Holistic Design for Critical Thinking Instruction: Case Studies of Instructional Practices

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ABSTRACT

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This exploratory study uses both qualitative and quantitative approaches to investigate the relationship between critical thinking outcomes and instructional practices. Three associate degree programs in radiologic technology are used as the context for comprehensive review of instructional practices for critical thinking throughout the two year time period. A comprehensive picture of each program's instructional approach is developed and compared with student outcomes in disposition and skill.

Qualitative methods are used to collect data about instructional practices at each site through interviews with faculty and students, classroom observation and document analysis. Consideration is given to planning for instruction, instructional activities, critical thinking processes and implementation strategies. Twenty-five students participate in measurement of their critical thinking outcomes using the California Critical Thinking Skills Test and Disposition Inventory and samples of student work. This small number of participants limits the statistical power of the analysis of outcomes differences.

While students at the three programs perform equally well on skills measures, there are likely differences among the sites in disposition to think critically. There are

more marked differences in how the three sites implement certain instructional activities and the choice of activity type than the differences in frequency of use. The study suggests that long term use of the following activities/strategies over the course of the educational program may be associated with greater critical thinking disposition: (a) analysis of real-world problems, (b) performance based problem solving, (c) verbalizing evidence supporting arguments or decisions, (d) extensive writing, (e) attention to classroom environment, and (f) use of group work in and out of the classroom.

Findings suggest that there is a continuum of program development for critical thinking instruction. At one extreme is a site with a nascent view of critical thinking instruction characterized by intuitive practices. At the other extreme is a program that incorporates many of the best practices for critical thinking development, including those that extend learning beyond the classroom. In the middle is a site that is consciously and regularly continuing to adapt classroom practice to improve its ability to encourage critical thinking among its students.

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And to my darling Lynn...for letting me ignore you and loving me anyway...for holding up *more than* your half of the partnership without resentment...for being my biggest fan...I owe you more than I will ever be able to give.

Table of Contents

List of Figures

List of Tables

CHAPTER 1

Introduction

Analyzing the path taken in developing a research question provides an opportunity to examine your own influence on the subsequent research. My interest in critical thinking instruction is grounded in my career as a radiography educator. In the mid 1990's the accreditation standards for programs in radiography became more outcomes based and included a required assessment of critical thinking and problem solving. Each program was supposed to identify its goals in this area along with instructional strategy and outcomes measures. At that point in time, I was in the same position as most educators are when it comes to critical thinking—unable to define it, but pretty sure I knew it when I saw it.

At about that same time, I began my doctoral program in Educational Technology. That in itself is worthy of a little explanation, since its connection to furthering the career of a radiographer is not all that evident. I've always been technically savvy…self-taught, willing to explore, an early adopter in many areas. I taught at a college that started an online distance education program in the early 1990's…again an early adopter. While I didn't teach in a discipline that could use this technology to deliver course work at that time, I was always intrigued by the concept. I wondered how the instructional design principles that I knew and used could be applied in that setting. What would be different, what would be the same? I saw the study of educational technology to be an optimal way to meld three things that one ought to get out of a doctoral program: immersion in a discipline, exploration of something that you are curious about and the opportunity to broaden your skills and horizons for potential career advancement.

In pursuit of that degree however, I was always frustrated when it came to developing research projects that blended my interest in applying the new concepts and skills that I was learning about instructional design and technology in my own disciplinary area—what was closest to my heart. There was so little basic research in the field of radiography, and particularly radiography education, on which to build. My early interest in developing spatial ability through the use of computer simulation and animation was frustrated by a lack of supporting research about the visual needs and abilities of the discipline. Without the time, interest or skills to confront that basic deficit, I was forced to re-examine how I would approach further research.

With a small group of fellow doctoral students and a research project due, collaborative molding of research interests turned to the study of critical thinking in online distance education courses. There, a common interest emerged in the study of how to design instructional activities to promote critical thinking. Again, however, a hurdle appeared. In order to measure the effectiveness of an instructional activity, one had to have a valid and reliable measure of critical thinking. The first research task then was to find, or develop, that measurement device. Two years of research later, I had a much greater appreciation for the difficulties of measuring critical thinking, as well as research methodology and the practical challenges that a researcher experiences along the way.

It was now time to frame the research that would become this study. After my two years of immersion in the theory and practice of critical thinking instruction and assessment, I had developed strong convictions about how critical thinking worked, how it is developed, and how it could (or could not) be measured. Those impressions are

important not only to the framing of this study, but undoubtedly serve as a lens through which I collected and interpreted the data.

Through my foundational research projects and readings, I became convinced that many of the non-significant findings in critical thinking research were a result of research designs that simply did not allow enough time for critical thinking to develop. Looking at a specific activity, or even a course-based set of activities, just didn't seem long enough. It takes an accumulation of instructional events across time and across contexts for critical thinking skills and dispositions to develop. Given that foundational belief, how was I going to conduct a research study that could contribute to the collective body of knowledge about instructional design in this area? Any one educational intervention is so complex and confounded by hundreds of variables that the study of a course or an entire educational program seemed impossible and insane.

However, back at work I was being asked to do just that. I directed an educational program that had a charge to design and assess critical thinking in that context. I had yet to implement anything in my own program, but a potential research context was emerging. I assumed that there were radiography programs in existence that had comprehensive and cohesive plans for critical thinking instruction. If I could just study some of those and then come to some conclusion about what was and was not working, that would be a great contribution to my discipline, as well as to educators in general. The disciplinary context provided the advantages of access, a common language, and the motivation that it takes to finish a project of this magnitude. But it also provided some challenges in that this unique context has features that make it less generalizable than some other contexts that might be used.

"In postsecondary education our major goal is to teach students how to think, not what to think." Glenda Price, Provost of Spelman College, made this claim in a presentation to a group of radiologic science professionals convened for an educational consensus conference in 1995 (Price, p.15). Her message was only one of several that served as a clarion call for radiologic science professionals to adapt their educational processes to meet the health care needs of the twenty-first century.

> By the year 2000, every adult American will be literate and will possess the knowledge and skills necessary to compete in a global economy and exercise the rights and responsibilities of citizenship. The proportion of college graduates who demonstrate an advanced ability to think critically, communicate effectively, and solve problems will increase substantially.

The National Educational Goals Panel (1991) set forth this goal and objective (among others) as a recommendation for building a nation of learners. In the years that followed, the educational community appears to have embraced this goal as evidenced by the tremendous volume of publications addressing various elements of critical thinking. Many educators and educational systems have joined the movement to devote greater instructional time to the development of critical thinking abilities and dispositions.

Unfortunately, integrative literature reviews reveal mixed success at producing college graduates that demonstrate this desired ability to think critically (Adams, 1999; Bangert-Downs and Bankert, 1990; Gibbs, 1985; McMillan, 1987; Norris, 1985). While some studies have shown the impact of the collegiate experience on the development of critical thinking ability based on gain scores over the four years (Adams, 1999; Gibbs, 1985; Keeley et al, 1982; McMillan, 1987; Pascarella & Terenzini, 1991; Stadt & Ruhland, 1995), the gains can be small and the factors elusive. There is little agreement about which curricular designs or instructional methodologies are effective in developing

critical thinking abilities and the disposition to use them. While this lack of clear direction can be somewhat explained by the complex nature of the educational environment, a number of other challenges impact the collection of conclusive evidence: varying definitions of critical thinking, difficulties in measuring an entity that is both process and product, disagreement about the domain-specificity of critical thinking and the related question of transfer.

