Eurasian Journal of Science and Environmental Education
2023, 3(2), 51-60
ISSN 2672-863X (Online)
https://www.ejsee.com/
Research Article
OPEN ACCESS

Critical thinking in national primary science curricula

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Citation: Karampelas, K. (2023). Critical thinking in national primary science curricula. *Eurasian Journal of Science and Environmental Education*, 3(2), 51-60. https://doi.org/10.30935/ejsee/13271

ABSTRACT

This research aims to identify elements of critical thinking that exist in primary science national curricula of several countries. Critical thinking is justified to be important in science teaching. It is considered a complex concept, which encompasses several skills. Science teaching is expected to promote the development and use of those competencies on behalf of the learners. The research around which of these elements are promoted in national curricula is still limited. Some models approach critical thinking as a concept comprised of five different groups of skills, which are basic clarification, decision, inference, advanced clarification and auxiliary skills. The model of Ennis was selected as appropriate for this study, which study examined the curricula of seventeen different countries. Through a content analysis approach, it investigated which of these groups and skills they mention. The data reveal that the majority of curricula refer to most of these skills.

Keywords: critical thinking, curriculum, primary school, science teaching

Received: 14 Mar. 2023 ◆ Accepted: 03 May 2023

INTRODUCTION

Science education is expected to contribute to the development of skills. One of such significant skills is critical thinking. Critical thinking is valuable as it helps learners develop a deeper understanding of science, rather than just viewing it as an accumulation of irrelevant, complicated, and rigid information. Critical thinking encourages learners to become more curious and open-minded towards information, concepts, and facts. Through critical thinking, learners can understand the importance of evaluating facts, gathering and analyzing diverse types of data, and drawing conclusions based on evidence. Lastly, learners can better understand some basic scientific principles such as cause and effect relationship, experimentation and knowledge implementation (Harlen, 2010; Vieira & Tenreiro-Vieira, 2016).

Critical thinking also helps learners understand and appreciate of the role of science in addressing social issues. In other words, critical thinking empowers learners to apply scientific knowledge to a wide range of contexts, allowing them to effectively address everyday problems, including social and economic challenges. Through critical thinking, learners can reject the misconception that science education is solely focused on providing the right answers to closed-ended questions, and instead recognize that it involves creating, suggesting, and offering solutions to practical topics (Byrne & Johnstone, 1987; Harlen, 2010;Vieira & Tenreiro-Vieira, 2016).

Similarly, Zemplén (2007) proposes that emphasizing critical thinking in science education can enable learners to comprehend subjects beyond the realm of science. By initially understanding the nature of science and what science entails, learners can gain a clearer understanding of the nature of knowledge, research, investigation, and various fields of study. This relies on the fact that science, along with other areas of study can relies on human activity when dealing and explaining phenomena and the word, wholistically.

Jones et al. (2012) connect critical thinking in science with other skills, attitudes and functions, which are oriented towards inquiry-based learning. These are detecting, planning, suggesting, hypothesizing, analyzing or assessing facts or data provided. They suggest that teaching science needs to involve all these, so that the learners can have a more accurate perception of what science is, how it works and how they can gain by learning and applying it. They claim that by promoting critical thinking this way; learners will become more active citizens, being more willing to engage in different social topics and offer more, whenever this is possible.

In fact, theorists agree on the necessity of relating science teaching with critical thinking. As explained, critical thinking is not limited to learning about science, but also encompasses learning about the nature of science, which can then be applied to a variety of subjects beyond science. Establishing this connection between critical thinking and science education can result in improved teaching outcomes that may have a lasting impact on learners' lives. Science will not be valuable solely to individuals pursuing careers in science-related fields, but rather has the potential to benefit individuals across various professions and disciplines. It will be recognized as useful means for all kinds of topics and activities (Harlen, 2010; Jones et al., 2012; Vieira &Tenreiro-Vieira, 2016).

LITERATURE REVIEW

Critical Thinking in Science Education

Critical thinking is therefore useful in science teaching. However, it is important for teachers to implement appropriate activities that will help learners develop their skill and ability to think critically. In order to identify what these activities should be, it is important to clarify certain points around this skill. Initially, it is necessary to precise what role it has in science teaching. It is also useful to define concepts or conceptions that relate to it. After establishing the importance of critical thinking in science education, it is necessary to identify and explore opportunities for its application in both theoretical and practical contexts. This means that it is wise to dismantle critical thinking to components and describe what someone who thinks critically does or behaves like. Then it is possible to know what activities can be used in science teaching and qualify learners with those components so that they become critical thinkers, as required (Santos, 2017; Santos Menesses, 2020).

Forawi (2016) argues that critical thinking can involve competencies such as conducting experiments, manipulating variables, gathering data, analyzing information, integrating knowledge, and processing insights. In addition, critical thinking in science education involves using scientific evidence-based argumentation to develop and propose ideas, plans, and solutions to problems that are not only scientific in nature but also social and beyond. Understanding, application, analysis, evaluation and creativity are key ingredients for the development of such components and critical thinking, overall. All these are based on the foundational idea that science should not be restricted to a body of knowledge for learners to memorize superficially. Science should be viewed as a human endeavor that facilitates a deeper understanding of the natural world and informs informed decision-making with respect to human interactions with it, considering broader societal implications. These are essential elements of contemporary science, or the nature of science, as well as scientific literacy. Learners are expected to gain these from teaching.

