chooses, the researcher must first check the quality of the research to see if it is good.

Scope of current study

The current study focused on Thai research involving critical thinking during 2010 to 2021 from the Thai Digital Collection (year).The total data collected consisted of 259 studies on critical thinking that met the following selection criteria: (1) an experimental study whose critical thinking is based on dependent variables and the population is students at the basic education level;(2) research involving basic statistics(mean, standard deviation, and the number of samples) and significance testing that were suitable for conversion into the effect size using standard indices in the meta-analysis; and (3) research that has passed the research quality check criteria listed on a research quality check form. The tool was divided into 7 parts: extraction, title, introduction, papers, related

research, research methods, results, conclusion, discussion, and suggestions. After passing all the criteria, the sample group consisted of 173 studies from 34 universities across Thailand, answering the research objectives: (1) to study the characteristics of research involving critical thinking during 2010 to 2021 using research synthesis; (2) to study the effect size of research on critical thinking; and (3) to propose a model of teaching and learning management to promote critical thinking by students at the basic education level to quantify the distribution characteristics, distribution of variables, and research characteristics, which were divided into two aspects: content and research methods and research methods; and (2) data analysis to answer research objectives by analyzing methods for teaching and learning or activities that result in critical thinking

Scope of variables

The independent variables were research characteristics consisting of: (1) research content variables, and (2) research method variables, as detailed below.
(1) There were 4 research content variables consisting of: (1) the theory or concept used in the research; (2) the educational level of the sample group; (3) the institute of the sample; and (4) independent variables.
(2) There were 11 research method variables consisting of: (1) objectives; (2) research design; (3) type of research hypothesis; (4) sample selection; (5) sample size variables; (6) duration of experimentation; (7) reliability of research tools; (8) types of tools; (9) statistics; (10) the level of statistical significance; and (11) results.

METHODOLOGY

Research tools

The researcher studied critical thinking, research synthesis method, and meta-analysis from books, articles, and research papers as a guideline for determining the recording format and research attribute variables affecting the magnitude of the effect size of critical thinking. Then, a code was designed for recording the values in each item as a separate coding guide from the research characteristic log. When completed, the data were checked for language clarity and research characteristics and revised as necessary before being reviewed by 3 experts to verify the content validity and the coverage of the variables in terms of research characteristics. The reviewer's feedback was incorporated into the process.

Data analysis

The analysis of this data were divided into two steps to answer the research objectives: (1) preliminary data analysis to study the characteristics and quantity of research studies on critical thinking among students at the basic education level, using descriptive statistics (percentage, frequency, mean, standard deviation) to

quantify the distribution characteristics, distribution of variables, and research characteristics, which were divided into two aspects: content and research methods and research methods; and (2) data analysis to answer research objectives by analyzing methods for teaching and learning or activities that result in critical thinking by calculating the effect size, which the researchers typically use Cohen's d = 0.20, 0.50, and 0.80 to interpret observed effect sizes as small, medium, or large, respectively (Brydges, 2019).

RESULTS

Research issues derived from research synthesis on critical thinking

(1) The research content variables characteristics showed that the sample group selected from 173 studies consisted of students from the elementary level to the senior high school level. Of these, 39.3% were students at the junior high school level (Grade 7–Grade 9), followed by 38.2% in senior high school (Grade 10–Grade 12), and then 19.1% in senior elementary school (Grade 4–Grade 6). The most frequently used concepts were from the Watson and Glaser study (38.7%), followed by the Ennis and Millman study (16.8%), the Dressel and Mayhew study (13.9%), and the Ennis study (11.6%). For the learning management model, 19.5% used a constructivist teaching method, followed by 7.2% using problem-based learning, 5.5% using digital media, 4.2% using the six thinking hats, and 3.8% using different learning types of co-operative learning and the science, technology, and society (STS) approach.
(2) The research method variables characteristics showed that most of the research designs (63.6%) used a one group pretest-posttest design, followed by 15.6% using a randomized control group pretest–posttest design. The largest sample group selection (44.5%) was using cluster sampling, followed by 35.8% using purposive sampling. The majority of research trials (65.9%) used one group of samples, while 33.5% of all trials had a sample size in the range 31 o 45 samples, followed by 29.5% in the range 15 to 30 samples. Regarding the duration of the study, 34.7% spent 16 to 20 hours, followed by 34.7% having 11 to 15 hours of study. The reliability of most of the instruments was 46.2%, in the range 0.85 to 1.00 and the most popular inferential statistic (75.9%) was the t-test.
3) The effect size was calculated for 168 studies, with an overall mean of 2.44, which was high. The highest effect size of 2.77 was for students at the elementary level (Grade 1–Grade 6), followed by an effect size of 2.37 for students in high school (Grade 7–Grade 12). Comparing high school into the junior and senior levels, the effect size of 2.86 was higher for senior elementary school students (Grade 4–Grade 6), followed an effect size of 2.58 for students in junior high school (Grade 7–Grade 9). The research design found that the most effective size was 4.24, using a one-group pretest-posttest design. Considering the size of the sample group, using a sample