The following question remains unanswered, "How do instructional practices focused on critical thinking relate to the quality of critical thinking outcomes?" This study proposes to contribute to the collective answer to that question by examining how a specific post-secondary educational community—radiologic sciences—addresses critical thinking instruction. This community will be unique in its approach to critical thinking because of a discipline-driven emphasis on this skill and distinctive educational program features, yet similar in so far as its educational environment provides a context in which critical thinking can be studied generally.

Given the paucity of research related to critical thinking definition, instruction, and assessment in the radiography profession, the research question that this study poses can potentially lead to significant contributions to this professional community. A survey will collect information regarding instructional practices for critical thinking to provide a needed baseline. In-depth study of a number of instructional programs will provide detailed description of how programs with particular goals and limitations have approached the instruction of critical thinking as well as indications of their successes and difficulties in terms of outcomes. These may serve as models for other programs with similar situations and challenges.

More importantly, this information will be of value not only to this professional community. As stated above, the instructional practices and assessment methods will be similar to those used in other disciplines. The connection between instructional practices and critical thinking outcomes will be applicable in many higher educational settings. Radiologic sciences may serve as a model for comprehensive curricular planning around critical thinking and as indicators of successful, and perhaps not so successful, outcomes as a result. As such, it serves as a valuable context for this research at the same time that its unique features are somewhat a limitation.

CHAPTER 2

Review of the Literature

While little has been published related to critical thinking (CT) in the radiologic science profession, much has been published in other fields (particularly nursing) and in the context of general thinking skills. A comprehensive consideration of the critical thinking literature should address issues of definition, generalizability, transfer, instruction and assessment. Additional consideration of the nursing literature related to critical thinking and a critical analysis of that available in radiologic science is essential for this study.

Definition

Lauren Resnick (1987) is often quoted as saying, "Higher order thinking is difficult to define but easy to recognize when it occurs" (p. 44). The same can be said of critical thinking, which is a key member of the family of higher order thinking skills (Lewis & Smith, 1993). The terms critical thinking and higher order thinking are often used interchangeably and frequently include other related skill sets in problem solving, decision-making and creative thinking. Alternatively, Ennis (1987) suggests that critical thinking is the umbrella under which the others sit. An examination of commonly referenced critical thinking definitions reveals both areas of convergence and divergence (See Table 1).

The Ennis, Kurfiss, and Paul & Nosich definitions are more product-focused with attention to making a decision or coming to a conclusion, while the McPeck and P. Facione definitions are more process oriented. Most of these definitions include the

Table 1

Critical Thinking Definitions

Author	**Year**	**Definition**
Ennis	1987	"Critical thinking is reasonable reflective thinking that is focused on deciding what to believe or do." (p.10)
P. Facione	1990	" Critical thinking is the process of purposeful, self-regulatory judgment. This process gives reasoned consideration to evidence, contexts, conceptualization, methods, and criteria." (p.3)
Kurfiss	1988	"...an investigation whose purpose is to explore a situation, phenomenon, question, or problem to arrive at a hypothesis or conclusion about it that integrates all available information and that can therefore be convincingly justified." (p.2)
McPeck	1981	"...the propensity and skill to engage in an activity with reflective skepticism." (p.8)
National Council for Excellence in Critical Thinking (Paul & Nosich)	1991	"...the intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication as a guide to belief and action." (p.4)

dimensions of self-reflection but none address dispositions directly, although Ennis and Facione include dispositions in their models. Dispositions are especially important to consider given widespread recognition that individuals do not always display the abilities to think critically that they might possess (Perkins & Grotzer, 1997). In addition, critical thinking is hard work. It requires investment of time and cognitive energy and so the results of that work need to appear to be worth the effort invested (Halpern, 1998) in order for the student to be inclined to use and demonstrate the skills that they have.

It is not uncommon to hear questions to the effect: "What makes critical thinking critical, as opposed to just thinking?" or "Is there such a thing as bad critical thinking?" A variety of answers to these questions have been proposed from various philosophical perspectives. Richard Paul (1990) argues that thinking becomes critical when it is subjected to intellectual standards such as clarity, relevance, accuracy, precision, breadth, depth, and logic. Johnson (1992) focuses on the importance of community in deciding whether thinking is critical or not and hence the thinking must be articulated in order to be judged, not just submitted to self-reflection.

McMillan (1987) believes that one of the difficulties encountered in critical thinking research is the lack of a clear operational definition of the construct. In this 1987 paper, he suggested that the philosophical, educational and psychological traditions develop a convergent definition. The American Philosophical Association commissioned development of such a consensus definition of critical thinking using the Delphi Method in the late 1980's. Participants developing this consensus definition included Ennis, Paul and Johnson among the 46 experts in philosophy, psychology, education, social science and natural science. The result of this process was one of the definitions included in

Table 1 (P. Facione, 1990), along with six categories and 17 sub-categories of critical thinking skill as well as seven dispositions of the ideal critical thinker (Appendix A). This study has subsequently produced a number of assessment tools—a skills test, a disposition inventory, and a holistic scoring rubric, among others. The APA definition was selected for use in this study because of its broad and comprehensive development process and availability of related performance measures.

Generalizability and Transfer

The questions of generalizability and transfer of critical thinking are two closely related issues. If one advocates the generalizability of critical thinking, that is the notion that CT skills can be applied in any number of contexts, then one would also likely believe that their transfer to new and unique situations is possible. On the other hand, if one believes that critical thinking is rooted in specific domains and that there would be subject specific differences, then the possibility of transfer of critical thinking skills from one domain to another would be unlikely.

Among the philosophical analysts of critical thinking, McPeck (1981) is the primary advocate for subject specificity. He bases this claim on the assumption that critical thinking occurs within discreet subject areas and is subject to the norms and beliefs of that particular subject. What constitutes "good" reason is rooted within the domain and therefore critical thinking occurring within another domain would not appear the same. While acknowledging that there are some commonalities among domains (e.g., identifying assumptions), McPeck argues that these general concepts are not nearly as important as considering how the skill is demonstrated within the particular domain (Brell, 1990).

Alternatively, Halpern (1998) supports the position that critical thinking is generalizable in her statement of purpose for critical thinking: "...the goal is to promote the learning of transcontextual thinking skills and the awareness of and ability to direct one's thinking and learning" (p. 451). Brell (1990) believes that a synthetic approach is appropriate because general and domain specific skills work too closely together to try to identify them separately. Similarly, Perkins and Salomon (1989) suggest that general cognitive skills operate on a domain and are modified to work within it. Perkins and Grotzer (1997) take a mediating approach to this debate by suggesting the use of both approaches in order to compensate for the weaknesses of each.

With regard to the question of transfer, both Halpern (1998) and Perkins and Grotzer (1997) present approaches that are consistent with the general literature on transfer. Halpern focuses on explicating the structural elements of problems and arguments so that the learner develops a schematic representation of these structural elements for future use. The specific surface features provide the detail for the underlying substantive structural elements. This is similar to the approach of providing practice on a number of diverse cases of problem solving accompanied by reflective abstraction of how they are similar and/or different (Perkins and Grotzer, 1997). Brell (1990) suggests a completely different approach because he believes that the ability to transfer is rooted in development of the dispositions rather than the skills. As a result he suggests that the most important elements in promoting transfer are teacher modeling, challenging student beliefs and engaging other viewpoints.

While the APA definition and its consensus report do not specifically address the issue of generalizability, it is obvious that their assumption is that critical thinking is

generalizable. Assessment measures developed from the definition are deliberately content neutral and are designed for use in a college setting without regard to disciplinary major.