Santos (2017), in an effort to state exactly what tasks can lead to the development of critical thinking has come up with a set of specific skills or activities: researching, observation, exploring; finding, defining or identifying problems, questions or challenges; planning activities to solve problems or answer research questions; make decisions; acquiring information and data; forming research questions, based on appropriate critique; constructing reliable knowledge; participating in argumentation and support of ideas through scientific discourse, dialogue and debate; evaluating, benchmarking and testing against criteria; confirming, accepting or rejecting hypotheses; point out misunderstanding and restating statements in a scientifically appropriate way; and providing clarified meanings.

It is generally accepted that these competencies can be taught or achieved better with the help of activities, which refer to appropriate contexts. In fact, contexts inspired by everyday life themes of issues. Environmental challenges, life topics, health and safety, electricity and magnetism, mechanics, energy can be helpful contexts, that may inspire the design of appropriate activities. Teachers need to have the relevant support and guidance to take advantage of these contexts and activities, so that they can promote these competencies and achieve in having their learners thinking critically (Santos, 2017; Santos Menesses, 2020).

Research Around Critical Thinking in Science Education

Certain groups of researchers have aimed to precise how to promote critical thinking in science classes. Mai et al. (2019), have carried out an in-depth study to analyze weather lower primary science textbooks in Malaysia emphasize on critical thinking. In doing so, they adopted the model of Thompson (2011), where the critical thinker is considered a person who can demonstrate certain skills: inquisition and curiosity; information; motivation further learning; open-mind; flexibility; objectivity in judgements; organizational abilities; rationalization; problem solving skills in inquiry-based activities; identification of barriers and challenges. Through a content analysis approach the authors concluded that the textbooks contained several abilities of the critical thinkers. Emphasis was paid in specific skills. Such a skills was linking concepts, phenomena or topics with particular characteristics, with the help of texts or images. Another skill was analysis of data that will lead to a scientific finding, which would be the new knowledge. Limited though was the emphasis on skills such objectivity or accuracy of statements. Indeed, as the authors claim, activities that pay attention at evaluation of findings, or detecting bias were non-existent (Mai et al., 2019).

Muntaha et al. (2021), published similar research in textbooks in Indonesia. They carried out content analysis on critical and creative thinking skills in three science textbooks of middle schools. The research focused on units around environmental pollution. Through a quantitative descriptive analysis, the authors implemented a validation instrument, which approached critical and creative thinking, as a cohesion of skills or components, which they call 'indicators': interpretation; analysis; conclusion; evaluation; elaboration; self-regulation. The analysis of the textbooks included identification of activities that promoted these indicators. Both absolute and relevant frequencies were calculated. The most frequent indicator was found to be 'conclusion'. On the other hand, 'self-regulation' was the least frequent indicator. The authors attributed that finding to the nature of the unit. As they explain, teaching around environmental challenges, aims mainly at description and understanding of these challenges, along with relevant problem-solving tasks. The general conclusion is that critical thinking is promoted overall by determining information that will lead to new knowledge. Evaluation and elaboration of information do not get appropriate attention though.

These two research projects conclude that science textbooks in different countries contain several aspects of critical thinking. Attention is paid in skills that have to do with using evidence or data to create new knowledge. However, there seems to be minimal attention in evaluating the credibility or accuracy of knowledge and information. A major topic in the design of those studies though was to define how critical thinking will be examined (Mai et al., 2019; Muntaha et al., 2021).

Defining and Teaching Critical Thinking

Snyder and Snyder (2008) claim that defining critical thinking is complicated, as well deciding the practices that can help learners develop this skill or ability. Certainly, activities, technique and practices that solely rely on memorizing do not suffice, although they can be

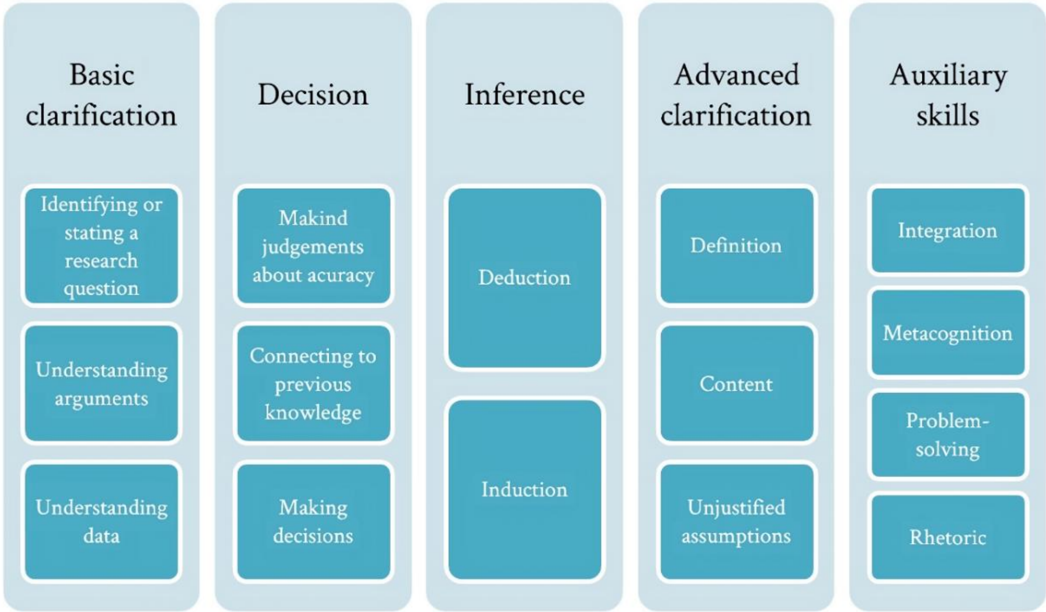

Figure 1. Components & competencies of critical thinking according to the model of Ennis (1993, 2018)

helpful. Since critical thinking is a mental habit, any technique aiming to promote it should stimulate learners to think, reconsider their thinking, reflect and engage actively. This can be developed gradually, within a continuous process, and not in a single session. Therefore, critical thinking should be integrated across the curriculum in different subjects or units. Activities and tasks that require modeling, questioning, argumentation, creativity as well as discourse are essential for that purpose. For that reasons, relevant activities and goals should exist in multiple units across curriculum of a subject, including science.

