IOWA STATE UNIVERSITY
Digital Repository

Graduate Theses and Dissertations

Iowa State University Capstones, Theses and Dissertations

2017

Assessment of critical thinking skills in undergraduate animal science students and curriculum

Sarah Al-Mazroa
Iowa State University

Follow this and additional works at: https://lib.dr.iastate.edu/etd

 Part of the Agricultural Education Commons

Recommended Citation
Al-Mazroa, Sarah, "Assessment of critical thinking skills in undergraduate animal science students and curriculum" (2017). *Graduate Theses and Dissertations*. 16067.
https://lib.dr.iastate.edu/etd/16067

This Thesis is brought to you for free and open access by the Iowa State University Capstones, Theses and Dissertations at Iowa State University Digital Repository. It has been accepted for inclusion in Graduate Theses and Dissertations by an authorized administrator of Iowa State University Digital Repository. For more information, please contact digirep@iastate.edu.

Assessment of critical thinking skills in undergraduate animal science students and curriculum

by

Sarah Al-Mazroa

A thesis submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Agricultural Education

Program of Study Committee:
Michael Retallick, Major Professor
Brad Skaar
Gregory Miller

The student author, whose presentation of the scholarship herein was approved by the program of study committee, is solely responsible for the content of this thesis. The Graduate College will ensure this thesis is globally accessible and will not permit alterations after a degree is conferred.

Iowa State University

Ames, Iowa

2017

Copyright © Sarah Al-Mazroa, 2017. All rights reserved.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Page

Chapter Four

Chapter Five

ACKNOWLEDGMENTS

There are many individuals who I will forever be grateful to that provided continuous support during this adventure at Iowa State University. Without their amazing support, I would not have been able to grow and gain the knowledge and skills to become the person I am today.

To my major professor, Dr. Michael Retallick for his dedication and continuous support throughout this journey. Dr.Retallick, your dedication to my success, mentorship, and encouragement truly made me push past my doubts to succeed. I am ever so grateful to you for opening my eyes to different opportunities within agricultural education.

To my committee members Dr. Brad Skaar and Dr. Greg Miller. Thank you for your commitment to my overall success. Dr. Brad Skaar, thank you for taking me under your wing and allowing me to teach alongside you and apply the skills I was learning in my coursework in your classes. Your dedication to your students is overwhelmingly amazing and I will be ever grateful for your guidance. Thank you once again for all of the coffee, beef cattle talks, and teaching brainstorming sessions. It has been quite the adventure and I know everything I have learned from my experiences, I will take with me wherever I may go. Dr. Greg Miller, thank you for making such a positive impact on my life during my first graduate course at Iowa State University. You opened my eyes to the endless possibilities for agricultural education research and sparked the interest I have today to continually do research to make a positive impact in agricultural education.

I would also like to acknowledge my work support system at the Jeff and Deb Hansen Agriculture Student Learning Center more specifically, Marshall Ruble and Rod Berryman. Both of you are so passionate about agriculture and the success of your student employees. It has been

an honor to work beside both of you. Thank you for pushing me in and outside the workplace and always supporting my academic endeavors and for being some of the best mentors I've had here at Iowa State University.

Finally, I must thank my family and friends for the endless support you've given me while I've been working towards my dreams. To my mother, who's always been the biggest supporter of my life. Thank you for never letting me quit when things got tough and reassured me that I could achieve anything I set my mind to. To my father, thank you for getting me involved in agriculture. If it wasn't for you, I wouldn't have found the industry I am most passionate about. Thank you both once again for always believing in me and cheering me on in any dream I set my mind to.

To my soon to be husband, Benjamin Smith. Thank you for the continuous support throughout my entire graduate program. The endless hours spent editing my papers, providing me coffee and all the encouraging words truly pushed me to achieve my goals. I am forever indebted to your selfless acts of kindness and support.

"Because the greatest part of a journey isn't arriving at your destination. It's all the wild stuff that happens along the way."

ABSTRACT

The purpose of this thesis was to explore differences in critical thinking skills between freshmen and senior Animal Science Students at Iowa State University and determine where in the curriculum the critical thinking skills are being taught. This study encompassed 4 objectives: 1) compare freshmen and senior animal science students to the national critical thinking skill norms 2) determine if there's a difference between freshmen and senior animal science students in critical thinking 3) determine if there's a difference in critical thinking skills based upon selected demographics variables 4) map critical thinking skills instructional methods in core animal science courses.

For objectives one, two, and three a group of freshmen (n=55) and seniors (n=60) in the Department of Animal Science at Iowa State University were randomly selected to participate in taking the Critical Thinking Assessment Test (CAT) during the fall 2016 semester. The results were analyzed for comparisons with national norm scores, between each group, and based upon specific demographics.

For objective four, twelve of the core animal science courses were selected to be analyzed to determine where the critical thinking skills were being taught. Instructors of each course participated in a self-reporting interview to gather the information which skills were being taught and examples of each of the fifteen critical thinking skills described by the CAT Exam being implemented. From there, an analysis of how effective the methods were to teach critical thinking skills was conducted.

For objective one the freshman group scored better than the national norm with a $p< 0.05$, while the senior group scored less than the national norm $p <0.05$. In objective two the senior group scored significantly higher than the freshmen group $p<0.05$. Objective three results

showed no significant difference within gender, however there was a difference between freshmen males and senior females. Objective four, there was no consistency in teaching critical thinking skills within the curriculum.

Overall this study provides the Department of Animal Science at Iowa State University a better understanding of the level of critical thinking skills for each grade level and where the skills are being taught within the curriculum.

CHAPTER 1. INTRODUCTION

Higher order thinking has been the expectation of higher education. With the current desire for students being able to utilize critical thinking skills out in the industry, universities have to critically evaluate their curriculum to ensure the students are being given the chance to learn and exercise these skills (Wagner, 2008). These skills not only will impact students' experiences within formal education but also impact their personal development and career advancements within the industry. This chapter provides a background of critical thinking as applied in education and in agriculture and the needs of assessing students' critical thinking skills in higher education and where they can be developed throughout a curriculum.

Background and Setting

As the agriculture industry continues to evolve, students need not only technical skills but also skills to problem solve and critically think. Higher order cognitive skills such as critical thinking skills prepare students to make an impact in the industry as they can perform more complex tasks (Tsui, 2002). Throughout higher education programs, students should be able to develop specific skills to think critically which advances their ability to reason (Paul & Elder, 2006). By connecting the technical aspects of higher education to personal development skills, students will be able to analyze, assess, and improve their thinking skills (Paul & Elder, 2006). Critical thinking, as defined by Rudd, Baker and Hoover, is a reasoned, purposive, and introspective approach to solving problems or addressing questions with incomplete evidence and information for which an incontrovertible solution is unlikely (Rudd, Baker, & Hoover, 2000, p. 5). Critical thinking skills outcomes and individual processes are best assessed to be successful through individual educational assignments (Garrison, 2001).

Although learner centered teaching approaches can be beneficial to students' critical thinking skills, currently there are multiple debates over what are the best ways to effectively teach and exercise critical thinking skills (Perry, 2014). Instructors can teach these skills within the subject matter or the skill of critical thinking can be taught alone (Kuhn, 1999). The best method is to combine the approaches to incorporate critical thinking skills within the subject matter of the course while being open about teaching the skills (Burbach et al., 2012). Instructors must focus on analyzing the material of their course to see if they are actually putting methods in place to teach critical thinking skills (Perry, 2014).

The industry values critical thinking skills as they see a strong correlation between an individual who possess critical thinking skill and a positive relationship with their peers (Kegan, 1994). Not only can these individuals lead a group of their peers but they can also work through demanding situations in the work place (Kolb, 1984).

Today, employers and universities desire graduates who acquire critical thinking skills by the end of a higher education program (Association of American Colleges and Universities [AACU], 2004, 2007, 2010). Wanting these college graduates to have critical thinking skills, specific departments are now analyzing how they are teaching these skills. Colleges and universities see the importance in their setting when teaching students critical thinking skills as there's a direct correlation between critical thinking skills and advanced grade levels (Williams, et. al, 2003).

By identifying the need for graduates to obtain critical thinking skills, the Department of Animal Science at Iowa State University values the industry's desire for graduates with critical thinking skills. Within the Animal Science curriculum, one of the goals states that animal science students will develop problem solving skills during their time at Iowa State University

(E.Lonergan, Personal Communication, January 31, 2017). This goal consists of sub-goals that include a) students will be able to assess specific situations, b) gather information, c) identify sources for information needed, d) distinguish relevant from irrelevant information, and e) other critical thinking skills (E.Lonergan, Personal Communication, January 31, 2017).

In Fall 2013, the College of Agriculture and Life Sciences (CALS) Outcomes Assessment Committee required departments to assess their graduating seniors critical thinking skills as outlined within the department and college outcomes (Skaar, 2013). There are many different assessment tools to assess critical thinking skills, however the department utilized the Critical Thinking Assessment Test (CAT) developed by researchers at Tennessee Tech University (Skaar, 2013). This specific assessment of the seniors in the Department of Animal Science was led by Associate Professor of Animal Science, Dr. Brad Skaar.

After this study, Skaar concluded that animal science students in the fall of 2013 scored at the national peer average for the domains tested by the CAT exam (Skaar, 2013). One of the fifteen critical thinking skills assessed by CAT was significantly different than the national means. ISU Animal Science students score below national norm (1.03 versus 1.35 at $p< 0.05$) for Question 3, “provide alternative explanations for a pattern of results that has many causes” (Skaar, 2013). All the other questions and overall score were comparable to the national norm (Skaar, 2013). With the students scoring the same as the national norm, the department was unable to answer the CALS Assessment Committee question, “Seniors in your Department meet CALs problem solving/ critical thinking learning outcomes?” (Skaar, 2013).

Skaar’s study obtained a greater understanding of where the seniors from Iowa State University in Animal Science compare to other institutions. The specific comparisons of critical

thinking skills allow faculty in the department to understand what skills the students need more help developing.

Although Skaar's study was a good starting point, it didn't provide enough data to completely answer Iowa State University College of Agriculture and Life Sciences outcome questions. One question that was left unanswered after this study was, "What impact does the Department of Animal Science curriculum have on animal science student's critical thinking skills?" To more fully understand the impacts and answer this question, the department needs to study a group of freshmen and seniors along with the animal science courses to see if there is a change between the two groups of students and what activities instructors in animal science are performing (maybe incorporating) to enhance critical thinking skills.

Statement of the Problem

There are limited data collected that have analyzed the Department of Animal Science curriculum's impact on critical thinking skills. The department faces a problem as they do not fully know the impact that the curriculum has on students in the area of critical thinking skills. To fully understand the impact of a program on critical thinking skills, a comparison between two class standings must be evaluated. Along with an assessment of specific critical thinking skills students have, an examination of the core courses that they are taking is needed to map out where the skills are being taught throughout a student's time in the program.

Purpose and Objectives

The purpose of this study was to explore differences in critical thinking skills between freshmen and senior Animal Science students and determine where in the curriculum the critical thinking skills are taught. Four objectives guided this study:

1. Compare freshmen and senior Animal Science students to the national critical thinking skill norms
2. Determine if there's a difference between freshmen and senior Animal Science students in critical thinking
3. Determine if there's a difference in critical thinking skills based upon selected demographic variables
4. Map critical thinking skills instructional methods in core animal science courses

Significance of the Study

The results from this study will create foundational knowledge for the department to understand if there's a difference between the two groups of animal science students and where the instructors of core courses are reporting that they teach critical thinking skills. As a result of this process, faculty, staff and administrators will be able to understand the impact the current curriculum has on students' critical thinking skills. Additionally, this study will go deeper into the course work to analyze how the students are being assessed on critical thinking skills.

Definition of Selected Terms

1. Critical thinking- "a reasoned, purposive, and introspective approach to solving problems or addressing questions with incomplete evidence and information for which an incontrovertible solution is unlikely" (Rudd, Baker, & Hoover, 2000, p. 5).

2. Critical Thinking Assessment Test (CAT)- a fifteen- question, short answer assessment tool designed to assess a broad range of skills that are components of critical thinking and real- world problem solving (Center for Assessment and Improvement of Learning (CAIL), 2017).

CHAPTER 2. LITERATURE REVIEW

This chapter outlines the numerous definitions of critical thinking and how this study operationalizes critical thinking skills. In addition, this chapter will explore the foundations of curriculum mapping, review multiple assessment tools and develop an operational definition of critical thinking skills. From assessing critical thinking skills, we will also look at how an individual learns so that educators can utilize methods to teach and improve critical thinking skills.

Definition of Critical Thinking

When looking at critical thinking skills, one must understand what this specific skill can be defined as and how it can best be utilized in a learning environment. Critical thinking skills utilize higher order thinking from the individual (Rudd, Baker & Hoover, 2000). Higher order thinking and critical thinking skills are not equal to one another as the individual has to utilize the higher order thinking to be able to practice critical thinking skills (Rudd, Baker & Hoover, 2000).

Researchers have created and modified multiple definitions of critical thinking skills over the years. According to Paul (1995), critical thinking is the purposeful thinking process where the individual systematically imposes criteria and intellectual standards upon a thought. Pierce (2005) modified the definition of critical thinking as the "thinking that a discipline needed and relied upon by practitioners in that discipline- thinking that is accurate, relevant, reasonable and rigorous, whether it be analyzing, evaluating, supporting argument and hypotheses, solving problems, or making decisions"(p.81). As research continues to build upon the basic definition, the discipline of agricultural education utilizes the definition of critical thinking which describes the skill as "a reasoned, purposive and introspective approach to solving problems or addressing

questions with incomplete evidence and information for which an incontrovertible solution is unlikely" (Rudd, Baker & Hoover, 2000, p.5).

Critical thinking has been defined as "purposeful self-regulatory judgement" (Facione, 1997, p. 3) to "reasonable and reflective thinking that is focused on deciding what to believe or do" (Norris and Ennis, 1989, p. 3). According to Paul and Elder (2001), critical thinking is "the mode of thinking about a subject, content, or problem in which the thinker improves the quality of his or her thinking by skillfully taking charge of the structures inherent in thinking and imposing intellectual standards upon them" (p.xx). These definitions stem from a metacognitive approach. Metacognitive approach is a sense making, self-assessment, and reflection approach on what worked and what needs improving (Behavioral and Social Sciences and Education National Research Council, 2000). Learners exposed to this type of approach are able to predict their own performance on the task at hand, while monitoring their current levels of mastery and understanding (Behavioral and Social Sciences and Education National Research Council, 2000). From those definitions, critical thinking in general has four steps to achieving this higher order thinking skill. Learners must be exposed to a structured problem, assessment of thinking, learners' self-assessment of thinking, and improvements of the thinking (Broadbear, 2012). Researchers have deemed these steps essential to achieving critical thinking (Broadbear, 2012).

Conceptual Framework

Since individuals utilize higher order thinking to be able to practice critical thinking skills, literature has extensively used Bloom's Taxonomy. Bloom describes this hierarchical theory with six different levels (Fig. 2.1): evaluation, synthesis, analysis, application, comprehension, and knowledge (Bloom, 1956).

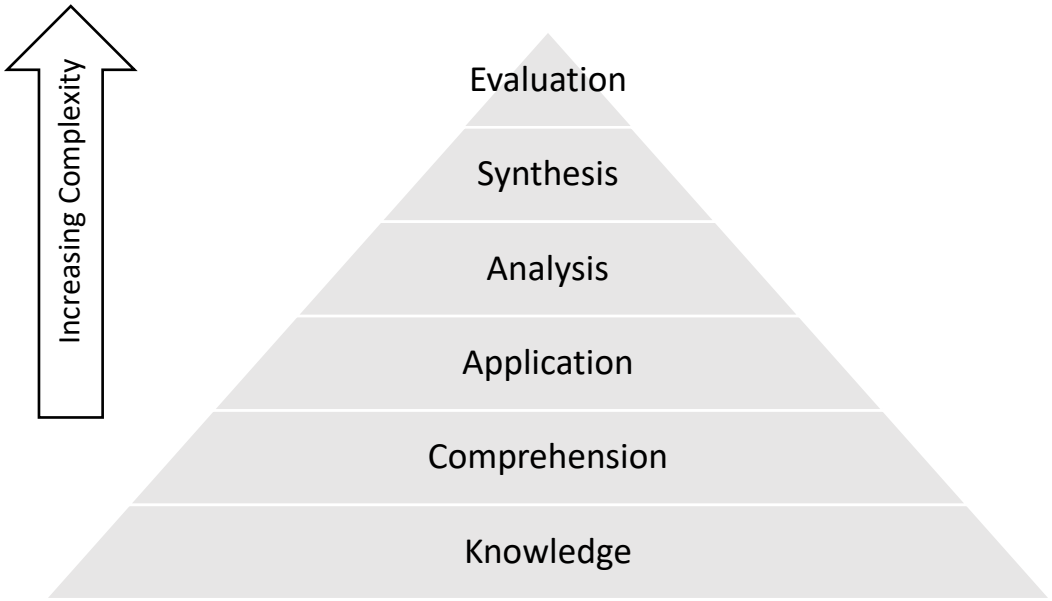


Figure 2.1. Bloom's Taxonomy. From Bloom,1956.

Bloom (1956) believed that to accomplish higher order thinking as one starts at the lowest complexity and moves to more complex thinking skills. *Knowledge* is the basis of cognitive skills and describes the individual's ability to retain specific pieces of information (Adams, 2015). Being able to recall facts and then being able to understand the meaning of that information is the difference between *knowledge* and the next step *comprehension* (Adams, 2015). Putting the *knowledge* into your own words shows the skill of *comprehension* and utilizes more cognitive skills. Climbing the pyramid of taxonomy, next is *application.* When experiencing this level of thinking, the individual can apply known strategies to new situations (Adams, 2015). The next level one enters is where the skills of thinking critical are put into practice (Adams, 2015). The ability to sort through relevant and irrelevant information and the ability to build an argument with supporting facts require the level of *analysis*. The fifth skill on the pyramid is *synthesis*. This skill allows the individual to create a product within a situation being faced (Adams, 2015). Lastly, the highest level on the Bloom's Taxonomy pyramid is

evaluation. *Evaluation* is the most complex trait within critical thinking (Adams, 2015). When an individual evaluates a situation, one must not only evaluate the situation on hand but also tie all elements of Bloom's Taxonomy such as knowledge or comprehension to have an effective evaluation (Adams, 2015). The ability to master higher order thinking, which Bloom describes in his taxonomy pyramid, is one of the most significant activities in life according to Brookfield (1987).

