

# Perceptions on Critical Thinking Attributes of Science Education Standards

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**Abstract.** Science teachers can make classroom learning more meaningful by incorporating critical thinking skills into their instruction. This study aimed to assess and identify the science content objectives that require critical thinking abilities as perceived by pre-service teachers. Sample of 120 pre-service teachers participated in the study by examining science education standards of K-12 curriculum using the Critical Thinking Attribute Survey (CTAS) originally developed and validated by the authors. Results of the study identified those standards and activities of science curriculum that were thought to have critical thinking. The process-oriented standards, i.e. the inquiry, nature of science, technology and personal & society perspectives had the highest means than the content standard, life, physical and earth. Interviews, supported the statistical analyses that the science inquiry standard was seen to provide an open-ended, high cognitive skill require of students. Specific examples of activities were presented to support findings along with teacher education and K-12 instruction implications.

**Keywords:** critical thinking attributes, science education standards, pre-service teachers.

## 1. Introduction

The development of critical thinking is regarded as one of the most essential objectives of science education for more than a century. Terms such as *higher level thinking* and *reflective thinking* have often been confused and used interchangeably with the term *critical thinking* throughout the literature [1]; [2]; [3]. However, while there are many definitions of the term *critical thinking* for the purposes of this study, [4]'s critical thinking definition is used-“the art of thinking about thinking in an intellectually disciplined manner.” According to Paul, this type of thinking involves three essential components, (1) analyzing (2) assessing and (3) improving. As one embarks on the process of analyzing and assessing, thinking is taken to more critical levels or thinking is made better. This involves the notion of imposing intellectual standards and restraint on ones thinking [1].

Evidence for the provision of opportunity to acquire such intellectual skills has been rare and research data not encouraging [5]; [6]; [7]. The emphasis of thinking in science curriculum had a long history. [8] stated that problem solving through reflective thinking should be both the method and valued outcome of science instruction. This is not surprising if one accepts the statement by [7] that distinguishing between the science-based information and everything else that contributes to decision-making process is a complex process. Recently, [9] stated positive attitudes of elementary science teachers toward developing critical thinking skills with use of ICT. Also, [10] found that students in PLTL, one of the very effective STEM undergraduate programs that involves peer leaders teaching and learning in small group dynamics, showed small but significantly greater critical thinking gains than non-PLTL students in science but not in math groups. This finding encourages more research to be conducted on this topic, particularly to further investigate critical thinking skills related to science curriculum. In our previous research studies, [11] and [12], we found that process skills and integrated inquiry instruction for example were common science buzzwords linked to new science curriculum and development of critical thinking. [13] described how scientists view working with science teachers and educators in a manner that developed critical thinking and reasoning. To additionally support the importance of the nature of the subject matter that is used to develop these high order thinking skills. Therefore, the main purpose of this study was to investigate the ability of

pre-service teachers to identify and assess critical thinking attributes of the United States' national science education standards. The study also reported those activities of science national education standards that relate to critical thinking.

## 2. Methods

One hundred twenty pre-service teachers who were in their senior year in a US Midwestern university participated. The students were part of an NCATE accredited teacher education program for both graduate and undergraduate. Seventy four were female (62%) and forty six were male (38%) which seemed representative of teacher education programs in this region.

This study aimed to identify the science content standards and objectives that require critical thinking from pre-service teachers' perspective. The science content standards, referred to here, are part of the national science education standards (NSES) developed by the United States' National Research Council [14] for kindergarten to grade 12's science curriculum. The standards outline what students should know, understand, and be able to do in natural science at k-12 levels. The content standards- Science as Inquiry, Physical Science, Life Science, Earth and Space Science, Science and Technology, Science in Personal and Social Perspectives, History and Nature of Science- are a complete set of outcomes for students to attain. Therefore, it is important for teachers (pre- and in- service) to be familiar with them as curricular guidelines that do not prescribe a full curriculum. These content standards were designed and developed as one component of the comprehensive vision of science education in the US and they will be most effective when used in conjunction with all of the other standards.

### 2.1. Critical Thinking Attribute Survey (CTAS)

A set of the Critical Thinking Attribute Survey (CTAS) was developed and validated by [15]. The major premise of the CTAS rests on the understanding of critical thinking as a process of evaluating ideas and investigations. More specifically, the CTAS tests the accuracy of statements and the soundness of reasoning that leads to conclusions and interpretation of results. The CTAS encompasses ten major attributes, thinking independently and suspending of judgment or prior conceptions; utilizing various processes to resolve; re-address and re-analyze complex situations to gain new insight; developing and using valid criteria for evaluation; raising and pursuing significant questions; generating and assessing solution; and making interdisciplinary connections to everyday life. Cronbach's [16] alpha internal consistency coefficient for the CTAS was 0.73.