Assessment

A variety of standardized tools exist that are geared toward assessment of a multifaceted conceptualization of general critical thinking abilities. These instruments often deal with such skills as deduction and induction, logic, credibility of sources, etc. in a multiple-choice format. Paul and Nosich (1991) suggest that a comprehensive evaluation of critical thinking would include both intradisciplinary and interdisciplinary measures that examine both the selective and generative capabilities of students in this area. Locally designed instruments serve as valuable formative evaluation measures and provide high construct validity, but make comparison across contexts less meaningful.

Questions have also been raised regarding the sensitivity of standardized tests (such as the Watson-Glaser Critical Thinking Appraisal) and their ability to detect any impact that a change in a single variable (within a complex environment) might have, especially over the short term (Adams, Stover & Whitlow, 1999; McMillan, 1987). Some of the greatest impacts found in previous studies have occurred when using locally developed measures. McMillan suggests that future studies use multiple measures including standardized and locally developed measures (as do Paul & Nosich, 1991), as well as student and teacher perceptions and evaluating written work in order to triangulate results and give strength to the studies. Multiple measures are used in this study.

Instruction

Peters (quoted in Garrison 1991, p. 287) proposes that "There is no innate tendency to think critically, nor is it easy to acquire." Beyond not being innate, de Sanchez (1995) specifically claims that it must be taught, it does not just happen. Much attention has been devoted to the instruction of critical thinking and the study of instructional results. However, there is still much disagreement about the effectiveness of various methods. Part of that disagreement results from the challenges of conducting experimental studies with such a complex cognitive skill in a multifaceted educational environment. More than a decade ago, Resnick (1987) questioned what we know about teaching critical thinking and determined that "if we were to demand solid empirical evidence supporting a particular approach to higher order skill development before implementing educational programs, we would be condemned at this time to inaction" (p. 34). Since that time her position has been confirmed in reviews by McMillan (1987), Bangert-Drowns and Bankert (1990) Adams (1999), and Daly (2001).

Methodological Issues

In general, studies often deal with only one factor in a complex and interconnected environment. They tend not to consider the impact of out-of-classroom variables. Most studies have been either quasi-experimental or descriptive of an instructional methodology with little evidence supporting its efficacy. Many are of short duration and use small numbers of participants. McMillan found only 27 studies between 1950 and 1985 that used critical thinking as the dependent variable. Of those, 13 related to instructional variables, seven were based on courses or course equivalents in critical thinking, and seven considered students participating for one year or more in a

comprehensive critical thinking program. His study resulted in a series of methodological recommendations: measurement that coincides closely with intervention, control for instructors and content areas, use of large samples, carefully developed instruments, adequate designs, consideration of initial ability, and use of a variety of measures (e.g., combinations of measures such as student perception, faculty perception, locally developed and standardized tests).

While these recommendations makes sense from the experimental perspective, some directly conflict with other findings that suggest that the impact of the college experience on critical thinking is a more holistic phenomenon for which controlled studies are unrealistic. Other recommendations could be applied in a variety of methodological approaches that more closely honor the complexity of the environmental effect.

Since McMillan's review of the literature, several studies have contributed to our understanding of the impact of post-secondary education on critical thinking by using large samples, although without experimental methodologies. A 1997 study by Noreen Facione aggregated the data provided by nearly 8,000 cases in 50 nursing programs to demonstrate the efficacy of the nursing curriculum in developing students' skills and dispositions in critical thinking. Tsui (1999) conducted a mixed quantitative and qualitative study using the Cooperative Institutional Research Program (CIRP) data of self-reported growth in critical thinking, followed by study of selected institutional context variables thought to be associated with successful outcomes. One of the weaknesses of the study is its use of self-reported growth as the only critical thinking outcome measure.

These studies share the strength of investigating large populations across multiple institutions in exploring the features of instruction that influence critical thinking development at the college level. While the Tsui study was weakened by the use of self-reported growth in critical thinking as its dependent variable, the N. Facione study was strengthened by its use of standardized measures of critical thinking ability and disposition. Yet, Tsui's mixed method design combined broad quantitative analysis with targeted case studies as a means of cross-validating and allowing exploration of a broad range of variables and identification of a number of environmental variables worthy of further research.

Three other issues dominate basic methodological challenges in critical thinking research. It is widely believed that critical thinking skills and dispositions develop over longer periods of time and this makes experimental designs difficult, at least, and probably inappropriate. The ability to make random assignment to instructional conditions is limited and control for such variables as faculty impact, student engagement and student characteristics is statistical only, if at all. Finally, the development of critical thinking is likely a holistic phenomenon that involves both in-class and out-of-class components (Pascarella, 1989). While it appears that there is an impact of the college experience as a whole, it is not clear how strongly various components of that environment each contribute.

Studies of critical thinking instructional process vary in how broad a view they will take in studying instructional impact: the institutional level, the program or major level , the single course, or the single instructional activity.

Institutional Level

While there is little support for the efficacy of any particular instructional variable or course design, there does appear to be an increase in critical thinking ability over the length of a college education (Dressel and Mayhew, 1954; McMillan, 1987, N. Facione, 1997). Not all studies are confirmatory, however. A curriculum study by Mentkowski and Strait (1984) at Alverno showed no significant differences in cross sectional study of freshmen and seniors and showed gains in the longitudinal repeated measures study using the Watson-Glaser Critical Thinking Appraisal, but not with other CT tests.

The large-scale study of nursing programs conducted by N. Facione (1997) demonstrated gains in critical thinking skill across the nursing curriculum using both cross-sectional and matched pre-test/post-test data. Gains in critical thinking disposition for both cross-sectional and longitudinal populations were also evident, although much less data was available in this domain. Other studies in this area have been unable to demonstrate that the nursing curriculum produced greater critical thinking abilities in "soon-to-graduate" senior students than in those just entering the major (Adams et al, 1999; Daly, 2001).

Alternative explanations (beyond curriculum impact) have been suggested and explored. One such explanation is a developmental impact of age or maturation through the traditional college years. While age/maturation cannot be ruled out as impacting critical thinking development, several studies have found contrary evidence. Pascarella & Terenzini (1991) report on a study conducted by Klassen (1983-1984) that showed gains in critical thinking for non-traditional age (adult) students in a college environment but not in a comparable sample not enrolled in college. Similarly, Steele (1986) found that

differences in critical thinking between freshmen and senior students were much greater than the differences among three different age groups in the senior sample. This suggests that the impact of the college experience is more pronounced at completion of the undergraduate experience than is the impact of age or maturation. However, the impact of student withdrawals prior to senior year testing still plagues these lines of research.

A second alternative explanation relates to the impact of student characteristics prior to embarking on the post-secondary education. Terenzini, Springer, Pascarella and Nora (1995) suggest that pre-college characteristics explained more variance in critical thinking performance than other variables. Important attributes were parents' educational level, number of hours spent studying, and number of non-assigned books read. Similarly, critical thinking ability at college entrance has been shown to explain 44% of the variance in gains over four years (N. Facione, 1997). Verbal SAT scores and socio-economic status entered with significant beta weights in the stepwise regression of self-reported CT growth in the Tsui study (1999). However, the model overall accounted for less than 10% of variation in CT growth. These pre-college characteristics lost their significance as other variables related to the institution, curriculum, class and out-of-class experiences entered, indicating that other features of the educational experience mediate these initial effects.

Program Level

There is less consistency in findings about curricular design effects (type and frequency of courses). While some studies have found effects for course type (Astin, 1993; Dressel and Mayhew, 1954; N. Facione, 1997, Tsui 1999), others have not (Dressel and Mayhew, 1954). Tsui (1999) suggests that some of the discrepancy about curricular

findings is, in fact, a result of the influence of instructional approaches that have not been considered. In this study, changes in Beta weights in a multiple regression suggest that some of the change in critical thinking resulting from a course is explained by the instructional methods used within it and perhaps the faculty member as well.