Anderson and Krathwohl revised the framework of the *Taxonomy of Educational Objectives* to a *Theory Into Practice* in 2001 (Anderson, Krathwohl, et al., 2001). Anderson and Krathwohl's theory has two parts the Knowledge Dimension and the Cognitive Process Dimension. Knowledge Dimension (Fig. 2.2) of Bloom's Revised Taxonomy consists of four parts: *Factual Knowledge, Conceptual Knowledge, Procedural Knowledge and Metacognitive Knowledge* (Krathwohl, 2002). *Factual Knowledge* is the basic element a student needs to obtain to understand a specific discipline or solve a problem (Krathwohl, 2002). Students are able to practice this step by learning terms or specific details and elements of a discipline. *Conceptual Knowledge* is the interrelationship between basic elements that make up a larger structure allowing them to work together (Krathwohl, 2002). Knowledge of categories, principles, theories, models, and structures allow one to be successful in this step (Krathwohl, 2002). One must contain the knowledge of specific skills and techniques in a subject area to act on *procedural knowledge* which is taking the skills one has and putting it into action (Krathwohl, 2002). Lastly, metacognitive *knowledge* is the knowledge of cognition in general along with the awareness of the individual's cognition (Krathwohl, 2002). Self and strategic knowledge are essential actions within this step (Krathwohl, 2002).

Knowledge Dimension
1) *Factual Knowledge*
2) *Conceptual Knowledge*
3) *Procedural Knowledge*
4) *Metacognitive Knowledge*

Figure 2.2. Knowledge Dimesion of the Revised Bloom's Taxonomy. From Krathwohl, 2002.

The second part of the Revised Bloom's Taxonomy is the Cognitive Process which is a six step process (Fig. 2.3). The first step is remember what an individual must retrieve relevant information from their long term memory (Krathwohl, 2002). Second, is determining the meaning of various types of communications which involves interpreting, classifying, summarizing, and explaining (Krathwohl, 2002). Third, apply allows one to carry out a procedure in a situation which they must execute or implement the knowledge they have (Krathwohl, 2002). Fourth step is to analyze the information by breaking it down into parts to see how things work amongst themselves to support the overall structure or purpose (Krathwohl, 2002). One might differentiate or organize pieces of information to achieve this step. Fifth, is the step of evaluating or making judgement based on a given criteria or standard by checking or critiquing what one has available to them (Krathwohl, 2002). Lastly, the sixth step is to create. This allows an individual to pull all the different elements together to produce an original product (Krathwohl, 2002).

Cognitive Process
1) Retrieve relevant information from long term memory
2) Determining the meaning of various types of communications
3) Execute procedure/ Implement information
4) Analyze the information
5) Evaluate or make judgement based on a given criteria
6) Gather different elements together to produce an original product

Figure 2.3. Cognitive Process of the Revised Bloom's Taxonomy. From Krathwohl, 2002.

Critical thinking skills embody the ideas that Bloom's Taxonomy describes from utilizing the individuals own beliefs, opinions, and judgement through the process of forming a solution for a situation on hand (Paul, 1985). Research supports the theory that to think critically is an essential skill to possess (Whittington and Stup, 1997). Application of theories behind higher order thinking and critical thinking is crucial to help make a positive impact on higher education.

One element often missing when teaching critical thinking skills is the overall approach to teaching these skills. Educators focus on infusing these skills into just a few activities in a course which is opposite of what it should be (Broadbear, 2012). To effectively teach these skills, educators must focus on integrating these skills within the curriculum, individual courses, and then the lesson plans to have critical thinking as the overall outcome when thinking about teaching and learning (Broadbear, 2012; Swartz, 2000). Within different educational activities, students struggle with the self-assessment portion of critical thinking (Broadbear, 2012). If students aren't able to assess themselves, the ability to transfer that skill to perform other assessments will also be lacking (Broadbear, 2012).

Even though higher education understands the importance of higher order thinking, they haven't been able to keep up with utilizing new techniques to teach critical thinking skills (Fisher & Grant, 1983). In a study done by Fisher and Grant (1983), they found that most college

courses were primarily teaching at the lowest levels of cognitions from the level of course, subject area or even the time period spent on the specific topic. There has been a lack of research to fully understand critical thinking abilities within students (Rudd, Baker, & Hoover, 2000).

The importance of critical thinking has been seen throughout many disciplines not only within academia but also in the industry. Burris and Garton (2007), express that the ability to think critically is a way to find meaning in the world. Educators almost consistently believe that the development of critical thinking skills should be the main focus, goals and objectives within education (Pithers & Soden, 2000). Coming together as educators with one important goal in mind is the first step to incorporate the practice and development of critical thinking skills throughout curriculums across disciplines. To change how learners exercise and develop critical thinking requires educators to incorporate a problem-solving environment while providing learners with the opportunity to analyze information and practice effective oral and written communication (Wagner, 2008).

Critical thinking has always been important within education. Lancelot (1929) observed that an individual's knowledge and thinking ability were essential for that individual to function effectively and successfully in the science and technology field. Lancelot (1929) associated the success of the individual with their ability to solve problems everyday while applying general thinking skills. There have been many advances in the agriculture industry in regard to science and technology since Lancelot's era. Students are dealing with the continuous change of information and knowledge needed to succeed in the industry (Rollins, 1990) creating an even greater need to develop critical thinking skills.

The Secretary's Commission on Achieving Necessary Skills (1991) reported critical thinking, decision making, and problem solving skills as the highest workplace skills needed by employees. The interpersonal skills sought out by employers are skills that students are needing to learn within higher education (Scanlon, Bruening, & Cordero, 1996). Recent studies show that 75% of employers want colleges to place more emphasis on critical thinking skills and real world problem solving (AACU, 2013). These employers even believed that teaching these skills were more important than the technical information within a major (AACU, 2013). With critical thinking skills being the want and need of skills from the industry, it is important higher education provides opportunities for students to gain these skills to match what the industry is wanting their future employees to possess.

Curriculum Mapping

According to Higher Education Research Institute, over 99% of faculty across the United States deemed that critical thinking skills are "essential" or "very important" to teach in higher education curriculums (DeAngelo et al., 2009). Before one starts teaching critical thinking skills, a program must evaluate and identify exactly where in the curriculum the skills are taught. Just as Bloom's Taxonomy has six different-levels of cognitive thinking and an individual must master each level prior to moving to the next level, within a curriculum, there is a systematic way to coordinate courses to ensure that students are consistently being taught these skills. The way to accomplish this is to implement curriculum mapping.

Curriculum mapping allows instructors within a program to answer three important questions to see exactly where a specific skill is being taught (Jacobs, 2004).

1) Who is doing what?
2) How does the work align with the program's goals and outcomes?
3) Are we working efficiently and effectively?

Experts have seen that curriculum mapping not only allows a program to align the curriculum with the goals of the program but also allows collaboration between instructors within the mapping process (Uchiyama & Radin, 2009). Collaboration allows these instructors to bring their ideas and beliefs to the table to improve the teaching and learning process (Uchiyama & Radin, 2009). When getting instructors involved with the learning and teaching process, the weaknesses and strengths of the current program are apparent (Haynes, et. al., 2016).

Curriculum mapping has been around for quite some time. The development of the curriculum process was specifically driven by a technical scientific approach in 1920 (Tyler,1950). Modifications were made to the process by Tyler (1950) and Taba (1962) to make a specific model for the curriculum mapping process. The model developed by Tyler (1950) and Taba (1962) guided programs through the following process:

1) Define the goals, purposes, or objectives
2) Define experiences or activities related to the goals
3) Organize the experiences and activities
4) Evaluate the goals

Later work performed by Wiggins and McTighe (1998) utilized a similar model to Tyler (1950) and Taba (1962). Instead of a four step process, Wiggins and McTighe applied a three step process:

1) Identify the desired results
2) Determine the acceptable evidence
3) Plan learning experiences and instruction

Wiggins and McTighe (1998) identified the results educators felt students should achieve at the end of the course prior to the educator putting together a lesson plan. Researchers saw that when educators utilized this method of lesson planning, students gained and retained more knowledge and skill with the lesson they went through. Prior to Wiggins and McTighe, Danielson (1996) utilized a similar approach to curriculum mapping by identifying the end results first. This "backward method" actually made positive results in education. Danielson (1996) saw that when the instructor kept the end goal in the forefront of their mind, the students had a higher content knowledge retention rate and could make connections between information across disciplines.

Critical Thinking Assessments

According to Merriam- Webster dictionary assessment can be defined as the action or an instance of making a judgement about something (Merriam-Webster, 2017). Researchers have also defined assessment in education as the means of enhancing instructional quality as well as student learning and performance (Duron et al., 2006). Because there is a need to teach critical thinking skills, one must identify where the students stand on the specific skill through assessments. There are multiple assessment tools that measure critical thinking skills. Studies have shown the most widely known assessment tools are the Watson- Glaser Critical Thinking

Appraisal (WGCTA), the Cornell Critical Thinking Test (CCTT), and the California Critical Thinking Skills Test (CCTST) (Jacobs, 1995; Fawkes, 2001). The next section will briefly look at these three tools and then introduce the Critical Thinking Assessment Test (CAT) that this study utilized.

California Critical Thinking Skills Test (CCTST)

The California Critical Thinking Skills Test was created by Peter Facione in 1990. This 45 minute, 34 question test assesses the cognitive skill of critical thinking. CCTST consists of multiple subcategories that look at the analysis of items, inference, evaluation, deductive reasoning and inductive reasoning (US Department of Education, 2000; Jacobs, 1995). This assessment consists of multiple choice exams which has its limitations to fully test critical thinking skills due to multiple choice exams not being the ideal assessments to test critical thinking skills (US Department of Education, 2000). However, these exams are inexpensive and you are able to do multiple assessments in a less amount of time (US Department of Education, 2000).

Watson- Glaser Critical Thinking Appraisal (WGCTA)

The Watson- Glaser Critical Thinking Appraisal was created by Goodwin Watson and Edward M. Glaser in 1980 to assess high school students through university graduates (US Department of Education, 2000; Hassan & Madhum, 2007). This 40-minute exam consists of 80 questions to measure the critical thinking skills of students (US Department of Education, 2000). More specifically, the exam looks at the five different areas of critical thinking: inference- determining the degrees of truth or falsity drawn from given data, recognition- recognizing assumptions from statements, deduction- determining whether certain conclusions follow the information, interpretation- deciding the general conclusion based on evidence and data given,

and evaluation- evaluating the arguments to see whether arguments are strong and relevant to the issue on hand (US Department of Education, 2000). This exam utilizes multiple choice questions which limits the scope of assessing critical thinking skills but the researcher is able to utilize this assessment with a large sample in a short amount of time (US Department of Education, 2000).

Cornell Critical Thinking Test (CCTT)

Cornell Critical Thinking Test was created in 1971 and revised in 1982 by Robert Ennis and Jason Millman (US Department of Education, 2000). This 50 question, multiple choice assessment looks at six areas of critical thinking within 50 minutes (US Department of Education, 2000). More specifically, the assessment looks at deduction, semantics, credibility, judging conclusions, induction, and being able to define and make assumptions of an identification (US Department of Education, 2000). According to Frisby (1992), students who took the assessment and scored low compared to those who took the assessment and simply guessed scored the same.

Critical Thinking Assessment Test (CAT)

Critical Thinking Assessment Test (CAT) was supported by the National Science Foundation and created by faculty members at Tennessee Technological University (Center for Assessment and Improvement of Learning (CAIL), 2017). This 15 short answer exam looks at four main domains of critical thinking which are: evaluating information, creative thinking, learning and problem solving, and communication (Center for Assessment and Improvement of Learning (CAIL), 2017). Within these four domains, this exam looks at a variety of skills that faculty members across the country who effectively represented critical thinking (Center for Assessment and Improvement of Learning (CAIL), 2017). This STEM-based assessment tool

can be applied to any discipline to assess the beginning levels or final levels within a course or a curriculum. Understanding the importance of getting faculty members involved with improving the teaching and learning process, the CAT exam allows the members to actually read and score the exams following a tested rubric from Tennessee Technological University (Center for Assessment and Improvement of Learning (CAIL), 2017). By getting instructors involved with the process (Fig. 2.4), the instructors can be more effective in developing learning processes to positively impact the students' critical thinking skills.

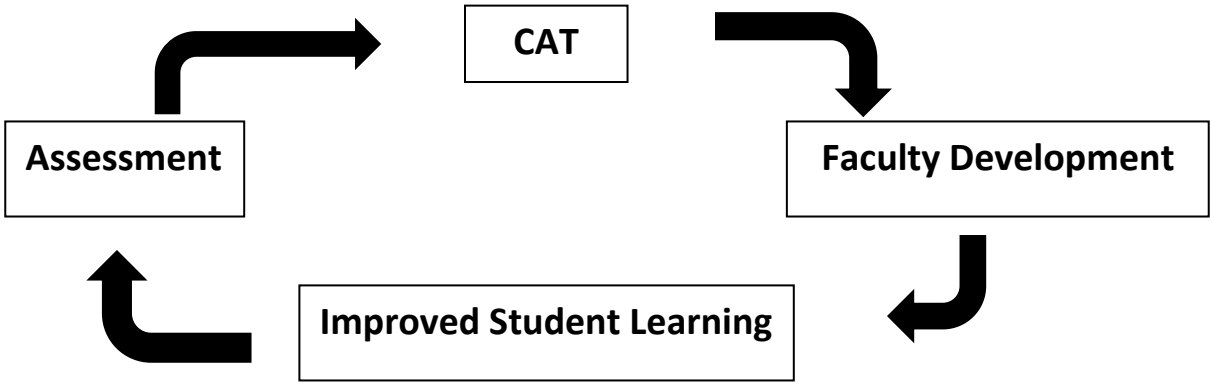


Figure 2.4. Involving faculty in assessments to the learning and teaching process utilizing CAT. From CAIL, 2017.

Teaching Methods to Improve Critical Thinking Skills

Research has shown there is a need to utilize different techniques in higher education to develop students' critical thinking skills (Haynes, et. al., 2016). Once faculty members can identify their own students' strengths and weaknesses within critical thinking, they will be able more effectively utilize the information and apply it to change higher education (Haynes, et. al., 2016). Higher education tends to emphasize the retention of factual information (Stein et al., 2009). Instructors often teach what to think rather than how to think (Vye & Bransford, 1981). Factual assessments are much easier than performing a critical thinking assessment tool (Haynes et. al., 2016). For examples, educators are teaching the specific breeds of beef or the type of

soybeans (Henderson, 1983). When utilizing critical thinking assessments these students should not only be able to tell the instructor the breeds of beef but also be able to describe the specific scientific characteristics behind these breeds and which breeds should be utilized in different operations with various scenarios. Students will study and learn to the extent that the educator will assess them. If the educator is not assessing the student utilizing critical thinking tools, then the students will not push themselves to master those skills. Assessment tools allow the educator to prioritize the important information while pushing the students to learn that specific detail (Haynes et. al., 2016). If the assessment tool emphasizes retention of factual information, then the students will just memorize the information for that assessment (Haynes et. al., 2016). The students will be practicing memorization instead of exercising and developing higher order thinking skills such as critical thinking skills.

To develop higher order thinking skills, students must be presented with the opportunities to exercise these skills. Whittington and Stup (1997) identified that students were given few opportunities to utilize higher cognitive levels of thinking when taking one hundred level class. As students move through the curriculum and enroll in a senior level course, the students are given the opportunities to think at the *analysis* level within the Bloom's taxonomy (Whittington & Stup, 1997). When courses had more than 51 students enrolled, the opportunities of higher cognitive thinking decrease (Whittington & Stup, 1997).

By utilizing effective teaching techniques, it allows students the opportunity to develop critical thinking skills. Educators must understand the correct steps to achieve this goal. Newcomb and Trefz (1987) utilized Bloom's Taxonomy to develop a frame work (Fig. 2.5) which provided educators a direction to improve the quality of learning in the classroom. By

taking Bloom's six level theory and turning it into a four-step process, educators are allowed to focus on the key items within education to teach these higher order thinking skills.

Bloom's Taxonomy	Newcomb- Trefz Model
Knowledge	Remembering
Comprehension	Processing
Application	
Analysis	
Synthesis	Creating
Evaluation	Evaluating

Figure 2.5. Comparison between Bloom's Taxonomy and the Newcomb- Trefz Model. From Newcomb and Trefz, 1987.

Critical thinking skills are developed within students when the educator utilizes critical thinking instructional techniques (Lundy et. al, 2002). To develop instructional techniques, the educator must understand the steps to move students towards critical thinking. According to Duron and colleagues (2006), to move students towards critically thinking there are five specific steps (Fig. 2.6). Identifying learning objectives, teaching through questions, assess learners through activities, review teaching and improve and then allow feedback, is an effective way to systematically develop higher order thinking skills within a course.

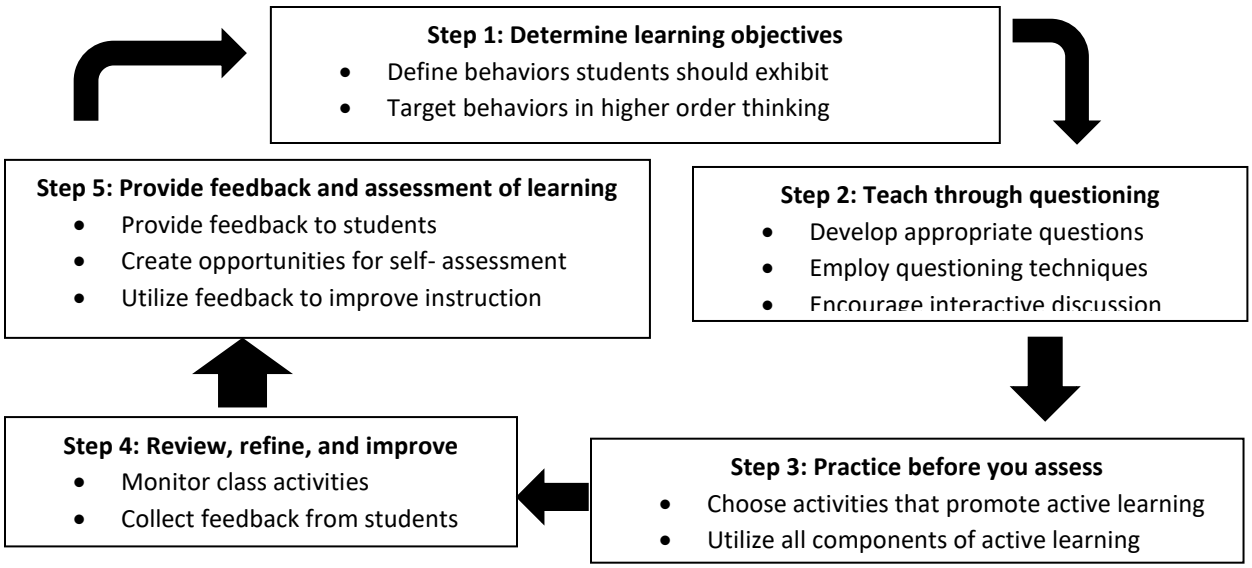


Figure 2.6. Five Step model to move students towards critical thinking. From Duron et al., 2006.