Sternberg (1987) along with Pithers and Soden (2000) point out eight basic points that teaching and developing critical thinking should pay attention to. First, teachers should rely on the idea that learners can contribute to the session, with their ideas and experience. Second, teaches should adopt the role of facilitator and not restrict their role to the traditional form of information delivery. Third, teachers must consider different routes in promoting critical thinking and not believe in a single one as a panacea. Fourth, teachers must combine different types of techniques, bearing in mind many factors, such as the context of the school, where they work and the curriculum. Fifth, they must implement practices such as open-ended questions, where learners can be motivated to think and not solely memorize or recall what they have learnt. Sixth, discussion for or on critical thinking should be treated as on-going, with no specific general end or target. Seventh, critical thinking should not be considered as a skill, which can be completely mastered. Instead, there is always room for further development. Eighth, critical thinking should not be dealt with as the be- and end-all of any intervention. Failure to apply the points can lead to a misleading idea about critical thinking and ineffective effort to develop it.

A systematic effort to point out what practices eventually lead to the desired form of critical thinking was published by Ennis (1993, 2018). After many years of work and research, the author concluded in a set of dispositions and abilities what critical thinkers entail. As far as dispositions are concerned, critical thinkers initially reassure themselves that their perceptions and knowledge are the acceptable ones. In doing so, they consider alternative ideas, they hypothesize, they try to get information and check its' accuracy. Simultaneously, they show understanding in other ideas, different points of view and they try to reason their own beliefs, ideas and knowledge, based on evidence and discussion. This implies respect to others, their arguments and their work, as this can help better understand why they come up with their ideas and can have more accurate appreciation towards them and their beliefs (Ennis, 2018; Schmaltz et al., 2017).

The Ennis Model

The model of Ennis (1993, 2018) aims to assist teachers and people involved in education, by stressing certain abilities that the critical thinkers have. These are the essential abilities that can lead a person to entail the dispositions described in the same model. They derive from and reflect the theories around critical thinking, its' rationale. They are grouped into five major categories. These are basic clarification; decision; inference; advanced clarification, which relates to supposition and integration; and supplementary, auxiliary skills. All abilities and categories are shown in **Figure 1**.

Basic clarification

Basic clarification relates to the way learners treat questions and arguments. For example, when learning about solutions and the relationship between temperature and solubility, they should be able to formulate a research question such as, 'Does heat affect how much sugar can be dissolved in water?' Afterwards, they should understand that they have to answer this question, by examining the relationship between both concepts. With an experiment, which can be by dissolving sugar in a glass of hot and a similar glass of cold water, they should be able to measure how much quantity can be dissolved in each, appreciate why they do it and draw conclusions. In case, they hear an idea different from their action or conclusion, they should be able to discuss about it and realize why others think differently. Learners, therefore, need to have the necessary skills to formulate and analyze the question along with the criteria that the answer to this question should satisfy. They need to have this question and criteria in mind, throughout the inquiry and learning process. Aside that, they should also be able to understand and analyze arguments. This means they should understand why a person supports an argument and what mental process has led him or her doing so. Moreover, they should be able to analyze basic graphs, figures, and data (Ennis, 2018; Forawi, 2016; Santos Menesses, 2020).

Decision

Decision relates to the manner learners behave in terms of credibility of a resource and observation. For example, when learners focus on sessions about energy saving habits, they may have to analyze resources to identify which solutions are energy saving and those which not. This means, they should collect evidence and resources. They should choose which ones are relevant and accurate, which could include collecting multiple resources and benchmarking. Learners should understand their content, their authors and how these authors justify their information or messages. Learners should also observe how they behave and relate it to the behaviors they aim at.

Decision skills therefore includes being able to judge the credibility of a source, analyze reports and observe. In doing so, learners may have to use previous knowledge to see how it relates to new contexts, topics or challenges. This previous knowledge may vary in nature. It may be about the content, in other words, it may be relevant to the subject or topic. It may be about resource collection or evaluation such as using the internet to find sites and data. Lastly, it may be about what a decision should be like (Ennis, 2018; Pithers & Soden, 2000; Sterberg, 1987).

Inference

Inference relates to the way learners make deductions and generalizations, while gaining new knowledge. For example, when learners experiment with a simple circuit, by connecting lamps with electrical source as batteries, they will start by making hypotheses on how they will construct it. Then, they will probably be motivated to test several connections.

In the end, they will have to identify the connections that cause the lamp to light and deduce why and when this happens. At that stage, they check if their hypotheses were correct or not. This way, they draw a conclusion about the flow of electric current. To state, this conclusion they may need to understand certain characteristics that the conclusion should have, such as what terminology or language they must use to express the generalized knowledge. Inference skills, therefore, have to do with deductive reasoning. This relies highly on logic and interpretation of data or facts with the help of appropriate terminology. Moreover, inference has to do with induction and making judgments, which are complex processes.