## 3. Data Analysis and Findings

The main results identified the national science education standards that exhibit critical thinking attributes. The total checks of participants for each standard was collated and recorded. The national science standards that marked as high, more than 50% of total responses, on critical thinking attributes included four science content standards: Inquiry; History and the Nature of Science; Science in Personal and Social Perspectives; and Science and Technology. These four science content standards were prescribed with their activities to mainly provide science processes and skills via delivering content. The objectives of the process standards tend to be more investigative and open-ended. The majority of their activities lacked critical thinking representations. Participants indicated low response regarding the benchmarks and the examples of science activities presented with each of the content science standards, as in Table 1 below.

Table 1. Summary of means, S.D., and ranges of pre-service teachers' responses of the NSES based the Critical Thinking Attribute Survey (N=120).

Standard	N (#checked)	# Benchmarks	Mean
Unifying	635	5	9.092
Inquiry	995	6	13.820
Physical	225	11	3.125
Life	388	13	3.388

Earth	321	9	4.458
Technology	644	7	8.944
Personal	732	12	10.166
NOS	804	7	11.194
Total	4109	70	7.870

Each of the eight standards subsumes the knowledge and skills of other standards. Students' understandings and abilities are grounded in the experience of inquiry, and inquiry is the foundation for the development of understandings and abilities of the other content standards. The personal and social aspects of science are emphasized increasingly in the progression from science as inquiry standards to the history and nature of science standards. Students need solid knowledge and understanding in physical, life, and earth and space science if they are to apply science. Multidisciplinary perspectives also increase from the subject-matter standards to the standard on the history and nature of science, providing many opportunities for integrated approaches to science teaching. The Unifying Concepts and Process Standard identify the conceptual and procedural schemes unify science disciplines and provide students with powerful ideas to help them understand the natural world.

Several standards and benchmarks were assessed by pre-service teachers as requiring critical thinking skills while others were regarded as lacking critical thinking attributes. Pre-service teachers perceived (Table 1) the objectives of the 'inquiry standard' to be most closely related to critical thinking as identify by Critical Thinking Attribute Survey (CTAS) with the highest mean of 13.820. It was followed by the other process standards which are perceived to be related to critical thinking with high means- the 'history and nature of science' (11.194), the 'personal and social perspective' (10.166), the 'unifying concepts and processes' 9.092, and the 'Science & Technology (8.944), respectively. The traditional standards, the content standards had the lowest means- earth 4.458), life (3.388), and physical sciences (3.125)- exhibited the least objectives with critical thinking attributes according to the CTAS instrument.

Table 2: Ten most often checked benchmarks in descending order

Benchmark	N	Min	Max	X
12. Abilities necessary to do scientific inquiry.	6.00	2.00	10.00	5.50
9. Understandings about scientific inquiry.	7.00	1.00	10.00	5.14
97. Personal and community health.	1.00	5.00	5.00	5.00
88. Abilities of technological design	1.00	5.00	5.00	5.00
130. Historical perspectives	13.00	1.00	10.00	5.00
113. Science and technology in local, national, and global challenges	7.00	1.00	10.00	5.00
124. Science as a human endeavor	11.00	1.00	10.00	4.82
101. Science and technology in local, national, and global challenges	5.00	3.00	10.00	4.80
128. Nature of science	6.00	1.00	10.00	4.67
41. Interactions of energy and matter	7.00	1.00	10.00	4.57

Table 3. Five least checked benchmarks

Benchmark	N	Min	Max	X
45. Properties and changes of properties in matter	5	1	3	1.8
52. Transfer of energy	5	1	3	1.8
61. Structure and properties of matter	5	1	1	1
101. Characteristics of organisms	5	1	1	1
120. Objects in the sky	5	0	0	0

#### 4. Conclusions and Implications

Developing national standards is an important and complex undertaking. Yet, once these standards are developed, they do not immediately impact policy and practice [17]. National curricula are also significant and of great magnitude that should be carefully prescribed. Actions by many individuals and institutions are needed if meaningful and lasting changes are to occur in a system. This study aimed to identify those science content objectives that require critical thinking from the pre-service teachers' perspective. Participants of the

present study developed a discourse and familiarized themselves with an instrument that measures critical thinking aspects of national science standards and their curricular activities. Findings of this study may advance research of pre-service teachers' perceptions and ability to identify critical thinking attributes related to science education curriculum and standards. Process standards, i.e., inquiry, history and nature of science, technology and personal and social perspective and their activities perceived to have more attributes of critical thinking. That the content standards. Pre-service and in-service science teachers often focus teaching on content knowledge as traditional science curriculum do.

Developing standards is not a trivial task, therefore, development of all subject standards and their activities should be regarded as important task as well that requires input from all experts, especially in connecting them to higher cognitive skills.

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