Research has shown numerous teaching techniques enhance the development of students' critical thinking skills in an education setting. Problem-based learning and inquiry-based learning are two methods that align well with the goals and outcomes of agricultural education. Problem based learning (PBL) is an approach that revolves around a real-world ill-structured problem (Jonassen, 1997). This technique allows the student to connect the technical knowledge being learned in the classroom while developing critical thinking skills. Studies have shown that PBL can help enhance critical thinking skills (Burris & Garton, 2007). Burris and Garton's study (2007) did not find any difference in critical thinking skills while utilizing PBL. This study was a two week unit which did not provide enough time to see a change in critical thinking skills. Burris and Garton (2007) observed that Lundy (2002) did see a change in critical thinking skills when the study was done over a semester long course to exercise these skills. These studies prove that critical thinking skills cannot just be taught overnight and that the educator must continuously utilize PBL to see a true change.

Another technique researchers have proven to have a higher scientific reasoning ability and the best practice for educating students about scientific principles is the use of inquiry-based learning (IBL) (Chiasson & Burnett, 2001; National Research Council, 1988). Inquiry-based learning challenges the students "by presenting questions, problems or scenarios to the students while implementing problem-based learning to help develop higher levels of thinking" (Parr & Edwards, 2004; Phipps et al., 2008). Phipps (2008) suggested that not only did the inquiry-based learning allow students to develop high order critical thinking skills but also encouraged curiosity amongst the learners and allowed them to master skills needed in the 21st century. Getting faculty members involved in improving teaching and learning by decreasing the amount

of lecture time and increasing the activities involved in critical thinking will make the greatest impact on a higher education curriculum (Haynes et al., 2016).

Problem-Based Learning and Inquiry-Based Learning are very similar in nature, however, they do have distinguishing differences. IBL foundation is based on a philosophical approach that started with the curiosity of the learner (Walker et al., 2015). This learner-centered approach utilizes activities that start with a question, allows the learner to investigate the question and through activity gains knowledge and critical thinking skills (Walker et al., 2015). PBL is a strategy in education. Learners have full responsibility of their learning in a problem-based atmosphere (Walker et al., 2015). The biggest difference between these two methods is the role of the educator. In IBL, the educator is both the facilitator of the learning and provides the learner with information (Walker et al., 2015). While in PBL, the educator facilitates the learning while the learner is responsible to explain their learning process and gather information on their own (Walker et al., 2015).

How People Learn

To effectively teach a skill set, educators must first understand how the learner takes a piece of information, processes it, and puts it into action. Researchers have discovered important principles and learning experiences to enhance people's learning capability (Behavioral and Social Sciences and Education National Research Council, 2000). The concept of learning might be complicated, but by breaking it down an individual (learner) observes, acts, gets feedback and then takes what they learn and does it again or does a different action from what one gathered in the process (Caine, 2010).

Before the learner gains new knowledge, they must have a basis of knowledge within that area to allow them to build upon background knowledge to move towards the expert level

(Behavioral and Social Sciences and Education National Research Council, 2000). Educators have to keep in mind that there is a difference between learning with understanding and just pure memorization (Behavioral and Social Sciences and Education National Research Council, 2000). If an individual merely memorizes the content on hand, they are not able to think at a higher cognitive level to achieve higher order thinking skills such as critical thinking. With problem solving-type questions and allowing students to understand the content, they can approach the higher order tasks (Bransford and Stein, 1993; Bransford et al., 1983). Once a learner is presented with the new pieces of information, educators must allow time to learn and process the new content. It takes a while to explore the underlying concepts to process the facts and topics that are being taught (Behavioral and Social Sciences and Education National Research Council, 2000).

Researchers have found that most curriculums skip this step as they quickly gloss over the facts and not focus on development and organization of the ideas (Behavioral and Social Sciences and Education National Research Council, 2000). Lastly, in the learning process is the feedback process. This step has been identified as most important step for successful learning (Thorndike, 1913). Feedback allows a student to see where they are at in the learning process and what changes they should make to keep moving forward to achieve the expert level (Behavioral and Social Sciences and Education National Research Council, 2000). Feedback for memorization is completely different than feedback for level of understanding a student might have on a topic (Chi et al., 1989, 1994). By giving them feedback, students are able to understand not only the knowledge one had but also the skill that they are learning and transfer that skill to another area of study (Behavioral and Social Sciences and Education National Research Council, 2000).

CHAPTER 3. METHODS

To assess the critical thinking skills of the students in the Department of Animal Science, the Critical Thinking Assessment Test (CAT) created by Tennessee Technological University was utilized. Utilizing the assessment tool allowed researchers to explore the difference in critical thinking ability between freshmen and seniors within the department.

Purpose and Objectives

The purpose of this study was to explore differences in critical thinking skills between freshmen and senior Animal Science students and determine where in the curriculum the critical thinking skills are being taught. Four objectives guided this study:

1. Compare freshmen and senior Animal Science students to the national critical thinking skill norms
2. Determine if there's a difference between freshmen and senior Animal Science students in critical thinking
3. Determine if there's a difference in critical thinking skills based upon selected demographic variables
4. Map critical thinking skills instructional methods in core animal science courses

Instrument

This study utilizes the Critical Thinking Assessment Test (CAT) which assesses a range of skills that faculty across the nation felt were important traits within critical thinking and real-world problem solving through a 15 question, short answer essay exam (CAIL, 2017). Funded for development by the National Science Foundation, the CAT Instrument analyzes 15 different traits within critical thinking (CAIL, 2017). The instrument allows faculty involvement through

the execution of the exam along with the scoring process assisted by experts from Tennessee Technological University (CAIL, 2017). To ensure the reliability and consistency of the scoring process, faculty members are provided a detailed rubric to score the exams.

The instrument was designed to be used to evaluate effects of college education, a program of study, a specific course, and informal learning experiences (Tennessee Tech University, 2017). These evaluations can be achieved through studies such as a Pre-Test/ Post-Test Design, Cross- sectional studies, evaluating changes in a program's outcome over time, or evaluating changes in programs or courses by comparing it to a control group (Tennessee Tech University, 2017). Figure 3.1 shows the 15 skills CAT assesses within critical thinking.

• Summarize the patterns of results in a graph without making inappropriate inferences • Evaluate how strongly correlational-type data supports a hypothesis • Provide alternative explanations for a patterns of results that has many possible causes • Identify additional information needed to evaluate a hypothesis • Evaluate whether spurious information strongly supports a hypothesis • Provide alternative explanations for spurious associations • Identify additional information needed to evaluate a hypothesis • Determine whether an invited inference is supported by specific information	• Provide relevant alternative interpretations for a specific set of results • Separate relevant from irrelevant information when solving a real-world problem • Use and apply relevant information to evaluate a problem • Use basic mathematical skills to help solve a real-world problem • Identify suitable solutions for a real-world problem using relevant information • Identify and explain the best solution for a real-world problem using relevant information • Explain how changes in the a real-world problem situation might affect the solution

Figure 3.1- Fifteen skills CAT exam tests. From CAIL, 2017.

These fifteen critical thinking skills were identified and evaluated by faculty members of various disciplines from six institutions which established the face validity of the instrument

(CAIL, 2017). As stated before, the instrument can be utilized as a pre-test/ post- test design as the reliability levels were >0.80 (CAIL, 2017).

To ensure that the scoring of the short answers is reliable, each of the questions is scored by a minimum of two scorers. If these two scorers don't agree upon the specific score, that question is looked at by a third scorer. Through this process and the scoring rubric, the scoring reliability is equal to 0.92 between the first and second scorer for the instrument (CAIL, 2017). Each question is awarded a specific number of points anywhere from 0 to 5 with more points being awarded to the more complex critical thinking skill.

Even though the instrument has fifteen questions and assesses fifteen skills of critical thinking, some of the questions assess more than one trait at a time (CAIL, 2017). Due to this characteristic of the exam, the internal consistency was established at a reasonable level of α= 0.70 (CAIL, 2017). The fifteen skills assessed by CAT can be organized into four domains: evaluating information, creative thinking, learning and problem solving, and communication (CAIL, 2017).

Objective One, Two, and Three Procedures

This study's purpose was to distinguish the difference between a group of freshmen students to senior students in the Department of Animal Science, compare the students to the national norm and to analyze the two groups of students by different demographics.

Participants

Two groups of undergraduate students participated in this study. The first group of students was traditional freshmen. Students in this group were enrolled in AnS 110 and came directly to Iowa State University from high school. For AnS 110, students were divided into peer groups depending on their specific species interest. Each group had the same species

interest but with various backgrounds of experience in animal science and hometown location. A random sample of freshmen with various species interest were assigned by the instructor to participate in the study.

The second group to participate in this study were seniors in the animal science department. Students enrolled in AnS 411 completed a questionnaire that consisted the of the following questions:

1. Did you come to Iowa State University directly from high school?
2. Did you take the following courses at Iowa State University?
    a. AnS 101, AnS 114, AnS 210, AnS 211, All the 200- level species courses, AnS 319, AnS 320, AnS 331, AnS 352, and AnS 411

Those students who answered "yes" to both of the questions became eligible for the study. From there a random sample of AnS 411 students were taken by the instructor and assigned to participate in the study.

From each group initially sixty students were involved in this study. The first group of students consisted of traditional freshmen (n=55) that were enrolled in AnS 110 Orientation Course that came to the university directly out of high school. The second group to participate in this study were seniors (n=60) enrolled in AnS 411 Senior Animal Issues Course. They came to the university directly out of high school and took all animal science core courses at the university. A sample size of 60 students was chosen with the confidence level of 95% resulting in a confidence interval of 26.2% for the seniors and 19.6% for the freshmen with only 55 students in the group due to 5 students failing to complete the assessment. Because of Department of Animal Science funding we were able to over sample and collect data from 60 students in each group.

Data Collection

The researcher submitted and received Institutional Review Board (IRB) approval from Iowa State University prior to collecting data for the study (Appendix A). There were two groups (freshmen and seniors) that participated in taking the CAT exam at two different times. The freshmen group was randomly selected from the AnS 110 Orientation course. Prior to the study the researcher requested from the instructor a group of freshmen students that came to Iowa State University directly from high school. The instructor of the courses provided the researcher with the names of the students from the assigned peer mentor groups of various species interest and a variety of demographics to participate in the study.

The group of seniors were enrolled in AnS 411 Issues in Animal Agriculture course. This required senior course represented half of the graduating seniors in the department. To control for impacts that other programs might have on a student, the traditional students were randomly selected to participate in this study. Traditional student was defined as a student that came to Iowa State University directly out of high school and took all the core animal science courses at Iowa State University (Fig. 3.2).

1. Student must have taken the following courses at Iowa State to be qualified as a traditional student:

100-Level Courses	200-Level Courses	300-Level Courses	400-Level Courses
AnS 101 AnS 114	AnS 210 AnS 211 AnS 224 AnS 225 AnS 226	AnS 319 AnS 320 AnS 331 AnS 352	AnS 411

Figure 3.2. Courses analyzed in study

The students were given the CAT exam on a predetermined date and location. The senior group participated on Tuesday September 27, 2016 from 4:10-5:10pm in Carver Hall at Iowa State University. Freshmen group participated in the study on Thursday September 29th from 2:00- 3:00pm in the Hixson-Lied building at Iowa State University. The researcher followed the training guidelines for proctoring the exam as set forth by Tennessee Technological University. Exams were then scored by a group of ISU faculty, staff, and graduate students following Tennessee Technological University's rubric and guidelines. These volunteer scorers were a mixture of instructors/ graduate students in and outside the department of animal science, scorers with and without prior experience of the scoring process. The exams from both groups were sent to Tennessee Technological University for accuracy testing (Appendix B). For the Iowa State University scoring of the CAT Exam the total error was <3%.

Data Analysis

Objective One

The first objective was to compare critical thinking skills between each Iowa State University groups to the national norm. The group means were compared to the national norm by CAT using a two-tailed t-test, alpha level set at 0.05.

Objective Two

This objective was comparing the difference in critical thinking ability between the freshmen and seniors in the Department of Animal Science at Iowa State University. A two-tailed t-test, alpha set at 0.05, was performed to compare the mean scores between class standing (freshmen vs. seniors). Tennessee Technological University breaks the fifteen critical thinking skills down into four domains: Evaluate and Interpret Information, Problem Solving, Creative Thinking, and Effective Communication. First a grand mean was calculated for each of the four

domains of critical thinking. From there, a two-tailed t- test with an alpha level of 0.05 was ran. Another two-tailed t-test was performed on the score of each of the 15 questions compare the freshmen and senior scores.

Objective Three

This objective compared the scores within the different demographics. First a two-tailed t- test with an alpha level of 0.05 was ran to compare the overall scores of males and females. From there, a Tukey HSD test was calculated to compare the combinations of gender and class standing to see if there was any difference within demographics in regards to critical thinking skills.

Assumptions and Limitations of Objectives One, Two, and Three

When completing this study, the researcher had to assume the random groups of students represented the seniors and freshmen of the animal science department. In the senior group, the assumption was made that the students had similar life experiences, had the same professors throughout the coursework and were at the same maturity level. The research was limited to the number of students as the entire student body wasn't tested in the study. Along with the number of students, time was a factor within the study. The same students weren't tested their freshmen year and again their senior year. Instead of having the same individuals, a sample representing the same types of students were taken in each group.

Objective Four Procedures

The purpose of this part of the study was to map out the Department of Animal Science core curriculum to see exactly where the fifteen traits of critical thinking defined by CAT are being taught. The following portion of this chapter will go more in depth about the procedure of

how the curriculum was mapped, what courses were included into the study, and how data was analyzed.

For objective four, a qualitative research design method was used to map out the curriculum in the Department of Animal Science to see if the fifteen critical thinking skills defined by Tennessee Technological University were being taught within the core curriculum. Twelve of the core courses were selected to be in this study (Fig. 3.3).

100-Level Courses	200-Level Courses	300-Level Courses	400-Level Courses
AnS 101 AnS 114	AnS 210 AnS 211 AnS 224 AnS 225 AnS 226	AnS 319 AnS 320 AnS 331 AnS 352	AnS 411

Figure 3.3. Courses analyzed in study

The courses were selected because the courses were required regardless of species interest and the two hundred-level species courses were the most popular species options to maximize the number of students able to participate in the study. Course instructors participated in a self-reporting interview with the researcher. These instructors only reported on the courses that they were teaching at the time. After the data were collected, the researcher went through the data and analyzed whether or not the skills were actually being effectively taught through the techniques the instructor reported.

Instrument

To map out where the specific critical thinking skills were being taught, the researcher created a chart to help organize and guide the gathering of the data. The chart included the fifteen different skills in critical thinking along with a series of questions the researcher asked the course instructors (Fig. 3.3). To ensure reliability, the researcher had the same set of questions for each instructor. This allowed consistency within the interviews to ensure that data were

fairly collected and recorded and could be repeated again at a future date. To control for internal validity the instructors that participated in the study self-reported on their own courses. Also prior to the interviews, the researcher started out by stating that this was an interview to simply record what was happening in the course and that there were no consequences for not teaching a specific number of the critical thinking skills. This helped to ensure validity of the interviews.

Data Collection

Instructors within the department of animal science who teach the core classes within the animal science curriculum participated in this study. From there, instructors of each course were contacted to participate in a short interview. In the interview, the researcher asked the following questions on the amount of time they spent in their courses allowing the students to develop the fifteen critical thinking skills defined by CAT.

1. Is this specific trait being directly taught in your class?
2. If you're not directly teaching it, do students practice the specific skill indirectly?
3. Examples of how the skill is being taught in the course

Data Analysis

Interview data were entered into a spreadsheet and coded for each of the responses. Once the information was collected, the researcher studied the data to see where the fifteen skills are being taught in the core animal science courses. Data were then analyzed to determine if critical thinking skills were being taught within the curriculum, where they were being taught and how they were being taught. After the interviews were recorded, the researcher went through the transcripts taken in the interviews to determine whether or not the techniques the instructors reported were effective techniques to teach critical thinking skills. Course teaching techniques had to fall within one of the following categories to be considered an effective critical thinking

teaching technique (Fig. 3.4 and Fig 3.5). When the data were reported, it was organized to have the responses from the instructors and then was analyze if it was an effective critical thinking teaching method or not. Effective methods were placed within the Knowledge and Cognitive Process Dimensions.

Concrete Knowledge → Abstract Knowledge			
Factual	**Conceptual**	**Procedural**	**Metacognitive**
-Knowledge of terminology -Knowledge of specific details and elements	-Knowledge of classifications and categories -Knowledge of principles and generalizations -Knowledge of theories, models, and structures	-Knowledge of subject-specific skills and algorithms -Knowledge of subjective-specific techniques and methods -Knowledge of criteria for determining when to use appropriate procedures	-Strategic knowledge -Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge -Self-knowledge

Figure 3.4. The Knowledge Dimension from Anderson and Krathwoh, 2001 (p. 46)

Lower order thinking skills → Higher order thinking skills					
Remember	**Understand**	**Apply**	**Analyze**	**Evaluate**	**Create**
Recognizing -identifying **Recalling** -retrieving	**Interpreting** -clarifying -paraphrasing -representing -translating **Exemplifying** -illustrating -instantiating **Classifying** -categorizing -subsuming **Summarizing** -abstracting -generalizing **Inferring** -concluding -extrapolating -interpolating -predicting **Comparing** -contrasting -mapping -matching **Explaining** -constructing models	**Executing** -carrying out **Implementing** -using	**Differentiating** -discriminating -distinguishing -focusing -selecting **Organizing** -finding coherence -integrating -outlining -parsing -structuring **Attributing** -deconstructing	**Checking** -coordinating -detecting -monitoring -testing **Critiquing** -judging	**Generating** -hypothesizing **Planning** -designing **Producing** -constructing

Figure 3.5. The Cognitive Process Dimension from Anderson and Krathwohl, 2001 (pp. 67-68).

Assumptions and Limitations of Objective Four

Data were collected from the individual instructors of the course. Therefore, the instructor had to give the best and honest response to the interview questions as the interview was self-reported. The researcher had to assume that the instructor was going to accurately report if the critical thinking skill was actually being taught in the courses. Also limited because this study was only a snapshot of time for each of these courses that might continuously change throughout the semesters.

Chapter Conclusion

This study's purpose was to determine the specific traits of critical thinking skills within in the Department of Animal Science. For objective one, freshmen and senior animal science students' critical thinking skills scores were compared to the national norm. The study utilized the CAT instrument to test and gather data of the critical thinking skills within the two groups of students also answered objective two where the freshman and senior groups were compared to each other. Demographics were compared between the two student grade levels to answer objective three. For objective four, animal science curriculum core classes were mapped to see where the fifteen critical thinking skills defined by CAT.