Dressel and Mayhew found a greater correlation between the number of general education courses and critical thinking skill (using a measure grounded in social science) than for professional related courses. Forrest (1982) also found higher critical thinking skills in those with more general education. Winter, McClelland and Stuart (1981) studied the nature of the general education curriculum and found that students enrolled in an integrative general education experience demonstrated greater skill in critical thinking than those in a traditional menu system. The N. Facione (1997) study confirmed the value of specific critical thinking courses in developing skills, but demonstrated a negative impact on disposition to think critically.

At the programmatic or curricular level, there appears to be some support that certain aspects of curricular planning are related to positive critical thinking outcomes (See Table 2). Specifically, programs in which nursing faculty have engaged in discussions about what critical thinking is or have adopted it as a focus of instruction have shown greater student outcomes in critical thinking skills and dispositions (N. Facione, 1997). Curricular planning has a similar effect but, surprisingly, identifying specific critical thinking outcomes appeared to have a detrimental impact on student skill (but not disposition). However, a contradictory finding comes from Daly's (2001) recent study of the curricular effects of nursing programs that concludes with the suggestion that

Table 2

Program Planning Variables Versus Student CT Outcomes (N. Facione, 1997)

Program Variable	**CCTST (Skills)**		**CCTDI (Dispositions)**	
	Type of Data	Finding	Type of Data	Finding
Adopting a CT focus	Aggregate exit	*		
Faculty discussing the meaning of CT	Aggregate exit	*	Aggregate exit	Consistently higher than overall population
Planning to make curricular changes	Aggregate exit	*	Aggregate exit	Consistently higher than overall population
Recently implemented curricular change	Aggregate exit	ns		
Identifying CT outcomes	Aggregate exit	*	Aggregate exit	Consistently higher than overall population
Requiring a CT course	Aggregate exit	*	Aggregate exit	Consistently lower than overall population
Analyzing & interpreting CT test score data	Aggregate exit & longitudinal	*		

* = significant at $p<0.05$

specific critical thinking abilities be identified as goals and that instruction and assessment be designed to promote these abilities.

Specific to this study is a consideration of the curricular planning and programmatic features of radiologic technology programs. In its 1995 educational consensus conference, the American Society of Radiologic Technologists (ASRT) identified critical thinking as the highest priority professional characteristic for both the technical and baccalaureate levels of radiography practitioner. Superior critical thinking skills were listed along with problem solving and decision making as desirable personal attributes in this same study (ASRT, 1995). The Joint Review Committee on Education in Radiologic Technology (JRCERT) includes a requirement for instruction and assessment of critical thinking and problem solving in its standards for the accreditation of a radiography program (JRCERT, 2001).

This 1995 ASRT National Educational Consensus conference asked the professionals in attendance, "What educational base is needed to promote critical thinking/decision making and scientific inquiry skills?" (ASRT, 1995, p. 40). Participants' recommendations included the study of ethics, research methods, statistics, management, cultural studies and higher-level math and science. More specific pedagogical techniques were suggested as well: real world problems, case studies, arguments and debates, and strategies to acquire, evaluate and synthesize information and knowledge (ASRT, 1995).

One could consider the curricular recommendations to be consistent with Tsui's (1998) suggestion that liberal arts and interdisciplinary curricular elements are supportive of CT. However, they are inconsistent with the experimental findings of Gressler (1976)

with regard to the effects of research methods courses and with Dressel and Mayhew's (1954) findings with regard to science courses at some colleges.

The lone research study available in the radiology literature (Stadt & Ruhland, 1995) focused on student abilities measured with the Watson-Glaser Critical Thinking Appraisal (WGCTA). WGCTA scores are compared with type of educational program, student age and student work experience. While demographic characteristics of students in associate degree and certificate programs were more similar, the critical thinking abilities of the certificate students were higher than their associate degree counterparts. Baccalaureate "near-graduators" displayed the greatest critical thinking abilities. One potential explanation for the finding that students in certificate programs scored higher on the WGCTA may be related to the development of CT skills during the more extensive clinical practice component typically seen in the certificate level radiography curriculum.

As suggested in the previous section, the actual classroom practices may have a greater impact on critical thinking outcomes than the specific elements of curricular design.

Classroom Practices

In part due to the methodological limitations already mentioned, even more variability is seen in investigation of instructional practices to develop critical thinking skill and disposition. The McMillan (1987) review offered little direction to faculty attempting to design courses and experiences that would help CT development. One finding in the Dressel and Mayhew (1954) studies was that faculty mattered. Students enrolled in different sections of the same course and taught by different faculty members achieved differing levels of gain in critical thinking. While their studies were not

designed to explore this specifically, this finding is likely a result of different instructional activities and approaches used by different faculty members.

McKeachie, Pintrich, Lin and Smith (1986) used essentially the same studies as McMillan (1987) with a meta-analytic (rather than box count) methodology and came to a slightly different conclusion. Their findings suggest that three features of instructional practice would improve student thinking: student discussion, emphasis on problem solving, and verbalization of metacognitive strategies.

One of the more consistent findings across the literature is that engaging students in discussions has a positive impact on thinking. This finding has been seen in large studies, with both skills measures (McKeachie, 1988) and self-reported growth measures (Astin, 1993: Tsui, 1998, 1999), in the classroom and outside of it (Astin, 1993; Light, 2001; Tsui, 1998), and when using quantitative as well as qualitative designs.

While not as consistently evidenced in the literature as student discussions, empirical evidence suggests that instruction for critical thinking should attend to student participation and active learning (Smith, 1977; Tsui, 1999), including solving problems (McKeachie, Pintrich, Lin and Smith, 1986) writing and rewriting (Tsui, 1999), thinking out loud (Logan, 1976; McKeachie, Pintrich, Lin and Smith, 1986) and reflecting on learning (Tsui, 1999). In designing instructional experiences in the classroom, faculty should consider how to involve students with their classmates in challenging activities (Smith, 1977; Tsui, 1999) inside and outside the classroom (Tsui, 1999). Faculty modeling of thinking practices appears to be beneficial when it is explicit (Logan, 1976; McKeachie, Pintrich, Lin and Smith, 1986), as is faculty encouragement and use of student ideas (Smith, 1977).

Angelo (1995) develops the findings of McKeachie, Pintrich, Lin and Smith into more directive pedagogical advice. Related to each of their three findings, he suggests the use of student discussions that are planned, focused and interactive and connect both backward in time to previous learning and forward to what is to come. He advocates teaching problem solving methods explicitly, providing practice and assessment of student performance. Finally, he encourages faculty to model critical thinking and metacognitive processes and to provide opportunities for students to practice and use them themselves.

Similar pedagogical recommendations have appeared in the discipline specific literature of radiologic technology, albeit not of an empirical nature. Tsui's (1998) recommendation to let students design their own laboratory experiences was previously suggested by Dowd in the context of radiography education as were active learning strategies such as debates followed by a written paper and raw data interpretation (Bugg, 1997; Dowd, 1993).

Student Actions

Up to this point, this literature review has focused on those actions that are in the control of institutions, programs and faculty, but has not looked at student actions. Specifically important is consideration of student engagement in the various activities, both in and out of the classroom.