First, induction has to do with generalizing, in other words, stating broad considerations, that can explain observed facts and predict future outcomes. Second, it has to do with hypotheses testing, in other words, confirming assumptions, rejecting it, explaining it further and in several cases dealing with exceptions or outliers. Lastly, it has to do with understanding and applying criteria that the new knowledge gained should have, as it should be simple, plausible and capable of explaining known or alternative data and circumstances (Ennis, 2018; Pithers & Soden, 2000; Santos Menesses, 2020).

Advanced clarification

Advanced clarification relates to the way learners treat definitions or unstated assumptions. For example, learners might engage in a discourse that might have to do with pseudoscience, false misconceptions of the past such as the geocentric model or cases, where there is disagreement between scientists and theorists. In that case, they will have to examine how these ideas or beliefs were disseminated, what opinion the scientific community might hold towards them and benchmark them against appropriate acceptable scientific theories.

Learners in these cases will have to judge the idea or definition. They will focus on the form of the definition or the idea and try to elaborate it with examples, counter examples, further analysis, synonym words and relevant expressions. They will also focus on the content by reporting it, stipulating it and expressing their position about it, with the help of relevant expressions. They will have to deal with ambiguous meanings, misunderstandings and equivocations, too.

Simultaneously to judging, the learners will have to deal with unstated assumptions. This can be done with advanced skills, which combine clarification and inference. This can help them deal with unjustified statements or ideas that can be insulting towards groups of people or generally. In order to deal with these challenges, learners will use presuppositions to understand what led to these statements. They also will apply previous assumptions to reason it and tested assumptions to reject it when necessary (Ennis, 2018; Forawi, 2016; Santos Menesses, 2020).

Auxiliary skills

The supplementary skills that can be linked to critical thinking vary. An example of such is integration. Indeed, science teaching is linked to integrating activities, especially when it comes to learning from projects inspired by everyday life. Such projects can be focused on environmental matters, where learners have to integrate science with geography, arts, mathematics and cultural subjects. They can also focus on technological projects, where learners might have to integrate science with design and mathematics. Integration is expected to lead to new knowledge or decision (Ennis, 2018; Vieira &Tenreiro-Vieira, 2016).

Metacognition is also an important skill, which addresses the ability of learners to revise what they knew in the beginning of a session, what they learned and how their ideas changed. That specific skill helps learners monitor their own thinking. This is particularly important when learners get familiar with inquiry-based learning and its' part. By revising how they achieve this approach, they can become more aware of what inquiry is and how they should perform it. This way, they gradually become able to carry it out effectively and independently with less assistance or instruction by the educator. Metacognition is also important for learners to understand how to test and reject misconceptions that they may have around natural phenomena (Ennis, 2018; Pithers & Soden, 2000; Santos Menesses, 2020).

Problem solving skills are also related to critical thinking. The specific orientation of problem solving might be to give answers to a certain challenge, such as how to check whether paper airplanes can fly longer. It can also be about providing a solution, such as precise in which part of the town, a new park can be established. In any case, it has to do with following certain steps, collecting, evaluating, interpreting data, presenting and justifying ideas (Ennis, 2018; Schmaltz et al., 2017).

Lastly, rhetorical skills can be useful for learners too. These have to do with adopting expressions and vocabulary that they can use when they want to express themselves either orally or written. These skills can be used to define a conclusion drawn after an experiment, which can be the new knowledge constructed in the session. They may be used in presenting data or resources as well. They can also be used to support an argument, during a discourse. Thanks to these, learners can deepen their understanding on the nature of science and scientific knowledge (Ennis, 2018; Forawi, 2016; Santos Menesses, 2020).

Overview

The model of Ennis (1993, 2018) contains five major groups of skills that a critical thinker has and uses. These are basic clarification; decision; inference; advanced clarification; and a final set of auxiliary, supplementary skills. By engaging these skills in a science class, the educator can avoid teaching science using an outdated approach for information transition with no participation by the learners. On the contrary, the learners can learn how science and understand its' contribution to everyday life. Certainly, the borderlines among those skills are not always very strict and clear. There are cases, where these skills overlap. For example, problem solving might include integration or metacognition and vice versa.

METHODOLOGY

Research Focus and Rationale

The purpose of this study is to examine how critical thinking is addressed in science curricula. In essence, this research seeks to investigate how science curricula instruct teachers to promote critical thinking and its components during their sessions and work. The role of the curriculum is, as explained, very important (Harlen, 2010; Santos, 2017; Santos Menesses, 2020). Existing research has demonstrated that recent reforms and policies in science teaching and curricula have placed significant emphasis on the importance of critical thinking and its association with specific skills (OECD, 2013; Osborne, 2014; Vieira &Tenreiro-Vieira, 2016).

There has been research examining whether textbooks promote critical thinking (Mai et al., 2019; Muntaha et al., 2021). However, there seem to be limited research that specifically examines the details of what the curricula state and how it is connected to the fostering of critical thinking. A dearth of studies has been found regarding the specific skills, attributes, and competencies of critical thinkers that are emphasized in the national science curricula. This is the specific focus of the current research.