CHAPTER 4. RESULTS

The purpose of this study was to assess critical thinking skills of freshmen and seniors in the Department of Animal Science while mapping out where these skills were taught. The two groups represented various demographics. In the freshmen group (n=55), there were 17 males (30.9%) and 38 females (69.1%). The group consisted of 94.5% white, 1.8% African American, 1.8% American Indian or Alaska Native, and 1.8% reported other race. In the senior group (n=60), there was 13 males (21.7%) and 47 females (78.3%). This group consisted of 98.3% white, 3.3% Asian, and 1.7% other. Objective one compared the animal science students to the national norm collected from the CAT tests. The results from the CAT tests were then analyzed to answer objective two and three by comparisons of different demographics which consists of individual group's scores, a comparison between the two groups looking at gender, class level, and combination of gender and class level. Objective four explored where exactly in the curriculum, critical thinking skills were taught. If the skills were taught, then the methods utilized in teaching were gathered as well.

Objective One. Comparison to National Norm

The two groups of student (freshmen and seniors) were compared to a national norm for their respective critical thinking skills. The skills were also categorized into four sub-groups: Evaluate and Interpret Information, Problem Solving, Creative Thinking, and Effective Communication (Appendix C). Each skill can be under a maximum of three sub-groups. When comparing the freshman to the national norm (Appendix C), Animal Science freshmen scored significantly higher than the norm for separating relevant from irrelevant information (Question 10, $p<0.01$). This group also scored significantly higher for using basic math skills to solve a real world problem (Question 12, $p<0.05$) and the CAT Total Score ($p<0.05$). In all the other questions, there were

no significant differences in the scores. The senior group (Appendix D) compared to the national norm group scored significantly lower than the national norm for the skill of evaluating how strongly data supports a hypothesis (Question 2, $p<0.05$), identifying additional information needed to evaluate a hypothesis (Question 7, $p<.01$), explaining how changes in a problem might affect the solution (Question 15, $p<0.01$), and the seniors also scored significantly lower in the CAT Total Score ($p<.05$). There were no significant differences between the senior group and national norm for the other questions.

Objective Two. Comparison within Department

To address objective two a comparison between the two grade levels was performed. The freshmen had a mean score of 15.19 points out of 38 points with a standard deviation of 4.34. The national norm was an average score of 13.66 points. In the senior group, the students had a mean score of 17.47 points out of a possible 38 points with a standard deviation of 5.01. The national norm mean score was 19.04 points for college seniors. Data were collected (Appendix E) to see the frequency of students and how they scored within each question amongst the two grade levels. This allowed the researcher to evaluate each individual question according to the number of points students earned.

To answer objective two, data were collected from each grade level. The first analysis compared the overall mean scores from freshmen to seniors (Table 4.1). A two-tailed t-test with an alpha level of 0.05 was completed to determine if there was significant differences between two grade levels. Freshman and senior means were found to be significantly different.

Table 4.1
Score Mean Comparisons between Freshmen and Seniors

Level	Std. Error	Mean
Freshmen	0.68	15.19*
Seniors	0.73	17.47*

Note: *Significantly different $p<0.05$ $\alpha=0.05$ $t= 1.98177$

Critical thinking according to Tennessee Technological University, can be broken down into four domains: Evaluate and Interpret Information, Problem Solving, Creative Thinking, and Effective Communication. A grand mean was calculated for each of the domains to compare the two grade levels. The researcher then compared the different grand means between each of the grade levels. When the analysis was completed it showed that seniors scored significantly higher in all domains except for Problem Solving (Table 4.2).

Table 4.2
Comparisons of the Four Critical Thinking Domains' Grand Means

CT Domains	Freshmen	Seniors	p- value
Evaluate and Interpret Information	1.19	1.35	0.03*
Problem Solving	1.26	1.41	0.08
Creative Thinking	0.8	0.97	0.02*
Effective Communication	0.92	1.14	0.01*

Note: *significantly different $p<0.05$ $\alpha=0.05$

Seeing that there wasn't a significant difference in all of the domains, the question then was which skills within problem solving were causing the domain to not be significant. A two-tailed t-test with an alpha level of 0.05 was completed to compare means for each question (Table 4.3). There were four questions that seniors scored significantly higher than the freshmen.

Table 4.3
Comparison of means between each class for each Question

		Seniors		Freshmen		
Question	Points Possible	Mean	Std Error	Mean	Std Error	p-value
1) Summarize the patterns of results	1	0.62	0.06	0.6	0.07	0.82
2) Evaluate how strongly data supports a hypothesis	3	0.91	0.13	0.84	0.14	0.69
3) Provide alternative explanations for results	3	1.10	0.12	0.71	0.13	0.03*
4) Identify additional information needed to evaluate a hypothesis	4	1.16	0.15	0.99	0.15	0.43

Table 4.3
Comparison of means between each class for each Question

		Seniors		Freshmen		
Question	Points Possible	Mean	Std Error	Mean	Std Error	p-value
5) Evaluate whether information supports a hypothesis	1	0.72	0.06	0.55	0.06	0.05*
6) Provide alternative explanations for spurious associations	3	1.55	0.10	1.13	0.10	<0.01
7) Identify additional information needed to evaluate a hypothesis	2	0.57	0.08	0.51	0.08	0.61
8) Determine whether an inference is supported by information	1	0.60	0.07	0.55	0.07	0.54
9) Provide relevant alternative interpretations for a specific set of results	2	0.74	0.09	0.75	0.09	0.97
10) Separate relevant from irrelevant information	4	3.24	0.10	3.51	0.10	0.07
11) Use and apply relevant information	2	1.28	0.09	1.00	0.09	0.03*
12) Use basic mathematical skills to help solve a problem	1	0.88	0.04	0.89	0.04	0.85
13) Identify solutions for a problem	3	1.22	0.12	0.80	0.12	0.02*
14) Identify and explain the solution for a problem		2.28	0.24	1.67	0.25	0.09
15) Explain how changes in a problem situation might affect the solution		0.69	0.10	0.71	0.11	0.90

Note: *Significantly different $p<0.05$ $\alpha= 0.05$

Objective Three. Demographics

To answer objective three comparison between gender as well as gender within each class was analyzed. A two-tailed t-test with an alpha level of 0.05 calculated to compare genders (Table 4.4). There were no significant difference between genders.

Table 4.4
Mean Comparisons between Males and Females (n= 115)

Gender	n	Std. Error	Mean
Male	30	0.86	14.87
Female	85	0.51	16.91

Note: *significantly different $p<0.05$ $\alpha=0.05$ t= 1.98177

As there was no significance between gender, a Tukey HSD test was ran to compare gender within each class with the alpha level set at 0.05. Table 4.5 shows the different least square means for freshmen males, freshmen females, senior males and senior females. As indicated in the table, there was a significant difference between freshmen males and senior females.

Table 4.5
Comparison between gender within each class- *Tukey HSD*

Gender and Level	Mean	Std. Error
Male, Freshman	14	1.34*
Male, Senior	16	1.30
Female, Freshman	15.72	0.76
Female, Senior	17.88	0.68*

Note: *Significantly different $p<0.05$ $\alpha=0.05$ Q= 2.60838

Objective Four. Curriculum Mapping

The purpose of this objective was to map the fifteen critical thinking skills being taught in the core classes (Table 4.6) of the animal science curriculum. Courses selected to be in this study were required by all the students for their degree. The sophomore level species courses (AnS 224, 225 and 226) were selected to be in this study because the majority of students elect to take a minimum of two out of these three courses.

Table 4.6
Core Animal Science Courses in study

Course Number	**Course Name**
AnS 101	Working with Animals
AnS 114	Survey of the Animal Industry
AnS 210	Career Preparation
AnS 211	Issues Facing Animal Science
AnS 224	Companion Animal Science
AnS 225	Swine Science
AnS 226	Beef Cattle Science
AnS 319	Animal Nutrition
AnS 320	Animal Feeds and Feeding
AnS 331	Domestic Animal Reproduction
AnS 352	Genetic Improvement of Domestic Animals
AnS 411	Addressing Issues in Animal Science

Data were collected throughout an interview process with each of the course instructors. The following charts provide the findings in the interviews. Critical thinking skills (Table 4.7) used for mapping out the curriculum were the same skills as the CAT exam.

Table 4.7
List of fifteen critical thinking skills utilize while mapping out curriculum

1) Summarize the patterns of results in a graph without making inappropriate inferences
2) Evaluate how strongly correlational-type data supports a hypothesis
3) Provide alternative explanations for a pattern of results that has many possible causes
4) Identify additional information needed to evaluate a hypothesis
5) Evaluate whether spurious information strongly supports a hypothesis
6) Provide alternative explanations for spurious associations
7) Identify additional information needed to evaluate a hypothesis
8) Determine whether an invited inference is supported by specific information
9) Provide relevant alternative interpretations for a specific set of results
10) Separate relevant from irrelevant information when solving a real-world problem
11) Use and apply relevant information to evaluate a problem
12) Use basic mathematical skills to help solve a real-world problem
13) Identify suitable solutions for a real-world problem using relevant information
14) Identify and explain the best solution for a real-world problem using relevant information
15) Explain how changes in a real-world problem situation might affect the solution

Overall Curriculum Data

Data were entered into a spreadsheet to allow researchers to analyze where skills were being taught in the curriculum. In the interviews, instructors were asked three specific questions. First, they were asked "Is this specific skill directly taught in your class." If the instructor said yes, it is coded as a 1 (Appendix F). Second question they were asked was, "If this skill was not directly taught in the course, do the students exercise these skills as a result of another lesson you were teaching?" If they said yes, it was coded as a 2 (Appendix F). The table shows an inconsistency of instructors teaching the different critical thinking skills. There is no method of spreading out the skills so that students get an even exposure throughout the four-year curriculum.

Course Skill Data

The following tables (Table 4.8 through Table 4.19) describe the findings. After the instructor reported what skills they taught, the research determine if the method was effective and how it was an effective method of teaching following the Knowledge and Cognitive Process Dimensions.

The AnS 101 instructor (Table 4.8) reported that none of the critical thinking skills were directly taught in the introductory course. However, four skills were indirectly developed within the course. Summarizing the patterns of results in a graph without making inappropriate inferences (Question One) was taught during lectures. The instructor shows students examples of graphs with patterns of the number of livestock in other countries. Students were assigned homework which require them to go out and find additional pieces of information for many topics especially about different breeds. This was an example of how the instructor is indirectly teaching identify additional information needed to evaluate a hypothesis (Question 4), which might not be directly taught. But it is an effective way to make the students practice the skill and gain factual knowledge in the Knowledge Dimension. Determining whether an invited inference is supported by specific information (Question 8) was taught through an irradiation lab where the instructor explains irradiation and what information backs up the practice. Lastly, the instructor, during a feeds lab, has the students calculate out how much an animal would eat. This allows the students to practice the use of basic mathematical skills to help solve a real-world problem (Question 12).

Table 4.8
AnS 101- Working with Animals

Question	Directly Taught	Indirectly Taught	Method Examples	Effective Method?
1) Summarize the patterns of results	No	Yes	Shows examples of patterns with the number of livestock in other countries	No
2) Evaluate how strongly data supports a hypothesis	No	No		
3) Provide alternative explanations for results	No	No		
4) Identify additional information needed to evaluate a hypothesis	No	Yes	Homework asks students to find additional pieces of information over different animal breeds	Yes
5) Evaluate whether information supports a hypothesis	No	No		
6) Provide alternative explanations for spurious associations	No	No		
7) Identify additional information needed to evaluate a hypothesis	No	No		
8) Determine whether an inference is supported by information	No	Yes	Irradiation lab- gives examples in a lecture based lab	No
9) Provide relevant alternative interpretations for a specific set of results	No	No		
10) Separate relevant from irrelevant information	No	No		
11) Use and apply relevant information	No	No		
12) Use basic mathematical skills to help solve a problem	No	Yes	Explains how many people one animal will feed	No
13) Identify solutions for a problem	No	No		
14) Identify and explain the solution for a problem	No	No		
15) Explain how changes in a problem situation might affect the solution	No	No		

The AnS 114 instructor reported directly teaching five of the critical thinking skills (Table 4.9). Students learn how to summarize the patterns of results in a graph without making inappropriate inferences (Question 1) when the instructor teaches them about production conception rates. Providing alternative explanations for a pattern of results (Question 3) that has many possible causes is taught when students have discussions over pasture vs. conventional raised eggs. In that same lesson, the instructor teaches about all of the housing systems which allows students to evaluate whether spurious information strongly supports a hypothesis (Question 5). For example, students must determine whether there are true claims between conventional and organic housing. The instructor also provides students with current event discussions, which students are able to determine whether an invited inference is supported by specific information (Question 8). These four approaches (Question, 1,3,5, and 8) aren't the most effective way to teach these skills. The methods reported were really a lecture-based technique. This approach doesn't really push the students to exercise the skills as all the students don't have the same opportunity to practice the skills in such a large lecture hall.

Students are assessed through scenario based exams which requires the students to use and apply relevant information to evaluate a problem (Question 11). The students in this class also get to learn the skill of identifying suitable solutions for a real-world problem using relevant information (Question 13). Students are expected to do to provide a suitable solution on an exam but the instructor does not directly teach this skill in the course. These skills are effectively assessed as the students are assessed with the skill in a scenario based exam. Students must have knowledge of principles and generalizations to fully understand the content in the course to apply it to the scenario problem that the instructor presents to the student in an exam. The methods being used fall within the Cognitive Process Dimension with the remember and apply category.

Table 4.9
AnS 114- Survey of the Animal Industry

Question	Directly Taught	Indirectly Taught	Method Examples	Effective Method?
1) Summarize the patterns of results	Yes	No	Explaining production conception rates	No
2) Evaluate how strongly data supports a hypothesis	No	No		
3) Provide alternative explanations for results	Yes	No	Discussion on pasture vs. conventional raised eggs	No
4) Identify additional information needed to evaluate a hypothesis	No	No		
5) Evaluate whether information supports a hypothesis	Yes	No	Lesson over different housing systems	No
6) Provide alternative explanations for spurious associations	No	No		
7) Identify additional information needed to evaluate a hypothesis	No	No		
8) Determine whether an inference is supported by information	Yes	No	Current news event discussions	No
9) Provide relevant alternative interpretations for a specific set of results	No	No		
10) Separate relevant from irrelevant information	No	No		
11) Use and apply relevant information	Yes	No	Scenario based exams	Yes
12) Use basic mathematical skills to help solve a problem	No	No		
13) Identify solutions for a problem	No	Yes	Presents a situation in an exam and asks to identify what the problem is	Yes
14) Identify and explain the solution for a problem	No	No		
15) Explain how changes in a problem situation might affect the solution	No	No		

In AnS 210 (Table 4.10), students were directly taught three critical thinking skills. One of the students' assignments is to write a cover letter. The instructor then gives them feedback and they have to pull in additional information to then improve the cover letter as a final draft. This assignment allows the students to practice identifying additional information needed to evaluate a hypothesis (Question 4). The instructor also gives them specific details for their resume and cover letter assignments which the students then have to provide relevant alternative interpretations of the specific set of results (Question 9). Lastly, students in this course are taught how to use and apply relevant information to evaluate a problem within their minor assignment. For this assignment, students have to research the different options and filter the relevant information to fill out a minor course schedule. All these techniques are effective techniques as every student is being assessed with their completion of the assignments. Students practice analyzing the different edits and instructions given to complete the assignment and implement the changes that are needed to improve their assignment. These methods fall into the Knowledge Dimension Factual category (knowledge of elements) and Cognitive Process Dimension within the apply and analyze categories.

In AnS 211 (Table 4.11), the instructor reported directly teaching the students eleven critical thinking skills. One assignment the students have is to develop a message point from a specific topic and summarize together in three headlines. Being able to summarize patterns of results without making inappropriate inferences (Question 1), allows the students to effectively communicate their message in the headlines. This effective method gives the students an opportunity to practice the paraphrasing or summarizing the information which falls within the Cognitive Process Dimension Understand category.

Table 4.10
AnS 210- Career Preparation

Question	Directly Taught	Indirectly Taught	Method Examples	Effective Method?
1) Summarize the patterns of results	No	No		
2) Evaluate how strongly data supports a hypothesis	No	No		
3) Provide alternative explanations for results	No	No		
4) Identify additional information needed to evaluate a hypothesis	Yes	No	Students pull in additional information to improve their cover letter	Yes
5) Evaluate whether information supports a hypothesis	No	No		
6) Provide alternative explanations for spurious associations	No	No		
7) Identify additional information needed to evaluate a hypothesis	No	No		
8) Determine whether an inference is supported by information	No	No		
9) Provide relevant alternative interpretations for a specific set of results	Yes	No	Interprets the edits in their resume and cover letter provided by the instructors	Yes
10) Separate relevant from irrelevant information	No	No		
11) Use and apply relevant information	Yes	No	Minor assignment- students have to research what classes they would have to take	Yes
12) Use basic mathematical skills to help solve a problem	No	No		
13) Identify solutions for a problem	No	No		
14) Identify and explain the solution for a problem	No	No		
15) Explain how changes in a problem situation might affect the solution	No	No		

Another assignment has the students create an infographic where they have to evaluate how strongly data supports a hypothesis (Question 2) so that they can use the scientific evidence as supporting facts. This effective method makes students practice the skill of application by applying what they know/ learned and apply it in the infographic assignment which falls within the Cognitive Process Dimension apply category. The instructor for the course assesses all the assignments on the students' ability to identify the appropriate additional information (Question 4). Being assessed on this skill is a good way to push students in the right direction of self-learning skills; however, this might not be the most effective method of teaching critical thinking skills.

AnS 211 is an issues based course so students discuss throughout the course various spurious relationships and if they support a claim or not (Question 5). Just because a course's outcomes include the skill, it still might not include the most effective methods to allow students to obtain the skills.

Not only does this course focus on spurious relationships but it also focuses on if invited inferences are supported by specific information (Question 8) which isn't taught in the most effective way. The instructor teaches this through discussions, assignment, and guest speakers. Students must gather information needed to evaluate a situation (Question 7) when making their crisis management plan. This assignment is an effective method where the students have to apply what they are learning into creating the management plan which falls within the Cognitive Dimension Apply category. Students are also presented with a change in the situation then must find a new solution (Question 15) which they are forced to practice the skills of application and analysis which can be categorized as apply and analyze within the Cognitive Process Dimension.

In the course, book assignment discussions are assigned to allow students to separate relevant from irrelevant information when presented a scenario by the instructor (Question 10). They then have discussions to apply the information and to identify the problem (Question 11). Having a large class participate in a discussion can be an effective method however, the instructor must make sure that all the students are getting equal opportunity to practice this skill. Students participate in a domestic food security assignment. They are presented with a scenario and a set of questions. Students must then identify the solution (Question 13) and then explain the best solution for the problem (Question 14). These methods are effective as students must evaluate, analyze and then apply (Cognitive Process Dimension) the information into the assignment that the instructor has for them. Students are exposed to the skill of providing alternative explanations for spurious associations through the instructor's lectures (Question 6) which isn't an effective method to teach this particular skill.