of fewer than 15 had the highest effect size (4.66), followed by an effect size of 2.91 using 31 to 45 samples. Regarding the duration of the study, the highest effect value of 2.76 was for 16–20 hours, followed by an effect size of 2.62 for 11 to 15 hours. The reliability of most of the instruments had an effect size of 3.04 with the range 0.85 to 1.00.

The results of the research show that in Thailand, conducting research on critical thinking, developing the concept and elements of critical thinking from Western concepts. Moreover, it's developed from a variety of theories which resulted in the use of a variety of teaching methods to develop critical thinking, which is different from the development of critical thinking in Western countries where teaching to develop critical thinking is traditionally taught.

DISCUSSION

Research issues derived from research synthesis on critical thinking

The 173 studies from 34 institutions used different teaching styles and subjects. Each study chose different concepts to create a tool for measuring critical thinking. The most frequently used concepts (38.7%) were from the *Watson and Glaser study which was composed of 3 scales: Interpretation, Dedication, and Inference*, followed by 16.8% for the *Ennis and Millman study (which was composed of 5 scales: deduction, induction, observation and credibility, and assumption)*. The ability to determine the reliability of the data is required, inductive ability to prioritize, and the ability to consider discrimination. A further 13.9% used the concept *of Dressel and Mayhew which were composed of* 5 aspects: define problems, select information related to a problem, discern basic agreements, and select hypotheses and reasonable conclusions, which is consistent with the two previous theories.
These three theories were used to create 120 study tools out of the 173 studies, representing 69.4%.The relevant causes at the core of these three theories were:

(1) understanding or defining the problem, which is the first and most important part;
(2) determining, distinguishing, or identifying preliminary agreement; and (3) evaluating, interpreting, or concluding the information. The process includes a systematic review of information that makes critical thinking the ideal process to cope with a rapidly changing world and conforms to the 2020 World Economic Forum report about future career issues, where countries are concerned about robots replacing humans, including as a response to the COVID-19 pandemic. The WEF conference surveyed the skills that were most in demand and found that critical thinking is one of the essential skills required by organizations in many countries globally

(World Economic Forum, 2020). In addition, there is now a great deal of fake information presented as news, inducing readers into erroneous judgments, causing damage to a legal entity or agency, obtaining a financial gain, or influencing policy, especially regarding COVID-19. It could be said there has been an "epidemic" of misinformation, misrepresentation, and distortion about the disease (Chaikij and Chitsawang, 2021; Phanmool and Propunprom, 2021).

Therefore, critical thinking can help in the analysis of large amounts of data and in considering and evaluating that data to make a decision. Especially, considering the information as facts or fake news. Collaboration between the Friedrich Naumann Foundation for Freedom (FNF) and six other networks reported in a joint press conference that the solution to addressing fake news should be via the education system promoting critical and creative thinking (Friedrich Naumann Foundation for Freedom, 2019). Considering the methods for teaching and learning used by most of the research analyzed in the current study to help students to think critically, from the synthesis of 173 research results, 19.5% used the constructivist teaching method. This process focuses on finding solutions to problems using the available information by asking questions on survey design, analysis, summarization, and invention to exchange ideas and communicate explanations that assist students to apply these findings to new knowledge. The main point of this learning management model is to focus on the process rather than the productivity (Carin, 1993: Wu and Hsieh, 2006).