Research Design

The main question that this study aims to answer is 'What components of critical thinking do national curricula of elementary science promote?' Critical thinking is crucial in science teaching. This can be achieved with the focus on relevant skills (Ennis, 2018; Pithers & Soden, 2000; Santos Menesses, 2020). Educators need the appropriate support to carry out the practices that will help learners apply critical thinking skills. This support should include relevant teaching materials, such as the curriculum. Indeed, the science curriculum can significantly influence the general outcome of teaching. This means that if teachers want to achieve developing critical thinkers, through the science sessions, the curriculum and its' goals should assist in that direction (Harlen, 2010; Santos, 2017; Santos Menesses, 2020).

Vieira and Tenreiro-Vieira (2016) have researched what reforms have been made in the curricula of several countries, in order to promote critical thinking in science. They concluded that, in these country's critical thinking was related with various dimensions. The first was the ability to learn through inquiry and problem solving. The second was to integrate and use knowledge, while making decisions about everyday life topics or challenges. The third was to evaluate the validity of knowledge or scientific findings. Science subjects are considered a valuable means for learners to develop critical thinking skills, which they can apply to their daily lives as responsible citizens.

Similarly, Osborne (2014), after researching science teaching policies and directions, as they are set in specific countries, has pointed out three basic 'spheres' that critical thinking in science teaching has. The first sphere is investigation, which includes focus on the real world, by observation, data collection, measurement, experimentation and testing. The second sphere is evaluation, which is based on argument and critique mainly with the help of dialogue and discourse. The third sphere is development of explanations and solutions. Explanation development is based on theories and models, which are approached by creative thinking, reasoning, calculating and planning. Solution development is based on hypothesizing.

Simultaneously, OECD (2013), within the program for international student assessment (PISA), defines three basic component or 'competencies' of critical thinking that can help learners become scientifically literate. The first competency is explanation of phenomena. This explanation though, should not be restricted in memorizing and recalling concepts, theories or information. It should be linked with knowledge surrounding how these concepts and theories were developed and why they are considered accurate and correct. The second competency is design and evaluation of scientific inquiry. This implies that learners should appreciate the role of science as means to understanding the natural world, the intervention of people in it and decide appropriately. Aside that, it implies that learners should familiarize deeper on what scientific knowledge really is. The third competency is the ability to analyze and interpret scientific data and evidence accurately. This suggests that learners need to recognize the importance of specific criteria when analyzing data.

In fact, there are commonalities in the national and international efforts to establish effective practices for science teachers to develop critical thinking skills in their students. These common points include placing emphasis on inquiry, judgement, evaluation of knowledge, and integrating with everyday issues, all of which align with the skills outlined in the Ennis'(1993, 2018) model.

Data Collection

The research data was obtained from the curricula of different countries or states that were collected. The curricula of 17 different countries or states were specifically collected and analyzed. These were Australia; Ontario, Canada; Quebec, Canada; Cyprus; France; Greece; India; Ireland; Malta; Nepal; New Zealand; Norway; South Africa; Sweden; United States and England. The selection of these curricula was based on certain criteria, such as availability and accessibility. The research analyzed primary science curricula that were available for free online access. The type of research is a content analysis study (Cohen et al., 2017).

The analysis utilized the Ennis (1993) model of critical thinking skills and competencies, which were categorized into groups and types based on the model's structure. The collected curricula were examined to determine if they included any references to the categorized groups and types of critical thinking skills and competencies. The first group examined was skills regarding basic clarification. This included three different types of skills. The first were skills for identifying or stating a research question. The second were skills about understanding arguments. The third were data interpretation from graphs, text, and figures (Ennis, 2018; Forawi, 2016; Santos Menesses, 2020).

The second group were skills about decision. This included three types of skills. The first was about making judgements about the accuracy and validity of data or information. The second was about connecting to previous knowledge. The third was about making decisions (Ennis, 2018; Pithers & Soden, 2000; Sterberg, 1987).

The third group was inference. This included two different skills. The first was about deduction, which relies mostly on analyzing and explaining information. The third was about induction, which relies mostly on hypothesis testing and generalization (Ennis, 2018; Pithers & Soden, 2000; Santos Menesses, 2020).

The fourth group were the skills of advanced clarification. This included three different kinds of skills. The first was skills about definition and its' form, which has to do with clarifying a definition in several ways, such as explanations or examples, or describing what a definition should be like. The second was skills about content, which has to do with the description of a concept or theory, again with the help of examples or by applying it in actual situations. The third was the skills referring to unstated or unjustified assumptions. Those skills relate to the way that learners deal with falsely supported arguments or pseudoscience (Ennis, 2018; Forawi, 2016; Santos Menesses, 2020).

Finally, the fifth group were the supplementary, auxiliary skills. This included four different kinds of skills. The first is integration skills, which refer to the way learners combine concepts, knowledge and parts of science with other subjects (Ennis, 2018; Vieira &Tenreiro-Vieira, 2016). The second was metacognition, which refer to the way learners monitor how their knowledge and ideas changed from the beginning of an intervention until its' completion (Ennis, 2018; Pithers & Soden, 2000; Santos Menesses, 2020). The third was problem solving skills, which refer to the way learners respond when exposed to a challenging situation in which they have to plan a solution, execute it, and come up with conclusions or decisions (Ennis, 2018; Schmaltz et al., 2017). The fourth group is rhetoric skills, which refer to the way learners justify or negotiate a point, a conclusion or an argument (Ennis, 2018; Forawi, 2016; Santos Menesses, 2020).

So, the curricula of the countries were checked to see which of these groups and types of skills they included. Afterwards, the absolute frequency reflecting how many times, totally, each group and type of skills was identified, was measured. The frequencies were analyzed to identify how critical thinking and its components are addressed in contemporary science curricula. Based on previous research related to this topic, it can be inferred that encountering such skills is to be expected (OECD, 2013; Osborne, 2014; Vieira & Tenreiro-Vieira, 2016).