Both recent and past publications have emphasized the importance of student and faculty interactions outside of the classroom, beginning with Pascarella and Terenzini in 1978. More recently, the Tsui (1999) study has proposed recommendations for both formal and informal out-of-class interactions between faculty and students. Faculty

interactions comprised two of the four elements of out-of-class experiences featuring prominently in supporting student growth in critical thinking. Similarly, Light's (2001) study of college freshmen confirmed the importance of this activity to student success in college, although not specifically to critical thinking development.

As well, student interaction with peers, particularly engaging in discussion, consistently appears as a finding supportive of critical thinking development (Astin, 1993; Pascarella & Terenzini, 1991; Tsui, 1999). However, the focus of these interactions should be a healthy blend between the intellectual and the social as studies also suggest that when social interactivity exceeds intellectual activity, then critical thinking growth declines (Pascarella & Terenzini, 1991; Tsui, 1999; Winter, McClelland & Stewart, 1981).

The vast majority of the literature related to both student and institutional impact on critical thinking development has focused on the skills of critical thinking. Equally, and perhaps more, important is consideration of students' tendencies to use the skills that they have...their dispositions.

Dispositions

Few research studies addressed critical thinking disposition outside the discipline of nursing. The N. Facione (1997) study found a general increase in student disposition overall and in the subscales of the CCTDI generally. Interestingly, students taking a critical thinking course demonstrated consistently lower levels of CT disposition than those students not taking a course, although the number of schools reporting this data was much smaller than for the rest of her study (n=50 to 57). Similarly, Colucciello (1997) found significant increases through the final two years of the nursing curriculum in

overall disposition and all but two scales of the CCTDI. The scales of Open-mindedness and Maturity not only did not demonstrate significant increases, but showed a roller coaster of scores from semester to semester. Both studies report overall weakness and concern for development in the scale of Truthseeking.

These findings in the nursing student population may be characteristic of this scientific domain rather than students in higher education overall. Arts and humanities students tend to show greater disposition to critical thinking in many of the scales (Giancarlo & P.Facione, 2001), while business, science and computer students show lower overall disposition. The scales of Maturity and Open-mindedness in this study demonstrated relatively high scores in freshman students thereby limiting the potential to show gains over the course of the college years. In this study as well, students showed the lowest tendency in the area of Truthseeking. This particular scale appears to be the most difficult to develop.

So what should be considered in the instructional planning for the development of both disposition and skill in critical thinking?

Developmental Process

Consistent with principles of instructional design and the study's theory of critical thinking, the following understanding of the development of critical thinking is the basis for this study. This requires many of the same instructional processes that are necessary for the development of other knowledge, skills and attitudes.

1. *Pre-requisite knowledge.* The ability to think critically about a particular subject requires some foundational knowledge of that subject. Learners must have something to think critically about (Resnick, 1997).

2. *Clarify that critical thinking is expected.* The instructor needs to be sure that learners are clear about the need for critical thinking in order to successfully complete the task. Consider a case study task that asks students to describe how they would solve a particular problem. It might be clear to the instructor that in order to perform this task successfully, one should consider a variety of possible solutions, evaluate each possibility and then choose the solution that most closely matches one's values and assumptions. On the other hand, students might not be clear that this critical thinking approach is expected and could present the first solution that comes to mind without careful thought about alternatives. This may be especially true when the learners' educational experiences have not historically called upon this type of approach.

3. *Motivation to engage in critical thinking.* Critical thinking, as opposed to more superficial cognitive activity, requires effort from the learner. The learner's willingness to invest the effort that it takes to think critically is impacted by a number of variables that are similar to the considerations in general motivation theories: intrinsic factors, task factors and environmental factors. One way to examine this is based on the expectancy theory of motivation. In order for a student to engage in critical thinking, the student has to perceive the task to have some value, believe that the outcome of engaging in the task will be worthwhile, believe that s/he can be successful in completing the task and believe that the time invested will be worth the benefits achieved.

4. *A task that calls on critical thinking processes.* According to the definition of critical thinking used in this study, CT processes include those that would be included

in the categories of interpretation, analysis, evaluation, explanation, inference and self-regulation. Instructional tasks must draw on these processes, the more explicitly, the better.

5. Feedback on CT performance. One important element of instruction in general is to provide the student with feedback about his/her performance on the assigned tasks. This is also important in critical thinking as the student needs to understand how well s/he is performing on the specific task and where improvement can be made. Ultimately, the critical thinker develops the ability to evaluate his/her own thinking as an outgrowth of skill and disposition development.

6. Use of feedback to strengthen or correct critical thinking or understanding. Consistent with item number five, the feedback provided about performance must be used by the student to further the development of critical thinking skills and/or dispositions or the learner's understanding of the discipline of study.

Summary

The student development in higher education literature, influenced heavily by Astin, Pascarella and Terenzini, suggests that development is a holistic phenomenon rather than a singular one. This is evidenced in the following quote by Pascarella (1989) in reference to the impact of college:

> ...rather than any one particular experience, it is the student's total engagement in the intellectual and social experience of college that positively influences the development of critical thinking ability.

Yet, few studies of critical thinking have attended to studying the student experience as a whole, Tsui (1999) being one exception. Even considering only the academic portion of the college experience in its totality is rare. I did not find any reports that focused

specifically on the academic experiences of an entire undergraduate education. Radiologic technology is a suitable discipline in which to embark on such an endeavor given its curricular structure and programmatic elements. This study explores the academic environment with the intention of teasing out the elements that are important in programmatic attempts to address critical thinking in the curriculum.

CHAPTER 3

Methodology

Research Question

The research focused on the core question: "How do instructional practices focused on critical thinking contribute to the quality of critical thinking outcomes?" Supporting questions help to add definition to the concept of instructional practices: How do educational programs plan for comprehensive critical thinking instruction? What features of planning are related to successful outcomes? Does the use of instructional activities calling on specific critical thinking processes result in high quality CT outcomes? What implementation strategies enhance or diminish the effectiveness of the activity? How do all these features combine to impact CT skills and dispositions?

Researcher Impact

I have already stated my belief that critical thinking is a skill that is slow to develop but need to expand that to include a conviction that dispositions are even slower to develop. There are other beliefs and assumptions that I must identify in the context of conducting this study. While there is a certain intellectual capability that must be present in order for critical thinking to occur, I believe that the capacity and the will to think critically will not develop naturally, they must be learned. While they can be learned on one's own and in the context of experiential learning, they also can be learned in the context of formal education. Therefore, I believe that critical thinking can be taught and that the skills and dispositions of the teacher are critical to the effectiveness of that instruction.

Given that belief, my discussions with educators in many disciplines in the past two years, and my knowledge of my own discipline, I began this research with other assumptions. I believed that many radiography educators would use unsophisticated instructional approaches: (a) they would have an intuitive sense of what critical thinking is, (b) they would believe they were teaching for CT, but probably weren't, and (c) they would use naïve methods of assessment. I struggled to admit this to myself and to my faculty advisors because it is demeaning to my profession and that does not feel very good. But the admission provided perspective, so that in my fieldwork I was more careful to try to accept that it was there, but was prepared to believe that it was not.

This study is based on the assumption that critical thinking skills are transferable. If they were not, it would make no sense to use a standardized, content neutral test of critical thinking. Rather, I would have developed and used a discipline specific tool. Part of this belief is based in my work with the APA's consensus definition of critical thinking and my experience in using this model in multiple disciplines. Through that practical research experience, I have seen that the underlying critical thinking processes are much the same in a variety of disciplines. If the underlying processes are the same, they should in fact be transferable. While I am aware of the issues surrounding the question of transfer, it is not a major feature of this study.