The AnS 224 (Table 4.12) instructor reported that three critical thinking skills are directly taught in the course. When students are involved in the color code discussions, they have to provide why a result occurs due to the code. Students are practicing the skill of providing alternative explanations for patterns of results that has possible causes (Question 3). In a large group, discussion isn't the most effective method as have all your students might not get the practice. In students' ethics assignments, they evaluate whether spurious information strongly supports a hypothesis (Question 5) as they must argue both sides. This assignment is an effective method to teach this skill as the students have to gain the factual knowledge (Knowledge Dimension) for the arguments and then create (Cognitive Process Dimension) an argument for both sides of the topic.

Table 4.11

AnS 211- Issues Facing Animal Science

Question	Directly Taught	Indirectly Taught	Method Examples	Effective Method?
1) Summarize the patterns of results	Yes	No	Students develop a message point from a topic summarized together in three headlines	Yes
2) Evaluate how strongly data supports a hypothesis	Yes	No	Students create infographic with scientific pieces of supporting facts	Yes
3) Provide alternative explanations for results	No	No		
4) Identify additional information needed to evaluate a hypothesis	Yes	No	Assignments are graded on appropriate additional sources	No
5) Evaluate whether information supports a hypothesis	Yes	No	Issues based course	No
6) Provide alternative explanations for spurious associations	No	Yes	Presented to students in lecture	No
7) Identify additional information needed to evaluate a hypothesis	Yes	No	Students gather information from other resources for crisis management plan project	Yes
8) Determine whether an inference is supported by information	Yes	No	Main focus of the course	No
9) Provide relevant alternative interpretations for a specific set of results	No	No		
10) Separate relevant from irrelevant information	Yes	No	Book assignment discussion presents students with questions of where the data is perspective	No
11) Use and apply relevant information	Yes	No	Discussions apply information and seek where the problem is	No
12) Use basic mathematical skills to help solve a problem	No	No		
13) Identify solutions for a problem	Yes	No	Domestic food security assignment students must find data	Yes
14) Identify and explain the solution for a problem	Yes	No	Domestic food security assignment students explain what should be done	Yes
15) Explain how changes in a problem situation might affect the solution	Yes	No	Emergency action plan assignment- students are presented with a change and must find a new solution	Yes

At the beginning of the course, the instructor specifically teaches students what a good essay looks like and how students can effectively use and apply relevant information to evaluate a problem (Question 11). This effective method allows students to fully understand this skill and then apply it the rest of the semester in different assignments and exams which both fall within the Cognitive Process Dimension.

The instructor indirectly teaches nine critical thinking skills. Since the instructor isn't purposefully teaching these skills, this is not an effective approach to stimulate effective learning. Students practice summarizing patterns without making inappropriate inferences (Question 1) when they participate in gene pattern discussions. While completing assignments, students are expected to identify additional information needed (Question 4) to complete the task correctly. Expectations of the students are set at the beginning of the course so that they understand, in assignment and exams, that they need to provide alternative explanations of spurious associations that they face (Question 6), identify additional information (Question 7), determine whether inference are backed by information (Question 8), and that there's right answer so they are able to provide relevant alternative explanations (Question 9). The instructor enforces these expectations through assignments, exams, and lectures. Students practice but are not specifically taught basic mathematical skills to solve a real-world problem (Question 12) within their nutrition assignments. In their ethics assignments, students are proposed a scenario which students have to identify a solution (Question 13) and explanation the solution to the problem (Question 14).

Table 4.12

AnS 224- Companion Animal Science

Question	Directly Taught	Indirectly Taught	Method Examples	Effective Method?
1) Summarize the patterns of results	No	Yes	Gene pattern discussion	No
2) Evaluate how strongly data supports a hypothesis	No	No		
3) Provide alternative explanations for results	Yes	No	Color codes discussions- students must provide why something happens	No
4) Identify additional information needed to evaluate a hypothesis	No	Yes	Provides examples through explanations of assignments and expectations	No
5) Evaluate whether information supports a hypothesis	Yes	No	Ethics assignment students must argue both sides of an issue	Yes
6) Provide alternative explanations for spurious associations	No	Yes	Instructor expects that information in assignment and exams are backed up	No
7) Identify additional information needed to evaluate a hypothesis	No	Yes	Ethics assignment students utilize additional information	No
8) Determine whether an inference is supported by information	No	Yes	Provides examples in lecture	No
9) Provide relevant alternative interpretations for a specific set of results	No	Yes	Ethics assignment students state facts on both sides. No one right answer for the assignment	No
10) Separate relevant from irrelevant information	No	No		
11) Use and apply relevant information	Yes	No	Instructor teaches students what a good essay looks like and how to support statements	Yes
12) Use basic mathematical skills to help solve a problem	No	Yes	Practices through nutrition assignments	No
13) Identify solutions for a problem	No	Yes	Ethics assignment must propose an idea	No
14) Identify and explain the solution for a problem	No	Yes	Ethics assignment must then explain if the idea is reasonable	No
15) Explain how changes in a problem situation might affect the solution	No	No		

The AnS 225 (Table 4.13) instructor reported that nine critical thinking skills were taught in the course. When students learn about parity distribution of piglets, they are able to summarize patterns of results without making inappropriate inferences (Question 1). This isn't an effective method as they are just presented the information in the course. During the scenario-based exams, students provide alternative explanations for a pattern when they are presented a problem of how people breeding sows might vary from farm to farm (Question 3). This effective method forces to understand the factual knowledge of what's going on and must then apply the information to the scenario which falls within the Cognitive Process Dimension. Not only are they able to provide alternative explanations during an exam but they are also able to use and apply relevant information (Question 11) and provide relevant alternative interpretations of specific set of results (Question 9) as there is always more than one right answer.

Exams are good ways to assess if students are gaining these skills; however, they aren't effective methods to teach the students the skills. During class activities, students identify additional information (Question 4) when understanding why meat prices change depending on the time of year. This isn't the most effective method to teach these skills as there isn't any higher order thinking being practiced. Students participate in a budgeting lab where they have to use basic mathematical skills to solve a problem (Question 12) and identify a solution when the problem is changed (Question 15). Through many activities the instructor presents the students with scenarios where students have to identify solutions (Question 13) and then explain the solution (Question 14). The methods that instructor implements for skills 12-15 are effective methods as it forces students to understand the information, analyze the scenarios and then create a solution for the problem which falls within Cognitive Process Dimension.

Table 4.13
AnS 225- Swine Science

Question	Directly Taught	Indirectly Taught	Method Examples	Effective Method?
1) Summarize the patterns of results	Yes	No	Explanation of parity distribution of piglets	No
2) Evaluate how strongly data supports a hypothesis	No	No		
3) Provide alternative explanations for results	Yes	No	Scenario questions such as how people breeding sows might vary from different farms	Yes
4) Identify additional information needed to evaluate a hypothesis	Yes	No	Lecture about pricing differences of cuts of meat depending on the time of year	No
5) Evaluate whether information supports a hypothesis	No	No		
6) Provide alternative explanations for spurious associations	No	No		
7) Identify additional information needed to evaluate a hypothesis	No	No		
8) Determine whether an inference is supported by information	No	No		
9) Provide relevant alternative interpretations for a specific set of results	Yes	No	Exam questions are open ended and have more than one right answer	No
10) Separate relevant from irrelevant information	No	No		
11) Use and apply relevant information	Yes	No	Exams pull in information that is provided in the class	No
12) Use basic mathematical skills to help solve a problem	Yes	No	Budgeting analysis assignment	Yes
13) Identify solutions for a problem	Yes	No	Instructor presents problems then students have to solve it	Yes
14) Identify and explain the solution for a problem	Yes	No	Exams are scenario based and students must back up their answer	Yes
15) Explain how changes in a problem situation might affect the solution	Yes	No	Budgeting analysis assignment changes the situation and students explain what the solution would now be	Yes

The AnS 226 (Table 4.14) instructor reported that ten critical thinking skills were taught throughout the course. Right away in the course, students practice summarizing patterns of results in a graph (Question 1) by completing an article assignment addressing the relationship between price and demand. For this article assignment, students also evaluate spurious information (Question 5) when reading about relationships between prices and the grading system. This assignment is an effective way to teach these two skills as they have to read the article and analyze and evaluate what is going on in the article which falls within the Cognitive Process Dimension. Students are also expected to provide alternative explanations for a pattern of results (Question 3) when they complete a SPA report assignment where students have to explain what happened for the different values within the report. This assignment forces students to analyze the data in the report and then apply what they found to the assignment (Cognitive Process Dimesnion).

The instructor teaches the class about partial budgets where students have to identify additional information needed (Question 7) and then separate the irrelevant from relevant information (Question 10) to solve the problem the instructor presents to them. This assignment allows the instructor to effective teach these skills as they have to analyze all the information (Cognitive Process Dimesnion). When students interpret EPDs they are providing relevant alternative interpretations (Question 9) depending on their scenario with which they are dealing. This effective method allows students to understand or interpret the different pieces of information given to them both categories fall within the Cognitive Process Dimension.

One part of the course is learning about live evaluation and carcass evaluation. Students in the carcass evaluation must use and apply relevant information to evaluate the problem (Question 11) that the instructor provides them. This effective method allows students to

analyze the pieces of information and then apply it to the assignment. The instructor then allows the students to use basic math skills (Question 12) when figuring out a price for the animal but does not directly teach the math skills, which isn't an effective method to teach these skills.

In labs and assignments, students must identify solutions for a problem like those in the pasture lab (Question 13) and then support (Question 14) their decisions they turn in. Having a lab where students have to identify solutions for a problem is an effective teaching method as students have to evaluate the information to identify a solution however expecting students to back up their answers without specifically teaching isn't an effective method. Students are also faced with scenarios where the situation changes and they must come up with a new solution (Question 15) such as in the ration lab. This effective method allows students to understand the content on hand, analyze the situation and then create a new solution for the change which all fall under the Cognitive Process Dimension.

The AnS 319 (Table 4.15) instructor reported eleven skills of critical thinking taught throughout the course. When students are learning about nutrition pathways, they are practicing the skill of summarizing patterns of results (Question 1). Throughout lecture discussions, students evaluate data (Question 2) and the instructor provides examples of whether spurious information strongly supports a claim (Question 5). Lectures and lecture discussions aren't an effective method as the students don't have to participate in the activity. With explaining relationships in nutrition, students learn how to provide alternative explanations for a spurious relationship (Question 6). This information is only delivered through lectures which doesn't allow students to actively learn this skill. During exams, students must provide additional information (Question 7) and provide relevant alternative interpretations of results (Question 9) to successfully answer questions which is an effective way to have students answer questions

Table 4.14
AnS 226- Beef Cattle Science

Question	Directly Taught	Indirectly Taught	Method Examples	Effective Method?
1) Summarize the patterns of results	Yes	No	Article assignment about the relationship between price and demand	Yes
2) Evaluate how strongly data supports a hypothesis	No	No		
3) Provide alternative explanations for results	Yes	No	SPA report assignment students explain what happened with the differences in values	Yes
4) Identify additional information needed to evaluate a hypothesis	No	No		
5) Evaluate whether information supports a hypothesis	Yes	No	Reading assignment students see statements of beef prices and the grading system failing	Yes
6) Provide alternative explanations for spurious associations	No	No		
7) Identify additional information needed to evaluate a hypothesis	Yes	No	Partial budget assignment students utilize various sources	Yes
8) Determine whether an inference is supported by information	No	No		
9) Provide relevant alternative interpretations for a specific set of results	Yes	No	Practice with EPDs in the bull buyer game	Yes
10) Separate relevant from irrelevant information	Yes	No	Partial budget assignment students don't utilize all the pieces of information	Yes
11) Use and apply relevant information	Yes	No	Students in the carcass evaluation lab take information to determine a price	Yes
12) Use basic mathematical skills to help solve a problem	No	Yes	Live evaluation pricing lab	No
13) Identify solutions for a problem	Yes	No	Pasture lab students are presented a problem	Yes
14) Identify and explain the solution for a problem	Yes	No	Students must back up all assignment questions	No
15) Explain how changes in a problem situation might affect the solution	Yes	No	Ration lab presents students with a question of what changes can occur and how would it affect your recommendation	Yes

utilizing higher order thinking skills and falls within both the Knowledge and Cognitive Process Dimension. These exams are also short answer-based questions so students must use and apply relevant information (Question 11), identify solutions to a problem (Question 13) that is presented to them and explain the solution (Question 14). Changing the problem challenges the students to provide another solution. In practice problems, the instructor teaches students how to use basic mathematical skills (Question 12) when solving dry matter problems. These methods (Question 11-15) are effective as they allow students to learn the material, apply it to the scenarios presented and then generate solutions for the problems which all fall within the Cognitive Process Dimension.

AnS 320 (Table 4.16) reported to teach six critical thinking skills. Students practice various critical thinking skills through completing problem sets every week. In the problem sets, students must make recommendations for animals' diets and provide alternative explanations for the pattern (Question 3). For these diets, students must identify additional information needed (Question 4) to be successful in making the rations. To ensure the best quality ration, students recalculate diets and make sure it supports the scenario that they are working with (Question 7). The instructor teaches students how to separate relevant from irrelevant sources (Question 10) while working through problem sets that are utilizing basic math skills (Question 12) to balance diets. All of these methods are effective ways to teach higher order thinking skills which falls within the Knowledge and Cognitive Process Dimensions. Students must have the factual knowledge of nutrition and remember what they have learned in the class. They then have to understand and summarizing the different characteristics of nutrition to then analyze the problem sets and then create a solution for the problems.

Table 4.15
AnS 319- Animal Nutrition

Question	Directly Taught	Indirectly Taught	Method Examples	Effective Method
1) Summarize the patterns of results	Yes	No	Nutrition pathway lectures	No
2) Evaluate how strongly data supports a hypothesis	Yes	No	Evaluating data in discussions	No
3) Provide alternative explanations for results	No	No		
4) Identify additional information needed to evaluate a hypothesis	No	No		
5) Evaluate whether information supports a hypothesis	Yes	No	Provides examples in lecture/ discussions	No
6) Provide alternative explanations for spurious associations	Yes	No	Explains different relationships in nutrition	No
7) Identify additional information needed to evaluate a hypothesis	Yes	No	Short answer exams that students must provide alternative explanations	Yes
8) Determine whether an inference is supported by information	No	Yes	Shows examples in lectures	No
9) Provide relevant alternative interpretations for a specific set of results	Yes	No	Students must provide other ways to explain the information	Yes
10) Separate relevant from irrelevant information	No	No		
11) Use and apply relevant information	Yes	No	Short answer exams	Yes
12) Use basic mathematical skills to help solve a problem	Yes	No	Dry Matter problems	Yes
13) Identify solutions for a problem	Yes	No	Scenario based exams	Yes
14) Identify and explain the solution for a problem	Yes	No	Scenario based exams where students have to explain answer	Yes
15) Explain how changes in a problem situation might affect the solution	Yes	No	Exam questions change the problem and students must come up with solutions	Yes

Table 4.16

AnS 320- Animal Feeds and Feeding

Question	Directly Taught	Indirectly Taught	Method Examples	Effective Method?
1) Summarize the patterns of results	No	No		
2) Evaluate how strongly data supports a hypothesis	No	No		
3) Provide alternative explanations for results	Yes	No	Students must make recommendations for diets and explain why they used certain feedstuffs	Yes
4) Identify additional information needed to evaluate a hypothesis	Yes	No	Students identify nutrition requirements for animals and explain	Yes
5) Evaluate whether information supports a hypothesis	No	No		
6) Provide alternative explanations for spurious associations	No	No		
7) Identify additional information needed to evaluate a hypothesis	Yes	No	Students must go back and recalculate diets and see if it's in reason of the hypothesis	Yes
8) Determine whether an inference is supported by information	No	No		
9) Provide relevant alternative interpretations for a specific set of results	No	No		
10) Separate relevant from irrelevant information	No	No		
11) Use and apply relevant information	Yes	No	Instructor teaches students to use relevant sources when solving problems in their problem sets	Yes
12) Use basic mathematical skills to help solve a problem	Yes	No	Practices in their problem sets	Yes
13) Identify solutions for a problem	No	No		
14) Identify and explain the solution for a problem	No	No		
15) Explain how changes in a problem situation might affect the solution	No	No		

AnS 331 (Table 4.17) reported eight skills of critical thinking being taught in the course. During lectures and lecture discussions students learn about developmental biology where the instructor points out patterns across genders (Question 1). This isn't the most effective method as students aren't utilizing higher order thinking skills. For assignments, students have to provide alternative explanations of results (Question 3) when they research journal articles and identify additional information needed when doing a literature search assignment (Question 4). This activity is an effective method of teaching as these students have to apply knowledge and then create explanations for results (Cognitive Process Dimension).

During class activities, students must identify additional information needed to evaluate the problem (Question 7), and determine if the inference is supported by information (Question 8). Students are able to learn from this effective method as they have to recognize additional information needed and then analyze if statements are supported by information (Cognitive Process Dimension). The instructor challenges students by providing them scenario-based questions in assignments and exams and posing the question "what went wrong?" so the students must use and apply relevant information to evaluate the problem (Question 11). This methods allows students to practice applying analyzing and evaluating information that relates to the problem on hand (Cognitive Process Dimension).

One specific assignment is a synch protocol assignment. Students are faced with a scenario and must identify and explain the best solution for the real-world problem (Question 13 and 14). This method forces higher order thinking skills to be practiced as students have to identify a solution and then distinguish between several solutions which one would be the best for the scenario (Cognitive Process Dimension). Students are provided examples of spurious

relationships and how to evaluate how strongly the information supports a claim (Question 5) during lectures but are not directly taught the skill which isn't an effective method to teach.

AnS 352 (Table 4.18) teaches twelve critical thinking skills throughout the course. While completing exams and problems sets, students summarize information given to them (Question 1) and interpret different genetic values (Question 3) and interpret the answer they come up with (Question 8). Quizzes are open note to allow students to go and find additional information (Question 4) to completely answer the question. For exams, students are given the formulas and they must assess the question and figure out which piece of additional information (Question 7) is needed to complete the problem. When completing a problem, students provide relevant alternative interpretations (Question 9) of the value they come up with to tie it back to the question the instructor provides them. One specific problem set students deal with is genetic change where students pick out what information is relevant to utilize in the problem (Question 10 and 11). These problem sets require the students to use basic mathematics skills to evaluate a problem (Question 12) as that is the basis of the course.