Classification will take into consideration the actual meaning and rational of each skill. This will help the classification of skills, whenever the distinction is not very clear. Some of the skills might be or sound similar. In these circumstances, the classification of the skill, would take into consideration the deeper meaning or goal of it. The skill would be included in the group that includes skills of such goal or rationale. For example, there were skills relevant to decisions in the homonymous group and in the auxiliary skills as part of problem solving. In that case, if decision was encountered as sole task or skill, it would be classified under the decision group. Otherwise, if it was part of a greater task that also included planning or executing, it would be classified under problem solving in the group of auxiliary skills. Similarly, there were skills about judging arguments in basic and advanced clarification. If these skills addressed simple, separate, explanations, they would be classified as basic clarification. On the other hand, if they addressed complex discourse, where argument would go into deeper analysis, such as to reject a false argument, then it would be classified as advanced qualification (Ennis, 1993, 2018).

FINDINGS AND RESULTS

In summary, the study's results indicate that the analyzed primary science national curricula uphold the main competencies that Ennis (1993, 2018) identifies as constituting critical thinking. Throughout these curricula, it was clear that critical thinking had a significant role in the teaching of science and vice versa, as seen in **Table 1**.

Table 1. Absolute & relevant frequencies of critical thinking components, as found in the curricula

Group & competencies	Absolute frequencies	Relevant frequencies
GROUP 1: BASIC CLARIFICATION	17	100.00%
Identifying or stating a research question	14	82.35%
Understanding arguments	12	70.59%
Understanding data	13	76.47%
GROUP 2: DECISION	17	100.00%
Making judgements about accuracy	15	88.24%
Connecting to previous knowledge	12	70.59%
Making decisions	14	82.35%
GROUP 3: INFERENCE	16	94.12%
Deduction	13	76.47%
Induction	13	76.47%
GROUP 4: ADVANCED CLARIFICATION	14	82.35%
Definition	12	70.59%
Content	11	64.71%
Unjustified assumptions	4	23.53%
GROUP 5: SUPPLEMENTARY & AUXILIARY SKILLS	16	94.12%
Integration	14	82.35%
Metacognition	8	47.06%
Problem-solving	12	70.59%
Rhetoric	15	88.24%

Components of critical thinking were stated as important in learning science and were expected to be used in several parts or activities. Simultaneously, science sessions were expected to promote and further develop such components. Therefore, there is a mutual, interactive relationship. This certainly can assist educators in their interventions (Harlen, 2010; Santos, 2017; Santos Menesses, 2020).

Basic clarification competencies were mentioned in all curricula. There was clear mentioning about the necessity for learners to precise, identify and express questions that can lead to scientific inquiry and knowledge. Frequently included relevant goals, which for instance expressed that science teaching, should help learners '*develop the ability to make inquiries about science and solve problems*'. Understanding arguments and data were also mentioned as an important ability in most curricula.

Several curricula made mention of goals such as '*evaluating claims*' or '*developing evidence based arguments*'. In particular, there was a statement that science teaching should focus on thinking and investigation development by motivating learners to make '*use of initiating and planning skills and strategies (e.g., formulating questions, identifying the problem, developing hypotheses, scheduling, selecting strategies and resources, developing plans)*'. These goals were directly and clearly linked to the idea of promoting inquiry-based learning in science. This involved learners' active participation in the learning process with the help of hands-on activities. In other words, the expectation is for learners to engage in hands-on learning experiences, as long as they have a defined question or topic to guide and focus their efforts. This way they can use and develop critical thinking (Ennis, 2018; Forawi, 2016; Pithers & Soden, 2000; Santos Menesses, 2020).

Similarly, decision competencies were frequently mentioned in the curricula. This was also linked to inquiry-based teaching. In particular, there was a goal in a science teaching guide, which explained that learners must become capable of '*proposing courses of practical action to deal with problems relating to science, technology, society, and the environment*'. Other curricula included goals, which also clearly implied the importance of making decisions such as '*… emerge, established ideas must be scrutinized and criticized by using theories, methods, arguments, experiences and evidence*'.

These objectives underscore the significance of appraising judgments, ideas, or statements within discourse, linking them with prior knowledge from science or other subjects, in order to make informed decisions. This decision is expected to be justified on actual knowledge or data, after the appropriate dialogue or questioning. The decision is also expected to provide a solution around a topic, which is relevant to the learners' experience or everyday life. The relevant goals also emphasize the importance of giving learners the opportunity to think, express themselves and not be restricted in memorizing and recalling theories, laws, statements with no understanding about their rationale (Ennis, 2018; Pithers & Soden, 2000; Sterberg, 1987).

With regard to inference abilities, it was found that the curricula pay attention to them as well. Deduction and generalization were mentioned as a main goal of science, as seen in quotes such as '*The science curriculum should enable children to … observe, ask questions, discern patterns, hypothesize, plan, experiment, design, make, measure, discuss, analyze and evaluate results and so develop a scientific approach …* This statement highlights the significance of learners developing proficiency in data collection, analysis, generalization, and statement formulation, enabling them to reflect on scientific discoveries and improve their quality of life. The fact that in certain curricula, such goals are pointed in the beginning, could signify the unique and fundamental relationship that science is thought to have with generalizations (Ennis, 2018; Pithers & Soden, 2000; Santos Menesses, 2020).