The final area of researcher impact on this study is not one that is unique to me or even this study. It is a phenomenon associated with every type of research: we do not know for sure what impact our mere presence has on our research environment. Were the individuals in these programs geared up to talk about critical thinking with me? Sure they were. Had they talked more about it in the week or two days preceding my visit? Maybe,

if they had the time. The one area of the study where this could have the greatest impact is in discussion of the importance of critical thinking as a goal for the program. The reality is that there are many competing goals for any educational program, and particularly for one that has a credentialing examination and is preparing students for careers in patient care. I can't be at all sure that the ratings of importance that participants gave were particularly real. In fact, in retrospect, I should not have even asked the question.

Of greater concern in this respect, however, is my own interest in critical thinking and the impact that this had, not only on the conduct of the research, but in the interpretation of the data. I found it difficult to be an interviewer and observer, particularly with those faculty who were struggling with how to teach for critical thinking. Here the intersection of being a teacher at heart and my own knowledge of critical thinking created a struggle to keep asking questions without giving advice and without leading the participants in a direction they wouldn't have otherwise gone.

With beliefs and assumptions exposed, it is now time to get to the business of revealing the methodology with which I attempted to answer my research questions.

Overview

This study used a theoretical replication, multiple-case study design. This design uses multiple cases, each selected because the outcomes are expected to vary in theoretically predictable ways (Yin, 1994). The basic research question, "How do instructional practices focused on critical thinking contribute to the quality of critical thinking outcomes?" served as the foundation for case selection. The approach was to identify cases where instructional practices varied and then examine deeply those

instructional practices and measure student critical thinking outcomes. It would also have been possible, perhaps even preferred, to answer this particular research question by first identifying cases where the outcomes were different and then conducting an in-depth analysis of instructional practice. However, this approach presented both logistical and methodological challenges that were prohibitive.

Information about instructional activity use was gathered via a survey of the directors of associate degree radiologic technology programs. Survey results were used to identify programs that claimed to have a high, medium, or low proportion of instructional focus on critical thinking and to gather demographic information about the program (e.g. size and selectivity). Three programs, one at each level of instructional focus, were selected for more in-depth study and standardized critical thinking outcome measures were administered. I chose programs with comparable selectivity and student/faculty ratios and gave preference to programs with larger numbers of faculty and students.

In-depth study of the instructional practices of each program was conducted via phone interviews, site visits and document review. Program and course level documents were examined for evidence of critical thinking definition and instructional activity use. Faculty were interviewed about program and course level planning and implementation. Where possible, classroom observation provided information about the nature of the classroom environment and in some cases allowed observation of an important CT instructional activity or demonstration of student outcomes.

Students completed a questionnaire about instructional activity use, a critical thinking skills test and a critical thinking disposition inventory. Focus group interviews

were conducted with a mixed group of first year and "about-to-graduate" second year students.

For each case study, a mixture of qualitative and quantitative data was obtained. Student outcomes data was primarily quantitative (skills test and dispositions inventory scores), but student work was also examined, providing a qualitative source as well. Instructional practice information is primarily qualitative data comprised of interview transcripts, classroom observations and document analyses. However, faculty and student survey questionnaire results provide a quantitative perspective to the instructional practices side.

Data Sources

This combination of qualitative and quantitative methods requires a wide variety of data sources. Table 3 summarizes the various sources and their use in answering the research questions. Multiple data sources contribute to the study of each question, although not necessarily both quantitative and qualitative.

Survey

The survey was designed to gather information about the program features of curricular design, selectivity, program size and instructional practices. The instructional practices section included descriptions of 17 activities that could be used to develop students' critical thinking (see Appendix B). The APA consensus definition (P. Facione, 1990) was used to develop the descriptions, one from each subcategory of the skills section of the definition. Program directors were asked to choose among gross indicators (not at all, a little, moderately, a great deal) of how frequently each of the activities would

Table 3

Summary of Data Sources

Research Question/Purpose	**Data Source**	**Participant**
Case Selection	Survey	Program Director
Validate program director's response to survey	Survey	Faculty and Students
Program planning for instruction: Includes methods of planning, resources used, curricular design, definition and importance, communication, and assessment	Document Review • Meeting minutes • Accreditation self-study or equivalent • Handbooks and marketing materials	
	Program Level Interviews	Program Director and Faculty
	Student Focus Group	Students
Instructional activities	Syllabus and Course Materials	
	Course Level Interviews	Faculty
	Classroom Observations	Faculty and Students
Implementation Strategies/Effectiveness	Course Level Interviews	Faculty
	Student Focus Group	Students
Student Critical Thinking Outcomes	CCTST	Students
	CCTDI	Students
	Student Papers and/or Presentations	Students

be required of students in their program. Program directors were also asked to indicate their willingness to participate in a follow-up phase of the study.

The survey was distributed to 306 associate degree programs in the United States that are approved by the American Registry of Radiologic Technologists (ARRT). These included programs that are accredited by the Joint Review Committee on the Education of Radiologic Technologists (JRCERT) or the six regional accrediting agencies for post-secondary institutions. Each program was assigned a number that was used for tracking completion, second requests for participation and for follow-up with those indicating a willingness to participate further. Program directors received a letter of invitation to participate and were directed to a web site to complete the survey. After a follow-up reminder sent two weeks after the initial invitation, 83 program directors had completed the survey for a response rate of 27 percent. One survey was unusable for follow-up because no identification was present.

Exploratory analysis of the survey results was conducted in preparation for its use to solicit participants for the case study phase. Completed surveys were coded for program selectivity (high, low or unknown) and willingness to participate in the case study phase. Responses in the instructional practices section were assigned a number value (0 to 3) and a cumulative instructional practices score (CTIP score) was calculated for each program, with the maximum score being 51. The mean CTIP score for all respondents was normally distributed with a mean of 30.6 and a standard deviation of 8.36. With CTIP as the dependent variable, statistical comparison of the means was used to examine the data for group differences based on selectivity and willingness to participate (detailed results and analyses in Chapter 4). This analysis helped to decide that

it was methodologically sound to proceed with selection of case study participants from either the low or high selectivity groups of potential participants.

Case Selection

Survey results were used as the basis for case study site selection. Since student outcomes were to be used as a dependent measure in the case study phase of the research, the selectivity of the program became an important element of site selection. It was important to study sites of similar selectivity in order to reduce the potential impact of student ability on outcome measures. The programs used a wide variety of selection procedures, including college entrance examinations, high school GPA, college pre-requisite course GPA and other more subjective measures. Programs reported SAT/ACT college entrance exam scores or selected from fixed choice options related to high school record. Low selectivity was defined as SAT or ACT scores at or below the national average or reporting that students graduated from the top half of their graduating class. High selectivity schools reported SAT/ACT scores higher than the national average or students graduating from the top ten or 25 percent of their graduating class. The low selectivity group was chosen as a focal area for a number of reasons: (a) there were more cases in the group, (b) there was a greater range of CTIP scores in this group, and (c) it is broadly believed that the influence of instructional practice is greater with students of lesser ability.

The original plan for case selection was to study two programs reporting high CTIP scores and two reporting low scores. It was not possible to find two schools in each category that met other criteria of the study (class size, number of faculty, willingness to participate, summer graduation date). The methodology was revised to study one

program with a low CTIP score (10^{th} percentile) one with a moderate score (50^{th} percentile) and one with a high score (90^{th}) percentile. This reduced the pool of potential participants from 28 to seven (three low, two medium and two high). Within this pool, class size, faculty-student ratio, graduation date and geographical distribution were considered.