The instructor provides lessons to the students where they have to identify the solution when dealing with a crossbreeding example and apply it to real world (Question 13), explain a solution when working through EPDs that are applying to a producer setting (Question 14) and find a new solution when the problem changes in predicting genetic change over time (Question 15). All of these methods are effective ways to teach critical thinking skills. By participating in problem sets, quizzes and exams students first have to remember the content and fully understand to then apply it to the problems presented to them. Students have to analyze the information and then evaluate to create a solution for the problem. All of these methods are categorized within the Cognitive Process and Knowledge Dimensions.

Table 4.17
AnS 331- Domestic Animal Reproduction

Question	Directly Taught	Indirectly Taught	Method Examples	Effective Method?
1) Summarize the patterns of results	Yes	No	Instructor points out trends across genders in development biology	No
2) Evaluate how strongly data supports a hypothesis	No	No		
3) Provide alternative explanations for results	Yes	No	Journal article assignment students come up with different explanations	Yes
4) Identify additional information needed to evaluate a hypothesis	Yes	No	Students do a literature search and learn biased vs. unbiased research	Yes
5) Evaluate whether information supports a hypothesis	No	Yes	Examples in lecture	No
6) Provide alternative explanations for spurious associations	No	No		
7) Identify additional information needed to evaluate a hypothesis	Yes	No	Research activity	Yes
8) Determine whether an inference is supported by information	Yes	No	Activity where students must find a product backed by factual data	Yes
9) Provide relevant alternative interpretations for a specific set of results	No	No		
10) Separate relevant from irrelevant information	No	Yes	Instructor utilizes case studies to lead class discussions	No
11) Use and apply relevant information	Yes	No	Scenario based question (assignments and exams) “what went wrong?”	Yes
12) Use basic mathematical skills to help solve a problem	No	No		
13) Identify solutions for a problem	Yes	No	Student utilize synch protocols and address the issue	Yes
14) Identify and explain the solution for a problem	Yes	No	With the synch protocols, they then have to explain the issue	Yes
15) Explain how changes in a problem situation might affect the solution	No	No		

Table 4.18

AnS 352- Genetic Improvement of Domestic Animals

Question	Directly Taught	Indirectly Taught	Method Examples	Effective Method?
1) Summarize the patterns of results	Yes	No	Students summarize information presented in assignments	Yes
2) Evaluate how strongly data supports a hypothesis	No	No		
3) Provide alternative explanations for results	Yes	No	Student interpret values in problem sets	Yes
4) Identify additional information needed to evaluate a hypothesis	Yes	No	Quizzes are open note to allow students to go and find additional information	Yes
5) Evaluate whether information supports a hypothesis	No	No		
6) Provide alternative explanations for spurious associations	No	No		
7) Identify additional information needed to evaluate a hypothesis	Yes	No	Formulas and students must assess the question and identify which one to use	Yes
8) Determine whether an inference is supported by information	Yes	No	Students must interpret the answer	Yes
9) Provide relevant alternative interpretations for a specific set of results	Yes	No	Students must understand what a value means and how to interpret it	Yes
10) Separate relevant from irrelevant information	Yes	No	Genetic change assignment- students pick and choose the relevant information	Yes
11) Use and apply relevant information	Yes	No	Must use a formula and then interpret it	Yes
12) Use basic mathematical skills to help solve a problem	Yes	No	Problems sets have students using math for calculating different genetic characteristics	Yes
13) Identify solutions for a problem	Yes	No	Instructor provides a crossbreeding examples and students apply how they could use it in management decisions	Yes
14) Identify and explain the solution for a problem	Yes	No	Students sort through EPDs and select the animal based on a scenario and explain why that one would work	Yes
15) Explain how changes in a problem situation might affect the solution	Yes	No	Predicting genetic change over time problems- if one thing changes what will happen	Yes

AnS 411 (4.19) reported that during the course seven critical thinking skills are taught. Through lectures and class discussions, guest speakers utilize infographics to base their discussion off of and evaluate how strongly data supports a claim (Question 2). These speakers also provide the class with real world examples of inferences support by specific information (Question 8). Even though this is a good way to expose students to this skill it's not the most effective way since guest speakers are directly teaching the skills in their lesson. Students during this course learn skills to successfully write editorials, write an issue statement and give a persuasive presentation. One of the skill building exercises students learn about is digital fragmentation. They are able to provide alternative explanations for the patterns of results (Question 3) of digital fragmentations through worksheets and discussions. This is an effective method as the students have to have the understanding of the new material to be successful to apply the information to the worksheet, small group discussions and then class discussions which falls within the Cognitive Process Dimension.

Before students give a persuasive presentation, the instructor gives an example presentation on fur farming. Students then practice evaluating the instructor and participates in a discussion on controversial topics where alternative explanations of spurious associations (Question 6) are brought up. For the presentations, students have to provide relevant interpretations of sets of results (Question 9) on their topic while identifying the problem on hand and explaining the solution (Question 13 and 14). These methods are effective methods as students apply factual information to a presentation where students have to create a unique topic that they are passionate about to talk about (Cognitive Process Dimension). Students are not directly taught how to separate relevant from irrelevant information or how to use and apply the

Table 4.19

AnS 411- Addressing Issues in Animal Science

Question	Directly Taught	Indirectly Taught	Method Examples	Effective Method?
1) Summarize the patterns of results	No	No		
2) Evaluate how strongly data supports a hypothesis	Yes	No	Guest speakers' utilize infographics to base their discussion off of for the class	No
3) Provide alternative explanations for results	Yes	No	Digital fragmentation lesson- student learn background knowledge and apply it in a group activity	Yes
4) Identify additional information needed to evaluate a hypothesis	No	No		
5) Evaluate whether information supports a hypothesis	No	No		
6) Provide alternative explanations for spurious associations	Yes	No	Must analyze an example speech and discuss the in small groups and with the class	Yes
7) Identify additional information needed to evaluate a hypothesis	No	No		
8) Determine whether an inference is supported by information	Yes	No	Guest speakers provide class with real world examples	No
9) Provide relevant alternative interpretations for a specific set of results	Yes	No	Students practice this in by giving their own presentation	Yes
10) Separate relevant from irrelevant information	No	Yes	Students research information for their editorials and presentations	No
11) Use and apply relevant information	No	Yes	Students research information for their editorials and presentations	No
12) Use basic mathematical skills to help solve a problem	No	No		
13) Identify solutions for a problem	Yes	No	Students write an issue statement	Yes
14) Identify and explain the solution for a problem	Yes	No	Students not only write an issue statement but then explain why it's important	Yes
15) Explain how changes in a problem situation might affect the solution	No	No		

relevant information but they practice those skills when writing their editorials and preparing their presentations.

Chapter Summary

The purpose of this study is to evaluate the current levels of critical thinking skills in the Department of Animal Science at Iowa State University. Objective one utilized a random sample of traditional freshmen and senior students to test their critical thinking skills and then compare them to the national norm. When comparing these two separate groups to the national norm, we found that the freshmen significantly performed higher than the national norm in three questions and the overall CAT Exam Total whereas the senior group underperformed significantly for two questions and the overall CAT Exam Total. The researcher can conclude that the animal science program has freshmen that perform better than the national norm but the senior group does not grow as much to be competitive when compared to other four-year institutions. After comparing the national norm, the two Iowa State University Animal Science grade levels were compared to one another to see if there were differences in critical thinking skills from each group to answer objective two. After comparing the two student groups by different demographics, there was a significant difference between the Animal Science seniors to the freshmen to answer objective three within gender within specific grade levels.

Objective four utilized curriculum mapping to map out where critical thinking skills are being taught in the core coursework of animal science. Even though instructors claim that they taught critical thinking, there was no direct impact on the students.

CHAPTER 5. DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study was to explore differences in critical thinking skills between freshmen and senior Animal Science students and determine where in the curriculum the critical thinking skills are being taught. Four objectives guided this study:

1. Compare freshmen and senior Animal Science students to the national critical thinking skill norms
2. Determine if there's a difference between freshmen and senior Animal Science students in critical thinking
3. Determine if there's a difference in critical thinking skills based upon selected demographic variables
4. Map critical thinking skills instructional methods in core animal science courses

Objective One- Comparison to National Norm

Summary

To address the first objective a comparison was done of the ISU Animal Science Students to the norms. The comparison not only looked at the overall comparisons but also looked at the individual critical thinking skills within CAT. The freshman group scored significantly higher than the national norm on separate relevant from irrelevant information when solving a real-world problem (Question 10, $p<0.01$), Use basic mathematic skills to help solve a real-world problem (Question 12, $p<0.05$), and for CAT Total Score ($p< 0.05$).

In the senior group, a two-tailed t-test was also completed. Seniors scored significantly lower than the nation norm When comparing this group to the national norm, it was found that this group was significantly lower for identifying additional information needed to evaluate a

hypothesis (Question 7, $p< 0.01$), explaining how changes in a real-world problem situation might affect the solution (Question 15, $p<0.01$), and evaluating how strongly correlational- type data supports a hypothesis (Question 2, $p< 0.05$). This group also scored significantly lower on the overall CAT Score ($p<0.05$).

Conclusions

It can be concluded that the freshmen entering the animal science program are outperforming the national norm freshmen as the Iowa State University animal science freshmen significantly scored higher on the overall CAT Score with a total of 15.19 compared to the national norm of 13.66 ($p<0.05$). On the other hand, seniors in animal science do not perform at the national norm level within critical thinking as the Iowa State University animal science seniors scored an overall total of 17.47 points where the national norm scored 19.04 ($p<0.05$) total points on the exam. This can be due to the fact that students are not given the opportunity to fully exercise these skills.

Recommendations

As the results showed, the freshmen in the department are thinking at a higher cognitive level. Due to this fact, instructors at the lower level courses could start at the critical thinking level that the students come in with. Traditionally, a program is trying to improve higher cognitive skills such as critical thinking skills you start at the lowest level and then challenge the student with higher order thinking levels (Fisher and Grant, 1983). In this case, the freshmen don't need to start at the lowest level but they are needing to be challenged right away so that they continue to make improvements.

Objective Two: Comparison between the Two Grade Levels

Summary

After seeing that the freshmen were outscoring national norm freshmen and that the seniors were below the national norm, objective two came about to see if there was actually a difference between the two groups. The first comparison that was completed was between the two student group's overall scores. After running a two-tailed t-test with the alpha level= 0.05, we found a significant difference between the freshman and senior groups.

The overall critical thinking skills defined by CAT can be categorized into four different domains: Evaluate and Interpret Information, Problem Solving, Creative Thinking, and Effective Communication. Each of the fifteen skills could be categorized from one to three of the domains. Understanding that there was an overall difference between the two student groups, we still wanted to check to see if that included the domains as well since the seniors don't score at the national norm. A t-test was completed to compare the grand means among domains. All the domains were significantly different with the seniors out-scoring the freshmen except for the Problem Solving domain in which significantly different was not. Seeing that not all the domains were significantly different means that the freshmen group might be out scoring the seniors within the individual skills.

Since the seniors weren't significantly different than the freshmen in all of the domains we wanted to look deeper into it to see which questions were different and what level of critical thinking the skills were. Looking at the fifteen skills the seniors actually only significantly scored higher than the freshmen for four skills: providing alternative explanations for a pattern of results that has many possible causes (Question 3, *p*-value= 0.03), evaluating whether spurious information strongly supports a hypothesis (Question 5, *p*-value=0.05), using and applying

relevant information to evaluate a problem (Question 11, *p*-value=0.03), and identifying suitable solutions for a real-world problem using relevant information (Question 13, *p*-value=0.02). Each of these skills ranged from low level (1pt) to medium level (3pt) of critical thinking.

Conclusions

From objective two, we can conclude that there's a significant difference between the two grade levels within the animal science department at Iowa State University. We do have to take into consideration that there are numerous factors causing this overall growth in the two student groups such as other courses outside the department of animal science and personal experiences within clubs, internships, jobs, etc. Even though there is a difference between the two groups the seniors are still not performing at the high level as are their peers at other institutions. This could be due to ineffective teaching strategies within the department.

To effectively teach these skills, educators must focus on integrating these skills within the curriculum, individual courses, and then the lesson plans to have critical thinking as the overall outcome when thinking about teaching and learning (Broadbear, 2012; Swartz, 2000). Most college courses were primarily teaching at the lowest levels of cognitions from the level of course, subject area or even the time period spent on the specific topic (Fisher and Grant, 1983). If the freshmen are coming in at a higher cognitive thinking level then instructors don't have to start at the lowest level allowing them to focus on higher order thinking skills.

Recommendations

Even though there are multiple factors that could be affecting the results of the two grade levels, the department needs to implement new strategies that they can control. The main recommendation for working with this objective is for the department to focus improving teaching techniques within courses to improve critical thinking skills. The best way to allow

students to utilize higher order thinking skills and gain critical thinking skills is to put them in a problem-solving environment. This allows them to take a situation given to them, process and analyze the information and practice effective oral, and written communication (Wagner, 2008). Danielson (1996) found that the most effective way to improve curriculums is from the "backward design method" which has the instructors identify the end results before creating the course materials. This allows the instructor to have the goals of the course on their mind always.

Even if an instructor exercises these skills, it is not effective if they do not assess the students in a correct way. The next step to improve critical thinking skills is to align assessments with the level of thinking that students need to master. Students will likely only work as hard as the assessment tool makes them. If instructors are trying to have their students think at a higher cognitive level, they must move away from factual information assessment tools (multiple choice, simple fill in the blanks). These types of tools encourage the students to strictly memorize the information which does not have high retention rate of information (Haynes et. al., 2016). Just as the exercises during the courses, the assessment tools need to be problem based assessments where the students have to utilize critical thinking skills to be successful on the assessment tool.

Objective Three: Demographics

Summary

Gender and grade levels were collected at the time of the students taking the CAT Test. A comparison was taken to see if there was any difference in gender within critical thinking skills. Utilizing the Tukey HSD with an alpha level of 0.05 no difference in gender was found. Digging deeper, a comparison was completed to look at gender within the class levels. There was a significant difference between senior females and freshman males.

Conclusions

From these comparisons, a conclusion can be made that there's no difference in gender within the program. There was significant difference between gender depending on their grade level within the comparison of freshmen males and seniors females ($p<0.05$). This difference however could be due to bias caused by gender and class.

Recommendations

With this study data showed that there were no significant differences based on gender which aligns with other studies in the literature. However due to many studies not finding the same relationship between gender and critical thinking skills there's an uncertain conclusion for the relationship between gender and critical thinking skills, further research on gender could be done but other demographic research could be more useful pieces of information for the department (Friedel et al., 2008). In future studies, research can focus on other traits within the department to discover items that will make a greater impact such as GPA, species interest differences, location demographics (rural vs. city) or background with animals prior to coming to Iowa State University.

Objective Four: Curriculum Mapping

Summary

To address this objective the instructors of the twelve core courses that were selected for this study went through individual interviews to report what they specifically do in their own courses to teach critical thinking skills. After the interviews there was an average of 75% of the core courses directly or indirectly teaching the skills within their courses. Even though these instructors reported that they were teaching critical thinking skills only 50% of those courses were utilizing effective methods.

Understanding that there is a disconnect between instructors thinking they teach critical thinking skills and effective methods, we separated the skills into their domains (Table 5.1). When looking at the results one could conclude that the Iowa State University Animal Science curriculum really focuses on problem solving-type skills. However, when you compare it to the students' scores from CAT, there wasn't a difference in scores. This might mean that even though the instructors teach these courses and report effective methods they might not be utilizing them in the correct way or might not be strategically teaching throughout their entire time within the program.

Table 5.1
Critical Thinking Domain Reported Teaching

CT Domains	% of Reported Teachings	% of Effective Reported Methods
Evaluate and Interpret Information	58%	57%
Problem Solving	66%	75%
Creative Thinking	58%	71%
Effective Communication	58%	71%

The main reason to utilize curriculum mapping is to strategically spread out skills throughout a program, students can really focus on a few higher order skills as it takes time to fully learn and then practice these skills. As you can see in Table 5.2, there really isn't a system in place within the Animal Science curriculum. Skills can be taught anywhere from twice throughout the curriculum to ten times. Instructors reported to be teaching critical thinking skills however, their methods are not effective in teaching these specific skills.

Table 5.2
Overall Instructor Skill Reports

Question	Direct Teaching	Indirect Teaching	No Teaching	Effective Teaching
1) Summarize the patterns of results	7	2	3	3
2) Evaluate how strongly data supports a hypothesis	3	0	9	1
3) Provide alternative explanations for results	8	0	4	6
4) Identify additional information needed to evaluate a hypothesis	6	2	4	5
5) Evaluate whether information supports a hypothesis	5	1	6	2
6) Provide alternative explanations for spurious associations	2	2	8	1
7) Identify additional information needed to evaluate a hypothesis	6	1	5	6
8) Determine whether an inference is supported by information	5	3	4	2
9) Provide relevant alternative interpretations for a specific set of results	6	1	5	5
10) Separate relevant from irrelevant information	3	2	7	2
11) Use and apply relevant information	10	1	1	8
12) Use basic mathematical skills to help solve a problem	4	3	5	4
13) Identify solutions for a problem	7	2	3	8
14) Identify and explain the solution for a problem	7	1	4	6
15) Explain how changes in a problem situation might affect the solution	5	0	7	5

Within the curriculum, all of the skills are being taught at least in one course. Each of the questions that were significantly different between the two groups ranged from two courses directly teaching it to ten out of the twelve courses teaching it (Fig. 5.1).

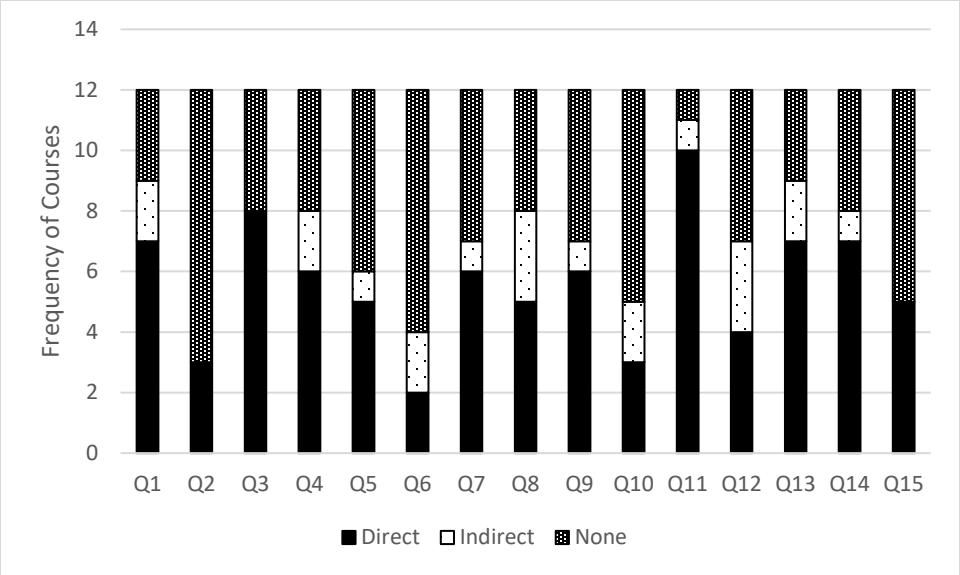


Figure 5.1. Overview of which skills are being taught

Conclusions

Overall a conclusion can be made that the instructors are trying to teach critical thinking skills; however aren't utilizing the best methods due to maybe a lack of training on different teaching techniques for critical thinking skills. There is no consistency between teaching and critical thinking scores. We wonder if the instructors are saying that they teach it but do not understand what the principles are behind critical thinking skills as none of the reported critical thinking teaching methods were 100% effective methods for critical thinking. Instructors claimed that students were taught these skills twice to six times throughout their curriculum. Having inconsistencies of teaching these skills, students are given the opportunity to exercise critical thinking. Are they teaching it but not assessing the skill correctly or are other courses outside of the department teaching these skills allowing the students to exercise and grow these skills?