Induction is mentioned in most curricula, too. This is reflected in relevant goals such as [to] '*interpret information and offer explanations*' or [to] '*draw conclusions from suitable aspects of the evidence collected*'. In relation to that, certain curricula emphasize on the importance of science as a subject in which learners can make models described as a significant aspect of the scientists work and life. Overall, inference abilities in science are associated with giving explanations and using them to explain or predict the development of phenomena. This is associated with adopting appropriate thinking from the side of the learners (Ennis, 2018; Pithers & Soden, 2000; Santos Menesses, 2020; Snyder & Snyder, 2008).

Advanced clarification competencies are also mentioned in various curricula, though not all. Competencies about providing definition are rather common, as justified in mentions, as [learners are expected to gain] … '*Knowledge and understanding knowledge of content (e.g., facts; terminology; definitions; safe use of tools, equipment, and materials) understanding of content (e.g., concepts, ideas, theories, principles, procedures, processes).*' This reflects the necessity for learners to become familiar with scientific knowledge, theories, laws, concepts and definitions, which should have clear and understandable meaning and validity for them. In that context, it is also important for them to understand how this knowledge is constructed (Ennis, 2018; Forawi, 2016; Santos Menesses, 2020).

Only a certain number of curricula though, seem to emphasize on the importance of consent and unjustified assumptions, at least in a direct and straightforward statement. Certainly, the need for learners to justify an assumption is frequently mentioned. For example, there are goals such as '*Putting forward logical scientific argument*,' or '*use of critical/creative thinking processes, skills, and strategies (e.g., analyzing, interpreting, problem solving, evaluating, forming and justifying conclusions on the basis of evidence)*', which relates indirectly to rejecting false arguments or statements (Santos, 2017). The fact that these competencies are not directly mentioned might be attributed to the belief that learners can develop them, as a result of clarification, decision and inference skills, which is logical for the achievement of advanced clarification. This could be achieved since learners will become familiar with engaging in scientific discourse within which statements should be evaluated, justified against data and findings, accepted or rejected(Ennis, 2018; Forawi, 2016; Santos, 2017; Santos Menesses, 2020).

The same applied for the auxiliary skills. Most curricula referred to competencies that fall under this category. However, there were categories that did not seem to be mentioned, candidly and plainly. Certainly, there was adequate reference to skills of integration. It was common to come across goals such as '*To relate science and technology to society and the environment*' or '*Interdisciplinary topics, sustainable development, democracy and human rights.*'

In fact, certain curricula made extended reference to the issue of integration, claiming that learners need to know how to relate the knowledge of science to other areas, such as mathematics, geography, technology and environment, so that they can apply it whenever required. This finding is in accordance with the main idea around critical thinking through integration within the context of projects around everyday life (Ennis, 2018; Vieira & Tenreiro-Vieira, 2016).

A skill that was mentioned less frequently, in comparison with the rest was metacognition. There were curricula that mentioned it and pointed out its importance in science, either directly or with goals such as [science teaching aims at] '*reflecting on investigations, identifying what went well, what was difficult or did not work so well, and how well the investigation helped answer the question*'. This reflecting skill addresses what learners need to have in order to understand how their knowledge, skills and attitudes changed during a teaching intervention. It is highly linked to inquiry-based activities, as metacognition within the prism of critical thinking should be (Ennis, 2018; Pithers & Soden, 2000; Santos Menesses, 2020). Perhaps, the reason why other curricula do not mention it might be because it is considered as part of other skills included in them, as a result of the complexity of critical thinking concept (Snyder & Snyder, 2008).

Problem-solving is disclosed in almost all curricula. It is quoted as a major part of science subject, and it is associated with real life context and challenges. This can be proved with goals such as '[science aims to ensure that students develop] *an ability to solve problems and make informed, evidence-based decisions about current and future applications of science while taking into account ethical and social implications of decisions.*' Likewise, there is a number of curricula that link problem solving to model designing. Such goals underline that through science, learners must gain skills that help them surpass simple knowledge memorizing. Learners should instead use knowledge in a critical and creative way. This fits the skills of critical thinking (Ennis, 2018; Schmaltz et al., 2017).

Lastly, rhetoric skills are acknowledged in the curricula as important. This is realized in goals such as '*using appropriate vocabulary, communicating findings in a variety of ways*', or '*discuss, listen, ask questions as well as express their own thoughts, opinions and arguments in different areas, such as aesthetic issues and ordinary events.*' The objectives aim to demonstrate that science education enables learners to participate in tasks, dialogues, and discourses, where they can present, evaluate and justify scientific ideas and findings. They are associated with using language and other means for science oriented dissemination, which is a rhetoric skill of critical thinkers (Ennis, 2018; Forawi, 2016; Santos Menesses, 2020).

In summary, the curricula studied linked critical thinking with science teaching. Critical thinking itself was mentioned multiple times, as foundational goal. There were mentionings such as '*teaching should contribute to pupils developing their critical thinking over their own results, the arguments of others and different sources of information.* 'This finding is compatible to the general theoretical approach of science education (Harlen, 2010; Santos, 2017; Santos Menesses, 2020).

DISCUSSION

The components of Ennis (1993, 2018) were found in most curricula. Basic clarification competencies were found, as most curricula seem to emphasize the importance of identifying research questions, understanding data or arguments. This was expected to contribute and benefit from appropriate teaching approaches, which are inquiry oriented. The expectation is for learners to critically construct knowledge by pursuing particular scientific concepts or phenomena through a specific question or inquiry. These are the elements of basic clarification (Ennis, 2018; Forawi, 2016; Santos Menesses, 2020).