Potential participants for the case study phase of the program were solicited initially by telephone. Those programs meeting the above criteria and responding "yes" to the "willingness to participate" question on the survey were contacted first. Telephone contact allowed discussion of the study with the program director using a question and answer guideline prepared in advance. The first three programs contacted in each of the levels of CTIP score indicated continuing interest in participation. Further documentation about the study was mailed (or e-mailed) to the director including: (a) a letter of invitation, (b) a one page description of the study detailing data collection procedures with each group of participants and student incentive information, (c) a site visit schedule request identifying required and optional activities for the visit along with estimated time requirements, and (d) consent forms for the institution, faculty and students. A follow-up telephone call provided the opportunity to clarify the requirements of the study, obtain verbal permission and agree upon the site visit schedule.

Prior to the site visit, the schedule was confirmed and varying amounts of documentation were reviewed. Each program's web site was consulted to gather information about program philosophy and curricular structure. Some sites provided copies of course syllabi in advance of the visit, as requested. One site also provided copies of the student and clinical faculty handbooks.

Site Visits

Site visits were conducted in May and June of 2002. The visits consisted of interviews with the program director and all other didactic faculty, classroom observations, student participant testing and a student focus group interview. Program and course documents were also reviewed while on site. All contact with students in the program was in scheduled events, no informal discussions were included in the data.

The first two site visits were conducted in a consecutive two-week period, with the final visit following some five weeks later. The length of the visit was planned for three to four days depending on the schedules of students, faculty and classes. The visit to Site B was shorter at two and one-half days because of last minute scheduling conflicts. Follow-up telephone interviews were conducted with faculty to complete the interview process.

Participation.

Each program director was asked to secure participation from faculty members in whatever way s/he determined was appropriate. The visit schedule indicated the faculty who would be participating, along with the testing, student focus group and classroom observations. Each faculty member received both a verbal and written explanation of the study at the beginning of the interview, including the opportunity to decline participation. A consent form was signed and verbal consent to tape the interview was obtained.

Student participation was also at the program director's discretion. An incentive for students to participate was provided to each study site. For each activity in which a student participated, s/he would receive one entry into a drawing for a membership to the American Society of Radiologic Technologists. In order to motivate those second year

students participating in the skills testing component to try to do their best on the examination, each student who scored at or above the national average on the skills test received an additional entry in the lottery. When student events were scheduled early in the morning or at lunchtime, breakfast or lunch was provided.

The three sites handled student participation and scheduling differently. Site A scheduled student testing on an afternoon when clinical practice was scheduled and gave students the option of staying at their clinical site or coming to campus to participate. All second year students participated. Site B students were asked by the program director to stay after classes, on their own time, to participate in the testing and to come in one hour early to participate in the focus group. Eight of 14 students participated. Site C students were given the option during a five-hour class on campus to perform practice board exam tests or participate in the critical thinking testing and focus group. Five of 15 students participated. However, all second year students agreed to complete the survey questionnaire and permitted access to their college admission records and transcripts.

For classroom observations, I obtained the consent of both the faculty member and students. Since the students did not have the option of leaving the classroom if they chose not to participate, they were asked to sign an individual consent form that allowed them to indicate that any data that they produced would be eliminated from notes or transcripts. Each student seat was assigned a number and each student interaction in the classroom was recorded by number so that the consent procedure could be implemented. One student at site A and one student at site C indicated that they wished not to participate. At Site B, the classroom observation was conducted in a class where students were the presenters. In this case, only the student presenters were asked for consent.

Program level interviews.

Following completion of the consent form, I conducted semi-structured interviews with the program's director and each of its faculty. The focus of these interviews was to investigate the issues of critical thinking definition, program planning, faculty preparation in instructional approaches to critical thinking and curricular contribution to critical thinking instruction. Each lasted approximately one hour, was tape-recorded and followed the basic structure of the interview protocol (Appendix C). The protocol questions were effective in obtaining the desired information and were changed little through subsequent uses. Beyond the structured questions, I asked clarifying questions and restated participants' replies in order to verify my interpretation. I asked each faculty member other than the program director to complete the instructional practices section of the initial survey used with the program directors and provide demographic information.

Course level interviews.

I interviewed each teaching faculty member about the course(s) that s/he teaches. The amount of time that each participating faculty member had available for interview varied. It was estimated that each course level interview would take approximately 30 minutes, but many took more time than that. I intended that each faculty member would be interviewed about each course that s/he taught in order to paint a comprehensive picture of each program's instructional practice. For a variety of reasons, that goal was not achieved in its entirety at any of the sites. In some cases faculty were unable to devote that much time, while in other cases it was obvious that the faculty member used the same methodology in multiple courses.

Course level interviews sometimes followed the program level interview and in other cases were completed over several periods of time. I asked faculty to identify the goals and objectives for the course and to describe the instructional activities that were used to develop students' critical thinking. After the faculty member described all of the activities that s/he could think of , I asked him/her to review a collection of suggested activities or prompts to help further recall of additional activities. The activities that were identified were then used as the basis for questions about effectiveness and how to make critical thinking activities be more effective. The interview protocol is contained in Appendix C.

The use of the collection of activity prompts (Appendix D) was problematic. Prompts similar to those used on the initial survey were made more specific and applied directly to the context of radiologic technology. I asked the faculty member to consider the cognitive activity being called upon by each prompt in a context neutral way and then to consider whether any similar type of activity was used in his/her class. Faculty were unable to separate the context from the prompt and think about it in relation to the relevant course. For example, a prompt asking about students using a case scenario as the basis for consideration of multiple possible solutions to a problem in the context of a science course was seen as not applicable in a course related to medical ethics. Whereas the intention was that this prompt would trigger the faculty member to talk about using case scenarios for the students to consider multiple possible perspectives in an ethical dilemma, the faculty member merely saw it as an example pertaining to a subject area that we were not talking about. In one interview at the final site visit, I explained the underlying cognitive task for each of the 39 prompts. This was somewhat more effective

but lengthened the course interview time considerably and was not used in subsequent interviews.

Document review.

A variety of documents were reviewed at both the program and course levels. Program level documents included student handbooks, clinical faculty handbooks, accreditation/institutional effectiveness reports, program faculty meeting minutes, and college catalogs or brochures. These documents were reviewed and coded primarily for information related to program level planning features. These included evidence related to goals and definition of critical thinking, communication of these goals to the students and clinical faculty members, assessment of critical thinking, planning for instruction in critical thinking and faculty development for critical thinking.

Course level documents included syllabi, laboratory manuals, sample assignments, course outlines, grading criteria, clinical evaluations, case scenarios, and textbooks. These documents were collected as evidence of the instructional practices of individual faculty members and collectively of the program. They were used both in triangulation of interview data as well as to enhance the detail available about the particular course. They were analyzed primarily on the basis of their ability to support critical thinking instruction and were coded according to the activity type, evidence for critical thinking, and APA category (See coding schema in Appendix F).

Student focus group interviews.

Each student focus group contained a mixture of first and second year students. Participation ranged from eight to twelve student participants. Again, a semi-structured interview format was used (protocol in Appendix C). Students were each assigned a

number and the data was collected by student number. Some questions were opened to the whole group for whoever wanted to answer; others were "round robin" where each student took his/her turn at answering. The focus group design also included a roundtable activity (Revak and Fitzkee, 1999) that asked students to work in small groups with the others at their class level (first or second year) to brainstorm and then prioritize what made instructional activities effective and ineffective at getting them to think critically. This activity was altered slightly through iterations of the focus group process in order to get students to focus more specifically on the features of an activity that make it work for CT rather than identifying various types of activities.

Student testing.