Recommendations

The first step in improving critical thinking in the curriculum is to map out where these skills should be taught and exercised throughout the curriculum. Instructors need to focus on

two to three skills per course to really allow students to fully learn and exercise those skills. One must first master each level of Bloom's Taxonomy to achieve higher order thinking skills. If there is no systematic way of moving students through each level of thinking, one cannot gain critical thinking skills. Collaboration amongst instructors in the department allows everyone to understand where and how these skills are being taught so that instructors can build upon on another moving student through the process of achieving critical thinking skills (Uchiyama & Radin, 2009).

To start mapping out the curriculum, it is best to first define the goals of the department and each course, define what activities an instructor might utilize, organize all the experiences, and then evaluate the goals at the end (Tyler, 1950; Taba, 1962). From curriculum mapping the department should be able to answer the three key questions or curriculum mapping which are a) Who is doing what? b) How does the work align with the program's goals and outcomes? c) Are we working efficiently and effectly? (Jacobs, 2004). Once the skills are assigned to specific courses then the instructor can start implementing effective teaching techniques.

Contribution to the Animal Science Department

This study adds knowledge to the department about its curriculum and the students' critical thinking skills. Prior to this project, the department did know that the students were not performing on the same level as the national norm in critical thinking skills (Skaar, 2013). Questions still were left unanswered, as the department did not know if there was a difference between freshman and seniors and if any of the core courses were teaching critical thinking skills. Now we can say that there is a difference from when students enter the program to when they leave. However, data show that students are not capable performing at a level that is comparable to other students in a four-year university.

With this information, the question now is how can the department change their curriculum to improve their students' critical thinking skills? The first step is to strategically plan where certain skills are going to be taught and exercised. Currently, there is no specific system of knowing what students are exposed to before they enter a certain course. The lower level courses should introduce the lower level critical thinking skills and as a student works their way through the curriculum, they should be taught the more complex critical thinking skills along with reinforcing the skills taught in previous courses.

Contribution to Literature

Researchers have stated that to gain critical thinking skills you must utilize higher order thinking skills (Rudd, Baker & Hoover, 2000). The higher order thinking skills goes through various levels of thinking to be able to achieve them. Bloom's taxonomy states that one does not start thinking critically until the fourth step in the Six Step Bloom's Taxonomy pyramid (Adams, 2015). Understanding the process behind critical thinking skill is essential to fully understand why students are achieving the levels of critical thinking they are. We already know that higher education has not fully utilized new techniques to teach critical thinking skills (Fisher & Grant, 1983). As the freshman entering the animal science program, they are performing at a higher level than their peers at other institutions. If instructors are not fully utilizing new techniques, there would not be significant change in their students. Although the seniors did score significantly higher than the freshman, we cannot say that the direct impact was from the animal science curriculum as we know professors are not utilizing the correct techniques.

Collaboration on curriculum is key to ensure an equal amount of teaching for each skill (Uchiyama & Radin, 2009). When instructors get together and map out the curriculum, it allows them to see where the skill is being taught, if it aligns with the programs goals and outcomes and

if it's being efficiently and effectively taught (Jacobs, 2004). Looking at where instructors say they are teaching different skills varies tremendously as the courses vary from teaching two of the skills all the way to twelve of the skills within a specific course. Evenly building these skills will allow instructors to focus on a small amount of skills for the students to master by the time they are seniors.

These skills are important to teach throughout the curriculum as there is a high demand from students' potential employers to have these types of skills. To continually learn after students leave a program, they need to have the ability to think to be successful in a science or technology field (Lancelot, 1929).

Importance of Findings

The ability to think critically enables someone to find meaning in the world (Burris and Garton, 2007). We know that employers want students coming out into the industry to be able to think critically. Majority of the employers (75%) want colleges to put more emphasis on critical thinking skills as they feel higher education is where the students should learn these skills not out in the industry (Scanlon, Bruening, & Cordero, 1996; AACU, 2013). Seeing the desire from the department's student's potential employers, it is essential that the Department of Animal Science should respond. Since we know that Iowa State University Animal Science students are not performing at the same level in critical thinking compared to the national norm, then to continually be competitive in the animal science teaching, new techniques must be added to allow the students to practice critical thinking skills. Students cannot grow and gain new skills if they are not given the opportunity to learn the skill, exercise them, and be assessed on the skill. By evenly spreading out the teaching responsibility across the entire curriculum, students would

efficiently and effectively be taught the skills that allow them to think at a higher order and to think critically as their future employers are requesting.

The goals for this project was to assess the level of critical thinking skills in both the freshman and senior class, see if there was a difference between the two classes, and to map out where these skills are being taught. The CAT test was utilized to measure these critical thinking skills. This STEM based exam aligns with the goals of the Department of Animal Science. The department wants to develop and with the assessment focused on science it pairs nicely with the curriculum. This assessment also gives faculty members an opportunity to be fully involved with the scoring process. By having faculty members read the responses of their students, they can understand the students thinking process. From seeing the students responses on the exam questions, faculty members can change the techniques in their classroom.

Further Research

After completing this study, doors have been open for further research to continually improve critical thinking skills in the animal science curriculum. Mapping out the courses where exactly instructors are teaching the skills of critical thinking is a great start but it does not answer the question of the exact techniques the instructors are utilizing to allow students to exercise critical thinking skills. After clarification of techniques of critical thinking exercises, there needs to be a study to ensure what is being taught aligns with the outcomes of the course and the department along with the assessment tools that the department will be utilizing to measure levels of critical thinking skills such as the CAT Test. We know there are several factors that play a role in the improvement of critical thinking skills. Working with the other faculty members that teach the animal science students' general courses might increase the overall awareness of what the students are exposed to during their time at Iowa State University.

REFERENCES

Adams, N.E. (2015). Bloom's Taxonomy of Cognitive Learning Objectives. *Journal of the Medical Library Association.* 103 (3) DOI: http://dx.doi.org/10.3163/1536-5050.103.3.010

Anderson, L.W. (Ed.), Krathwohl, D.R. (Ed.), Airasian, P.W., Cruikshank, K.A., Mayer, R.E., Pintrich, P.R., Raths, J., & Wittrock, M.C. (2001). A taxonomy for learning, teaching, and assessing: A revision of Bloom's Taxonomy of Educational Objectives (Complete edition). New York: Longman.

Association of American Colleges and Universities (2004) Liberal education outcomes: A preliminary report on student achievement in college. AACU Liberal Education and America's Promise (LEAP) initiative Washington, DC: AACU

Association of American Colleges and Universities. (2013). It takes more than a major: Employer priorities for college learning and student success. Retrieved from http://www.aacu.org

Association of American Colleges and Universities. (2007). How should colleges prepare students to succeed in today's global economy? AACU Liberal Education and America's Promise (LEAP) initiative. Washington, DC: AACU.

Association of American Colleges and Universities. (2010). Raising the bar: Employers' views on college learning in the wake of the economic downturn. AACU Liberal Education and America's Promise (LEAP) initiative. Washington, DC: AACU.

Behavioral and Social Sciences and Education National Research Council. (Eds.). (2000). *How People Learn- Brain, Mind, Experience, and School.* Washington, D.C.: National Academy Press.

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H. & Krathwohl, D. R. (1956). Taxonomv of Education Objectives Book 1: Cognitive Domain. New York: David McKay Company, Inc.

Bransford, J.D., and B.S. Stein (1993) The IDEAL Problem Solver (2nd ed.). New York: Freeman.

Bransford, J.D., B.S. Stein, N.J. Vye, J.J. Franks, P.M. Auble, K.J. Mezynski, and G.A. Perfetto (1983) Differences in approaches to learning: An overview. Journal of Experimental Psychology: General 3(4):390-398.

Broadbear, J.T. (2012). Essential elements of lessons designed to promote critical thinking. *Journal of the Scholarship of Teaching and Learning*. Volume 3, Number 3, pp 1-14.

Brookfield, S. D. (1987). Developing critical thinkers. San Francisco: Jossey-Bass Publishers.

Burbach, M. E., Matkin, G. S., Quinn, C. E. & Searle, T. P. (2012). The impact of preparing agriculture faculty to influence student critical thinking disposition. Journal of Agricultural Education, 53(2), 1-14. doi. 10.5032/jae.2012.02001

Burris, S., Garton, B.L. (2007). Effect of Instructional Strategy on Critical Thinking and Content Knowledge: Using Problem- Based Learning in the Secondary Classroom. *Journal of Agricultural Education*. Volume 48, Number 1, pp. 106-116. DOI: 10.5032/jae.2007.01106

Caine, G., Caine, R. (2010). Strengthening and Enriching Your Professional Learning Community. Alexandria: ASCD

Center for Assessment & Improvement of Learning, Tennessee Tech University (2017) CAT (Critical Thinking Assessment Test). Retrieved from https://www.tntech.edu/cat/

Chi, M.T.H., M. Bassok, M.W. Lewis, P. Reimann, and R. Glaser (1989) Self-explanations: How students study and use examples in learning to solve problems. Cognitive Science 13:145-182.

Chi, M.T.H., N. deLeeuw, M. Chiu, and C. LaVancher (1994). Eliciting self-explanations improves understanding. Cognitive Science 18:439-477.

Chiasson, T. C., & Burnett, M. F. (2001). The influence of enrollment in agriscience courses on the science achievement of high school students. Journal of Agricultural Education, 42(1), 61-71. doi: 10.5032/jae.2001.02061

Danielson, C, (1996), Enhancing professional practice: A framework for teaching. Alexandria, VA: Association for Supervision and Curriculum Development

David R. Krathwohl (2002) A Revision of Bloom's Taxonomy: An Overview, Theory Into Practice, 41:4, 212-218, DOI: 10.1207/s15430421tip4104_2

DeAngelo, L., Hurtado, S., Pryor, J. H., Kelly, K. R., Santos, J. L., & Korn, W. S. (2009). The American college teacher: National norms for the 2007–2008 HERI faculty survey. Retrieved from http://www.heri.ucla.edu

Duron, R., Limbach, B., & Waugh, W. (2006). Critical thinking framework for any discipline. International Journal of Teaching and Learning in Higher Education, 17(2), 160-166.

Facione, P. A. (1997). Critical thinking: What it is and why it counts. [On-line]. Available at: http://www.calpress.com/critical.html.

Fawkes, D. (2001). Analyzing the scope of critical thinking exams. APA Newsletter on Teaching in Philosophy, 0(2).

Fisher, C.G. & Grant, G.E. (1983). Intellectual levels in college classrooms. In C. L. Ellner & C. P. Barnes (Eds.), Studies in College Teaching, p. 47-60. Lexington, MA: D.C. Heath & Co.

Friedel, C., Irani, T., Rudd, R., Gallo, M., Eckhardt, E., Ricketts, J. (2008). Overtly Teaching Critical Thinking and Inquiry- Based Learning: A Comparison of Two Undergraduate Biotechnology Classes. Journal of Agricultural Education. 48(1), 72-84 DOI: 10.5032/jae.2008.01072

Frisby, C.L. (1992). Construct Validity and Psychometric Properties of the Cornell Critical Thinking Test (Level Z): A Contrasted Groups Analysis. Psychological Reports 71: 291–303.

Garrison, D.R., Anderson, T., Archer, W. (2001). Critical Thinking, Cognitive Presence, and Computer Conferencing in Distance Education. American Journal of Distance Education. Volume 15. No 1. pp 7-23.

Hassan, K. A. & Madhum, G. (2007). Validating the Watson Glaser Critical Thinking Appraisal. Higher Education, 54(3), 361-383.

Haynes, A., Lisic, E., Goltz, M., Stein, B., & Harris, K. (2016). Moving Beyond Assessment to Improving Students' Critical Thinking Skills: A Model for Implementing Change. *Journal of the Scholarship of Teaching and Learning*. Volume 16, No. 4, pp. 44-61.

Henderson, J. (1983). Personal Commitment to Cognitive Skill Development. Journal of the American Association of Teacher Educators in Agriculture. Volume 24, Number 3, pp. 71-75. DOI: 10.5032/jaatea.1983.03071

Jacobs, H. H. (2004). Getting results with curriculum mapping. Alexandria, VA: Association for Supervision and Curriculum Development.

Jacobs, S. S. (1995). Technical characteristics and some correlates of the California critical thinking skills test. Research in Higher Education, 36(1), 89-108.

Jonassen, D. H. (1997). Instructional design models for well-structured and ill-structured problem-solving learning outcomes. Educational Technology: Research and Development, 45(1), 65-95.

Kegan, R. (1994). In over our heads: The mental demands of modern life. Cambridge, MA: Harvard University Press.

Kolb, D. A. (1984). Experiential learning: Experience as the source of learning and development. Englewood Cliffs, NJ: Prentice Hall.

Kuhn, D. (1999). A developmental model of critical thinking. American Educational Research Association, 28(2), 16-25.

Lancelot, W.H. (1929). Permanent Learning: A Study in Educational Teachings. New York: John Wiley and Sons, Inc.

Lundy, L. K., Irani, T. A., Ricketts, J. C., Eubanks, E. E., Rudd, R.D., GalloMeagher, M., et al. (2002, December). A mixed-methods study of undergraduate dispositions toward thinking critically about biotechnology. Paper presented at the National Agricultural Education Research Conference, Las Vegas, NV.

Merriam-Webster (2017). Definition of assessment. *Merriam-Webster Dictionary.* Retrieved from https://www.merriam-webster.com/.

Miller, C. (1989). Cognitive levels of instruction and student performance in College of Agriculture courses. Unpublished doctoral dissertation. The Ohio State University, Columbus

National Research Council. (1988). Understanding agriculture: New directions for education. Danville, IL: The Interstate Printers and Publishers, Inc.

Newcomb, L.H. & Trefz, M.K. (1987). Levels of cognition of student tests and assignments in the College of Agriculture at The Ohio State University. Proceedings of the Central Region 41st Annual Research Conference in Agricultural Education, Chicago, IL.

Norris, S. P., & Ennis, R. H. (1989). Evaluating critical thinking. Pacific Grove, CA: Critical Thinking Press and Software.

Parr, B. A., & Edwards, M. C. (2004). Inquiry-based instruction in secondary agricultural education: Problem-solving – An old friend revisited. *Journal of Agricultural Education*, 45(4), 106-117. doi: 10.5032/jae.2004.04106

Pascarella, E., & Terenzini, P. (1991). How college affects students: Findings and insights from twenty years of research. San Francisco: Jossey Bass

Paul, R. W. (1985). Bloom‘s taxonomy and critical thinking instruction. Educational Leadership, 42(8), 36-39.

Paul, R. W. (1995). Introduction. In R. W. Paul (Ed.), Critical thinking: How to prepare students for a rapidly changing world. Santa Rose, CA: Foundation for Critical Thinking

Paul, R., & Elder, L. (2001). Critical thinking: Tools for taking charge of your learning and your life. Upper Saddle River, NJ: Prentice Hall.

Paul, R., & Elder, L. (2006). The miniature guide to critical thinking concepts and tools. In The Foundation for Critical Thinking (4th Ed.). Retrieved from https://www.criticalthinking.org/files/Concepts_Tools.pdf

Paul,R. W., (1995). Critical Thinking: How to prepare students for a rapidly changing world. Santa Rosa, CA: Foundation for Critical Thinking.

Peirce, W. P. (2005). The year of critical thinking at Prince George's Community College: An integrated professional development program. New Directions for Community Colleges, 2005(130), 79–85. doi: 10.1002/cc.198

Perry, D.K., Retallick, M.S., & Paulsen, T.H. (2014). A Critical Thinking Benchmark for a Department of Agricultural Education and Studies. Journal of Agricultural Education. 55 (5), 207-221. doi: 10.5032/jae.2014.05207

Phipps, L. J., Osborne, E. W., Dyer, J. E., & Ball, A. (2008). Handbook on agricultural education in public schools (6th ed.). Clifton Park, NY: Thomson Delmar Learning.

Pithers, R. T., & Soden, R. (2000). Critical thinking in education: A review. Educational Research, 42(3), 237-249.

Rollins, T.J. (1990). Levels of Critical Thinking of Secondary Agriculture Students. Journal of Agricultural Education. Volume 31, Number 3, pp. 47-53. DOI: 10.5032/jae.1990.03047

Rudd, R., Baker, M., & Hoover, T. (2000). Undergraduate agriculture student learning styles and critical thinking abilities: Is there a relationship? Journal of Agricultural Education, 41(3), 2-12. doi:¬ 10.5032/jae.2000.03002

Scanlon, D.C., Bruening, T.H., Cordero, A. (1996). An Industry Perspective on Changes Needed in Agricultural Education Curricula. Journal of Agricultural Education. Volume 37, Number 2, pp. 17-23. DOI: 10.5032/jae.1996.02017

Secretary’s Commission on Achieving Necessary Skills (1991). What work requires of schools: A SCANS report for America 2000. Washington D.C.: U.S. Department of Labor.

Skaar,B. (2013) Report provided to College of Agriculture and Life Sciences Curriculum Assessment Committee. (Available from the Department of Animal Science at Iowa State University, 1221 Kildee Hall, Ames, IA, 50010.)

Stein, B., Haynes, A., & Harris K. (2009). Assessing and improving critical thinking using the CAT instrument, ABET Best Assessment Processes Symposium XI. Symposium conducted at the meeting of Accreditation Board of Engineering and Technology, Indianapolis, IN. Retrieved from http://www.tntech.edu/cat

Swartz, R. J. (2000, June). Towards developing and implementing a thinking curriculum. Keynote address presented at the First Annual Thinking Qualities Initiative Conference. Hong Kong.

Taba, H, (1962), Curriculum development theory and practice. New York and Burlingame: Harcourt, Brace & World, Inc.

Tennessee Technological University. (2017) Report provided to Department of Animal Science. (Available from the Department of Animal Science at Iowa State University, 1221 Kildee Hall, Ames, IA 50010).