Decision competencies exist as well. Indeed, the curricula stress the need for learners to become familiar with making judgements about the accuracy of a statement, idea or finding. Additionally, emphasis is placed on learners acquiring the skill to connect previously gained knowledge with knowledge they are currently acquiring during any given session. Lastly, learners should be capable of using knowledge in order to make decisions about phenomena. These are the elements of decision (Ennis, 2018; Pithers & Soden, 2000; Sterberg, 1987).

Inference competencies are mentioned in the curricula as well. Learners' ability to generalize and apply deductive reasoning is frequently reported, as a basis for learners to gain, appreciate and apply knowledge and science findings. In relation to that, it is mentioned that learners should hypothesize, test their hypothesis and clarify basic characteristics of knowledge and hypotheses as well. Curricula, therefore, mention goals about deductive and deductive skills, which compose inference competencies (Ennis, 2018; Pithers & Soden, 2000; Santos Menesses, 2020).

Advanced clarification competencies are identified too. According to the curricula, learners are expected to be proficient in utilizing definitions and comprehending their properties. Similarly, learners should be capable to dealing with, and analyzing content. This way, they will not be restricted to memorizing knowledge and treating it simply as a sum of irrelevant information. Although, the number of curricula that stress the importance for learners to deal with issues such as pseudoscience is limited. However, through a broad perspective, curricula include competencies regarding definition and content, which are classified as advanced clarification competencies (Ennis, 2018; Pithers & Soden, 2000; Santos Menesses, 2020).

Similar is the case with auxiliary competencies. A considerable number of curricula point out that learners should engage in integrating activities. Metacognitive skills are also included, though in a smaller number, comparatively. Problem solving is mentioned in several curricula, too. Finally, it is reported that learners should become competent in rhetorical skills and use of language. As clarified, these skills are promoted within the idea of giving learners a general perspective of science and its' nature, which is helpful for critical thinking (Ennis, 2018; Forawi, 2016; Santos Menesses, 2020).

CONCLUSIONS

The objective of this study is to specify the approach that curricula take towards promoting critical thinking in science education. Over the last decades, critical thinking has gained interest in studies around research in education and science education. It is considered a basic goal of teaching, as it can help learners deepen their understanding of knowledge and apply it in decision making and problem-solving processes. Thanks to this approach, learners can better grasp the importance of science as a subject and use it appropriately in various aspects of their lives (Byrne & Johnstone, 1987; Harlen, 2010; Jones et al., 2012; Vieira &Tenreiro-Vieira, 2016).

Defining critical thinking is not easy. The reason is the complexity of this concept. Similarly challenging is identifying the characteristics of an individual with advanced critical thinking abilities and determining what schools and educators should prioritize in promoting these skills. Teachers need to adopt appropriate practices and aims. Theorists and researchers in science education claim that the pertinent approach to critical thinking is by engaging learners in active, inquiry-based intervention. This way, they participate in teaching, with hands-on activities and discourse, where they construct new knowledge and use it to understand and contribute to everyday life topics (Forawi, 2016; Santos, 2017; Santos Menesses, 2020).

Ennis (1993, 2018) has proposed a model to specify what critical thinking is composed of. According to this model, a critical thinker demonstrates a set of competencies, which are arranged in five categories. These are: basic clarification; decision; inference, advanced clarification; and auxiliary skills. Each of these groups includes two or more competencies. These competencies are compatible with skills used and promoted in inquiry-based science teaching activities (Santos, 2017; Santos Menesses, 2020). In order to foster these competencies in their teaching, teachers require appropriate materials, such as curricula (Ennis, 2018; Pithers & Soden, 2000; Santos Menesses, 2020). Similar conclusions were drawn from research studies that examine science textbooks and their potential to promote critical thinking (Mai et al., 2019; Muntaha et al., 2021).

This research, therefore, examines whether national curricula of science include these competencies. The curricula of seventeen different countries were collected and analyzed, through a content analysis approach (Cohen et al., 2017). The findings showed that generally, the curricula mention all the groups of Ennis (1993, 2018) model. There is a differentiation on specific competencies though. Certain competencies such as identifying or formulating questions, understanding data and rhetoric are very common. On the other hand, there were skills such as treating unjustified assumptions statements or metacognition mentioned in few curricula among those studied. This might be attributed to differentiation in treating the term critical thinking, due to its' complexity (Snyder & Snyder, 2008).

Recommendations

It would be interesting if further similar research is carried out in future, which might be able to examine a larger sample of national curricula. Conducting more in-depth research into various curricula, including their development, implementation, and perception among policymakers and teachers, could also be insightful. This would be particularly relevant since curricula may have been designed in different time periods and under varying national contexts (OECD, 2013). Such research can strengthen the accuracy of findings and assist generalization (Cohen et al., 2017).

Limitations

Prior to generalizing the conclusions stated, it is important to stress that the study focused on content analysis of certain curricula, which are available online. This sample proved that the model of Ennis (1993, 2018) is overall applied in the curricula studied and can therefore be used as a guide to approach critical thinking in science curricula and science education research.

Funding: The author received no financial support for the research and/or authorship of this article.

Acknowledgments: The author would like to thank Pedagogic Department of Elementary Education, University of the Aegean, for their assistance.

Ethics declaration: Author declared that the highest ethical principles are followed during the study.

Declaration of interest: The author declares no competing interest.

Data availability: Data generated or analyzed during this study are available from the author on request.

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