Issue of effect size of research on critical thinking

Of the 173 studies from 34 institutions, 168 effect sizes were identified, with an overall mean of 2.44 which was high (from Cohen's d method) because all the research has satisfied the criterion of being a valid research process. In addition, most (77.5%) of the students were in high school, making them especially suitable for developing critical thinking, because at this age range (13 to 17 years), conceptual development and thinking develop at an abstract level along with the ability to form hypotheses and to apply a systematic and rational thought process (Kowtrakul, 2016).

However, although most of the research used sample groups at a high school level, 25.5% used sample groups at the elementary school level, having an effect size of 2.77, which was not much different from that for high-level students. Notably, the instrument used to measure critical thinking had a variable reliability level; however, 46.2% of the research had reliability values in the range 0.85 to .00, with an effect size of 3.04, indicating the high reliability of the tool. The size of the effect would also be greater, in the context of research using tools for measuring students' critical thinking at the basic education level.

Suggestions for learning management to encourage critical thinking among students in their basic education

The learning management model that used the most (19.5%) was the constructivist teaching method and the studies showed the constructivist teaching method also being used to promote critical thinking among students at higher basic education levels, with an effect size of 2.32, which is high (from Cohen's d method). Therefore, the constructivist teaching method is the most popular method of using critical thinking among students at the basic education level.

Studies in many countries on critical thinking and the constructivist teaching method have been carried out, such as the study of the relationship between the constructivist learning environment and critical thinking ability using 967 Grade 9 students in Hong Kong based on structural equation modeling, which concluded that the constructivist teaching method could promote critical thinking (Kwan and Wong, 2015). Another study, involving 703 high school students in Croatia concluded that the students had higher levels of critical thinking when studying using the constructivist teaching method (Topolovčan and Matijević, 2017). In both Thai and international research, teaching at the basic education level can use the constructivist teaching method to encourage students to think more critically. In addition, the researchers found that critical thinking can be developed for students of all grades, whether in elementary or high school, since both groups had high effect size values.

Conclusion

The research synthesis on critical thinking from research reported during 2010 to 2021, involved studies that had passed the research quality examination criteria based on a research quality check form, involved 173 research criteria from 34 universities across the country. Most of the sample group (77.5%) was high school students divided into junior high school (39.3%) and senior high school (38.2%) levels. The most frequently used concepts (38.7%) were from the Watson and Glaser study, while 19.5% used a constructivist teaching method. Most of the research was experimental design, with 63.6% using a one group pretest-posttest design with sampling mainly using cluster sampling (44.5%). The reliability of most of the instruments was high (46.2% in the range 0.85 to 1.00) and the most commonly applied inferential statistic (75.9%) was the t-test.

The overall mean effect size was 2.44, which was high and the most effective size (2.77) was for students at the elementary level, with the effect size for students at the high school level almost as high (2.37). The reliability of the research instrument had a highest effect size of 3.04 with reliability in the range 0.85 to 1.00.

The suggested methods for teaching and learning showed the effectiveness of the constructivist teaching method that promotes critical thinking in students at the basic education level with 19.5% choosing to use an experiment, which was successful in promoting critical thinking, with an effect size of 2.32, which was high. In addition, the promotion of critical thinking can be encouraged in students at both the high school and elementary levels since both groups had similar and high effect sizes.

LIMITATIONS AND SUGGESTIONS FOR FUTURE RESEARCH

There were some limitations to this study. First, this research only considered students at the basic education level and thus may not be applicable to learners in early childhood or higher education. Second, it was a quasi-experimental research study that used the teaching process; therefore, other factors related to critical thinking were not studied.

However, teachers can apply the results to design methods for teaching and learning that are suitable to promote critical thinking for students at all levels of basic education. Future studies are necessary for research related to the early childhood and higher education levels, as well as other quantitative research to investigate other factors consistent with critical thinking, such as family factors, motivation, and personality.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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