Thorndike, E.L. 1913 Educational Psychology (Vols. 1 and 2). New York: Columbia University Press.

Tsui, L. (2002). Fostering critical thinking through effective pedagogy: Evidence from four institutional case studies. Journal of Higher Education, 73(6), 740-763. doi: 10.1353/jhe.2002.0056

Tyler, R, W, (1950), Basic principles of curriculum and instruction. Chicago: University of Chicago Press,

U.S. Department of Education, National Center for Education Statistics. The NPEC Sourcebook on Assessment, Volume 1: Definitions and Assessment Methods for Critical Thinking, Problem Solving, and Writing, NCES 2000--172, prepared by T. Dary Erwin for the Council of the National Postsecondary Education Cooperative Student Outcomes Pilot Working Group: Cognitive and Intellectual Development. Washington, DC: U.S. Government Printing Office, 2000.

Uchiyama, K.P., Radin, J.L. (2009). Curriculum Mapping in Higher Education: A Vehicle for Collaboration. *Journal of Innovation Higher Education.* 33: 271-280. DOI 10.1007/s10755-008-9078-8

Wagner, T. (2008). The global achievement gap: Why even our best schools don't teach the new survival skills our children need and what we can do about it. New York, NY: Basic Books.

Walker, A., Leary, H., Hmelo-Silver, C.E., Ertmer, P.A. (Eds.). (2015). *Essential Readings in Problem- Based Learning.*West Lafayette, IN: Purdue University Press.

Whittington, M.S., Stup, R.E. (1997). Assessment of Cognitive Discourse: A Study of Thinking Opportunities Provided by Professors. *Journal of Agricultural Education.* Volume 28, Number 1, pp. 46-53. DOI: 10.5032/jae.1997.01046.

Wiggins, G., & McTighe, J. (1998). Understanding by design. UppoSaddle River, NJ: Morill Prentice Hall;

Williams, R. L., Oliver, R., Allin, J. L., Winn, B., & Booher, C. S. (2003). Psychological critical thinking as a course predictor and outcome variable. Teaching of Psychology, 30, 220223. doi:10.1207/S15328023TOP3003_04

APPENDIX A. IRB FORM

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office for Responsible Research
Vice President for Research
1138 Pearson Hall
Ames, Iowa 50011-2207
515 294-4566
FAX 515 294-4267

Date: 8/12/2016

To: Sarah Al-Mazroa
201 Curtiss

CC: Dr. Michael Retallick
206 Curtiss Hall

From: Office for Responsible Research

Title: The enhancement that the animal science curriculum has on undergraduate animal science students' critical thinking skills

IRB ID: 16-269

Study Review Date: 8/12/2016

The project referenced above has been declared exempt from the requirements of the human subject protections regulations as described in 45 CFR 46.101(b) because it meets the following federal requirements for exemption:

- (1) Research conducted in established or commonly accepted education settings involving normal education practices, such as:
  - Research on regular and special education instructional strategies; or
  - Research on the effectiveness of, or the comparison among, instructional techniques, curricula, or classroom management methods.

- (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey or interview procedures with adults or observation of public behavior where
  - Information obtained is recorded in such a manner that human subjects cannot be identified directly or through identifiers linked to the subjects; or
  - Any disclosure of the human subjects' responses outside the research could not reasonably place the subject at risk of criminal or civil liability or be damaging to their financial standing, employability, or reputation.

The determination of exemption means that:

- **You do not need to submit an application for annual continuing review.**

- **You must carry out the research as described in the IRB application.** Review by IRB staff is required prior to implementing modifications that may change the exempt status of the research. In general, review is required for any modifications to the research procedures (e.g., method of data collection, nature or scope of information to be collected, changes in confidentiality measures, etc.), modifications that result in the inclusion of participants from vulnerable populations, and/or any change that may increase the risk or discomfort to participants. Changes to key personnel must also be approved. The purpose of review is to determine if the project still meets the federal criteria for exemption.

  Non-exempt research is subject to many regulatory requirements that must be addressed prior to implementation of the study. Conducting non-exempt research without IRB review and approval may constitute non-compliance with federal regulations and/or academic misconduct according to ISU policy.

  Detailed information about requirements for submission of modifications can be found on the Exempt Study Modification Form. A Personnel Change Form may be submitted when the only modification involves changes in study staff. If it is determined that exemption is no longer warranted, then an Application for Approval of Research Involving Humans Form will need to be submitted and approved before proceeding with data collection.

Please note that you must submit all research involving human participants for review. **Only the IRB or designees may make the determination of exemption**, even if you conduct a study in the future that is exactly like this study.

Please be aware that **approval from other entities may also be needed.** For example, access to data from private records (e.g. student, medical, or employment records, etc.) that are protected by FERPA, HIPAA, or other confidentiality policies requires permission from the holders of those records. Similarly, for research conducted in institutions other than ISU (e.g., schools, other colleges or universities, medical facilities, companies, etc.), investigators must obtain permission from the institution(s) as required by their policies. **An IRB determination of exemption in no way implies or guarantees that permission from these other entities will be granted.**

Please don't hesitate to contact us if you have questions or concerns at 515-294-4566 or IRB@iastate.edu.

APPENDIX B. CAT EXAM ACCURACY REPORT

Tennessee Tech UNIVERSITY

Center for Assessment and Improvement of Learning
Box 5031 • Cookeville, TN 38505-0001 • (931) 372-3252 • (931) 372-3611

FROM: Kevin Harris, Associate Director

SUBJECT: Scoring Accuracy Check

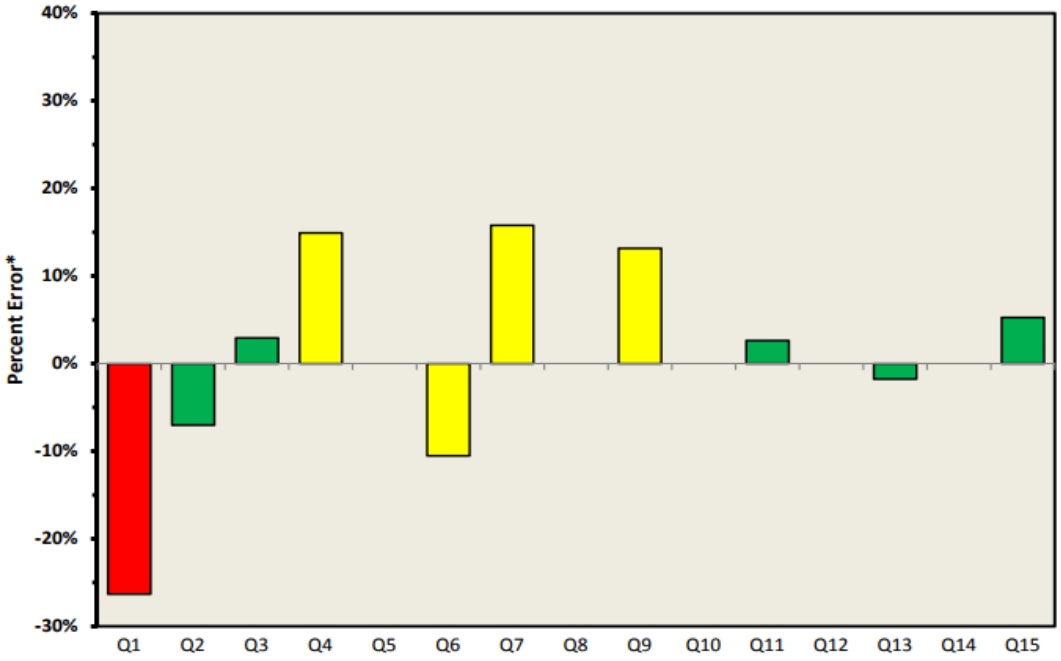
The information provided in this scoring accuracy check report was based on a random sample of tests from a scoring session conducted at your institution. The graphs illustrate the percent of error found in the sample on each question and for the overall test score. Bars colored in green indicate error that is well within an acceptable margin of error. Bars coded in yellow indicate error rates that are approaching concern. Bars coded in red indicate error rates that could lead to misinterpretation of results and indicate that that the scoring guide or training module should be reviewed before the next scoring session.

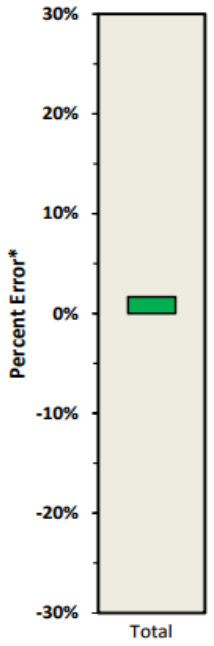
In most cases the overall score will not be seriously affected by individual questions that fall in the red warning area because questions that are scored too leniently are balanced by other questions that are scored too strictly. Infrequently, there is a consistent bias in one direction that leads to a significant deviation in overall score accuracy. If this is the case and your overall score accuracy is coded in red, we recommend adjusting your overall score by the margin of error indicated in this report before comparing to national norms.

Iowa State University-Animal Science **Accuracy Check**

Onsite Scoring Date: January 2017

Accuracy Check Date: March *2017*





	Question Error
Green	<10%
Yellow	<20%
Red	>20%

	Total Error
Green	<3%
Yellow	<5%
Red	>5%

Summary

Question #	Percent Error	Comments
Q1	-26.32%	Graders awarded too few points on this item, please review training module.
Q2	-7.02%	
Q3	2.92%	
Q4	14.91%	Graders awarded too many points on this item, please review training module.
Q5	0.00%	
Q6	-10.53%	Graders awarded too few points on this item, please review training module.
Q7	15.79%	Graders awarded too many points on this item, please review training module.
Q8	0.00%	
Q9	13.16%	Graders awarded too many points on this item, please review training module.
Q10	0.00%	
Q11	2.63%	
Q12	0.00%	
Q13	-1.75%	
Q14	0.00%	
Q15	5.26%	
Total	1.66%	CAT Total Score is validated for comparison to national norms.

APPENDIX C. FRESHMAN MEANS COMPARISON TO NATIONAL NORM

Evaluate and Interpret Info	Problem Solving	Creative Thinking	Effective Comm.	Skill Assed by CAT Question	National Mean	Institution Mean	Effect Size
X				1) Summarize the patterns of results in a graph without making inappropriate inferences	0.58	0.6	
X			X	2) Evaluate how strongly correlational-type data supports a hypothesis	0.69	0.84	
		X	X	3) Provide alternative explanations for a pattern of results that has many possible causes	0.67	0.71	
	X	X	X	4) Identify additional information needed to evaluate a hypothesis	0.96	0.99	
X				5) Evaluate whether spurious information strongly supports a hypothesis	0.52	0.55	
		X	X	6) Provide alternative explanations for spurious associations	1.04	1.13	
	X	X	X	7) Identify additional information needed to evaluate a hypothesis	0.57	0.51	
X				8) Determine whether an invited inference is supported by specific information	0.46	0.55	
		X	X	9) Provide relevant alternative interpretations for a specific set of results	0.7	0.75	
X	X			10) Separate relevant from irrelevant information when solving a real-world problem	3.01	3.51**	+0.56
X	X		X	11) Use and apply relevant information to evaluate a problem	0.88	1	
	X			12) Use basic mathematical skills to help solve a real-world problem	0.75	0.89*	+0.37
X	X			13) Identify suitable solutions for a real-world problem using relevant information	0.75	0.8	
X	X		X	14) Identify and explain the best solution for a real-world problem using relevant information	1.65	1.67	
	X	X	X	15) Explain how changes in a real-world problem situation might affect the solution	0.52	0.71	
				CAT Total Score	13.66	15.19*	+0.32

Note: Significant at *p<.05, **p<.01

APPENDIX D. SENIOR MEANS COMPARISON TO NATIONAL NORM

Evaluate and Interpret Info	Problem Solving	Creative Thinking	Effective Comm.	Skill Assed by CAT Question	National Mean	Institution Mean	Effect Size
X				1) Summarize the patterns of results in a graph without making inappropriate inferences	0.67	0.62	
X			X	2) Evaluate how strongly correlational-type data supports a hypothesis	1.21	0.92*	-0.27
		X	X	3) Provide alternative explanations for a pattern of results that has many possible causes	1.35	1.12	
	X	X	X	4) Identify additional information needed to evaluate a hypothesis	1.41	1.17	
X				5) Evaluate whether spurious information strongly supports a hypothesis	0.73	0.72	
		X	X	6) Provide alternative explanations for spurious associations	1.56	1.55	
	X	X	X	7) Identify additional information needed to evaluate a hypothesis	0.82	0.57**	-0.4
X				8) Determine whether an invited inference is supported by specific information	0.68	0.6	
		X	X	9) Provide relevant alternative interpretations for a specific set of results	0.93	0.75	
X	X			10) Separate relevant from irrelevant information when solving a real-world problem	3.14	3.25	
X	X		X	11) Use and apply relevant information to evaluate a problem	1.11	1.25	
	X			12) Use basic mathematical skills to help solve a real-world problem	0.82	0.88	
X	X			13) Identify suitable solutions for a real-world problem using relevant information	1.18	1.22	
X	X		X	14) Identify and explain the best solution for a real-world problem using relevant information	2.29	2.25	
	X	X	X	15) Explain how changes in a real-world problem situation might affect the solution	1.15	0.69**	-0.51
				CAT Total Score	19.04	17.47*	-0.28

Note: Significant at *p<.05, **p<.01

APPENDIX E. FREQUENCY OF POINTS AWARDED FOR EACH QUESTION

		Freshman		Senior	
Skill Assessed by CAT Question	Points Awarded	Freq.	Freq %	Freq.	Freq %
1) Summarize a pattern of information without making inappropriate Inferences	0	22	40.00	23	38.30
	1	33	60.00	37	61.70
2) Evaluate how strongly correlational-type data supports a hypothesis	0	26	47.30	26	43.30
	1	18	32.70	20	33.30
	2	5	9.10	7	11.70
	3	6	10.90	7	11.70
3)Provide alternative explanations for observation	0	29	52.70	19	31.70
	1	16	29.10	20	33.30
	2	7	12.70	16	26.70
	3	3	5.50	5	8.30
4)Identify additional information needed to evaluate a hypothesis	0	22	40.00	23	38.30
	1	17	30.90	16	26.70
	2	13	23.60	12	20.00
	3	1	1.80	6	10.00
	4	2	3.60	3	5.00
5) Evaluate whether spurious relationships strongly support a hypothesis	0	25	45.50	17	28.30
	1	30	54.50	43	71.70
6) Provide alternative explanations for spurious associations	0	12	21.80	4	6.70
	1	25	45.50	25	41.70
	2	17	30.90	25	41.70
	3	1	1.80	6	10.00
7) Identify additional information needed to evaluate a hypothesis	0	31	56.40	29	48.30
	1	20	36.40	28	46.70
	2	4	7.30	3	5.00
8) Determine whether an invited inference is supported by specific information	0	25	45.50	24	40.00
	1	30	54.50	36	60.00
9) Provide relevant alternative interpretations for a specific set of results	0	20	36.40	22	36.70
	1	29	52.70	31	51.70
	2	6	10.90	7	11.70

Skill Assessed by CAT Question	Points Awarded	Freshman Freq.	Freshman Freq %	Seniors Freq.	Seniors Freq %
10) Separate relevant from irrelevant information when solving a real-world	0	0	0.00	0	0.00
Problem	1	1	1.80	2	3.40
	2	3	5.50	9	15.30
	3	18	32.70	20	33.90
	4	33	60.00	28	47.50
	0	13	23.60	6	10.00
11) Use and apply relevant information to evaluate a problem	1	29	52.70	33	55.00
	2	13	23.60	21	35.00
12) Use basic mathematical skills to help solve a real-world problem	0	6	10.90	7	11.70
	1	49	89.10	53	88.30
	0	22	40.00	14	23.70
13) Identify suitable solutions for a real-world problem using relevant	1	25	45.50	27	45.80
information	2	5	9.10	9	15.30
	3	3	5.50	9	15.30
	0	24	43.60	19	31.70
	1	7	12.70	9	15.00
14) Identify and explain the best solution for a real-world problem using	2	2	3.60	0	0.00
relevant information	3	10	18.20	8	13.30
	4	9	16.40	18	30.00
	5	3	5.50	6	10.00
	0	27	49.10	27	45.00
15) Explain how changes in a real-world problem situation might affect the	1	20	36.40	26	43.30
solution	2	5	9.10	6	10.00
	3	3	5.50	1	1.70

*Note- High order of critical thinking skills are awarded a higher amount of points

APPENDIX F. OVERALL CURRICULUM DATA: REPORTED BY INSTRUCTORS

Questions	AnS 101	AnS 114	AnS 210	AnS 211	AnS 224	AnS 225	AnS 226	AnS 319	AnS 320	AnS 331	AnS 352	AnS 411
1) Summarize the patterns of results	2	1	**No**	1	2	1	1	1	**No**	1	1	**No**
2) Evaluate how strongly data supports a hypothesis	**No**	**No**	**No**	1	**No**	**No**	**No**	1	**No**	**No**	**No**	1
3) Provide alternative explanations for results	**No**	1	**No**	**No**	1	1	1	**No**	1	1	1	1
4) Identify additional information needed to evaluate a hypothesis	2	**No**	1	1	2	1	**No**	**No**	1	1	1	**No**
5) Evaluate whether information supports a hypothesis	**No**	1	**No**	1	1	**No**	1	1	**No**	2	**No**	**No**
6) Provide alternative explanations for spurious associations	**No**	**No**	**No**	2	2	**No**	**No**	1	**No**	**No**	**No**	1
7) Identify additional information needed to evaluate a hypothesis	**No**	**No**	**No**	1	2	**No**	1	1	1	1	1	**No**
8) Determine whether an inference is supported by information	2	1	**No**	1	2	**No**	**No**	2	**No**	1	1	1
9) Provide relevant alternative interpretations for a specific set of results	**No**	**No**	1	**No**	2	1	1	1	**No**	**No**	1	1
10) Separate relevant from irrelevant information	**No**	**No**	**No**	1	**No**	**No**	1	**No**	**No**	2	1	2
11) Use and apply relevant information	**No**	1	1	1	1	1	1	1	1	1	1	2
12) Use basic mathematical skills to help solve a problem	2	**No**	**No**	**No**	2	1	2	1	1	**No**	1	**No**
13) Identify solutions for a problem	**No**	2	**No**	1	2	1	1	1	**No**	1	1	1
14) Identify and explain the solution for a problem	**No**	**No**	**No**	1	2	1	1	1	**No**	1	1	1
15) Explain how changes in a problem situation might affect the solution	**No**	**No**	**No**	1	**No**	1	1	1	**No**	**No**	1	**No**

Note: 1= direct teaching, 2=indirect teaching, No= no teaching