Since my focus was to examine student outcomes near graduation, only second year students were invited to participate in the testing portion of the study. They were asked to complete three tasks: (a) the instructional practices questionnaire that the program director and faculty completed, (b) a critical thinking disposition inventory, and (c) a skills test. After signing consent forms the three tasks were completed in that order and over a period of approximately 90 minutes.

The *California Critical Thinking Disposition Inventory* (CCTDI) is designed for use with adults and intended for use in program evaluation and personnel development. It is based on the dispositions identified in the 1990 APA Delphi study and reports scale scores for each of the seven dispositions: 1) truthseeking, 2) openmindedness, 3) analyticity, 4) systematicity, 5) CT self-confidence, 6) inquisitiveness, and 7) cognitive maturity. Scales were determined by factor analysis, which resulted in non-orthogonal and non-discreet factors consistent with its theoretical definition. It is composed of 75

items using a 6-point Likert scale. Reliability of overall disposition is reported as 0.90 (Cronbach's Alpha) for the total inventory and from 0.72 to 0.80 for the individual scales (P. Facione, N. Facione & Giancarlo, 2000).

The *California Critical Thinking Skills Test* (CCTST) is a standardized, 34-item, multiple choice test with discipline neutral content for assessing the core critical thinking skills identified in the APA Delphi Study (P. Facione, 1990). The tool is designed for use in post-secondary settings and can be used as a placement instrument, an assessment instrument and an evaluation instrument. Six scores are reported, an overall score and 5 subscales: 1) analysis, 2) evaluation, 3) inference, 4) deductive reasoning, and 5) inductive reasoning. The 34 items are divided first among the three subscales consistent with the APA definition: analysis, inference and evaluation. The same items are also partitioned between the more traditional dimensions of deductive and inductive reasoning. Sub scores are not independent of one another and cannot be used to identify specific strengths and weaknesses. The internal consistency reliability reported by the Kuder-Richardson 20 ranges from 0.70 to 0.84 (Blohm, Howard & Giancarlo, 1998). Evidence of theoretical construct validity is provided by an experimental validation study conducted with students completing a critical thinking course and under conditions likely to produce no significant differences. Even so, the instrument demonstrated gains for students in the experimental group, but not the control group. Significant correlations have been found between the CCTST and the Graduate Record Exam ($\underline{r} = .72$), the Watson-Glaser Critical Thinking Appraisal ($\underline{r} = .41$ - $.54$), the SAT ($\underline{r} = .55$ verbal; .42 - .44 math) and ACT ($r = .40$) college board exams, and Nelson-Denny reading test ($\underline{r} = .49$) (Blohm, Howard & Giancarlo, 1998).

Data Analysis

Instructional Practice Data

Interview data was processed in a number of ways. Before the tapes were released for transcription, I listened to them and took notes, using the initial research questions as a guide. Short phrases were recorded where specific language was important. Quotes were generally used with respect to definition and goals, program features and features of successful or unsuccessful activity implementation. Interpretive notes were made where data were more objective or easily classified, such as courses that impact critical thinking, assessment, communication and types of instructional activity.

I transcribed the student focus group interviews myself and distributed them to the students for review. This transcription required listening to the tapes in their entirety twice. The first round was actual transcription of the text of the interview. The second round attributed each passage to an individual student by number. The order in which students spoke during the focus group had been recorded and the passages had to be aligned with the numbers. In some cases, students interrupted one another or several of them spoke at once and this attribution was difficult or impossible.

Most faculty interviews were transcribed by an assistant and then reviewed. While the interviews were being transcribed, data analysis continued. The interview notes described above were used as the foundation for building matrices of faculty and student perceptions in each of the 13 categories of data collected. I used these matrices to identify common themes among the various faculty and students who were interviewed. Notes were made about how phrases were being interpreted and combined. Similarities and differences between phrases were analyzed and recorded.

The next step in data analysis was to synthesize and analyze the perceptions of faculty and students from the interview with their actions as evidenced in the document analysis. First, the data from the two sources were combined into a single document. For each course, CT related course objectives and assignments from the syllabi were integrated with the data from the interviews and classroom observations, where relevant, in creating a comprehensive picture of the course. Then this compilation of course data was examined from a number of different angles: (a) match between objectives and activities calling on CT, (b) match between type of CT processes indicated in the syllabus and by the associated activities, (c) themes related to design or implementation of the activities (grading, verbal vs. written, group, planned, feedback), and (d) counts of various types of activities and CT processes used.

At this point, a comprehensive case analysis was prepared for each site following the template suggested by the research questions. The goal was to begin to develop a sketch of each site in relation to the key research questions. This activity forced some early exploration of themes that would become relevant in cross case comparisons. However, since the data that was being used from the interviews at this point was not directly from the transcripts, only broad brush strokes were filled in, specific features remained to be uncovered. Coding schemes were developed, tested and modified. Some of these schemes would be applied directly when the transcripts became available, others would be discarded and reinvented at that time.

When the interview transcripts became available, a new library of data was developed in each of the relevant categories: definition of CT, activities used, and implementation strategies. In addition, evidence of attention to dispositions in critical

thinking was seen, and so a fourth category for dispositions was added. This library was created by marking up physical copies of the transcripts for data related to each of the four categories and then blocking those text sections electronically, tagging them with interview reference data and importing them into a matrix for analysis. A matrix was developed for each of the four categories that summarized the perception data for each school and across the schools. By vertical review of the matrix, it was easy to scan the data for an individual site. By horizontal review of the matrix, I was able to detect the similarities and differences among the three sites.

These matrices of transcript data (example in Appendix E) were then coded along the various dimensions related to the category. This is where the previous analytical work was a benefit, in that coding schemes were already developed. Most required only minor modification, but one was abandoned at this stage. For instance, in the category of instructional activities, early analysis had suggested that case scenarios, experiments, film critiques, questioning techniques and research papers would be relevant coding features. However, at this early stage, it was not apparent that it would also be important to code for evidence descriptors or CT processes. These coding schemes were developed during the second stage of analysis as coding mutated from a strict activity description. It was necessary at this point to go back and recode all of the activity data along four dimensions: activity type, student or faculty focus, evidence and CT process. Not all entries in the matrix could be coded on all four dimensions, but most could be. Initially, the CT process descriptive terms looked a lot like the terms used for coding the definitions data, so the same coding scheme was applied. It later became apparent that these descriptors were closely aligned with the six APA categories and so these original

descriptions were again modified to be consistent with that coding scheme. This step allowed for more direct analysis of perceptions, syllabus data and initial survey questionnaire data.

The codes assigned to each passage and each site were transferred into yet another matrix for further analysis (coding scheme in Appendix F). Here codes were sorted and counted and patterns of use were established for each site and across all the sites. This was the beginning of the cross case analysis. These coding matrices allowed for easy identification of similarities and differences across sites as well as features that were unique to a particular site. Activities that were seen with high frequency (case scenarios and film critiques) were further analyzed for patterns of usage in evidence and CT processes within and across sites.

The category of implementation strategies followed this same process. However, at the point of trying to develop written descriptions for both individual and cross case findings, it became very difficult to come to any summation or comparison. While they could be counted and compared, they didn't seem to make any practical sense. These data were examined yet again and a new coding scheme was developed that was able to bridge theoretical concepts with their practical application.

As a result of the two stage processing and coding of the qualitative data, first from notes and then from transcripts, coding and analyses were confirmed and revised. During the first four months of analysis, I always worked with data from one program at a time, first from notes and then from transcripts. After being immersed in one site's data for two to three weeks, I left it alone for more than a month. When I returned to look at that data again, in some respects, it was as if I were looking at it for the first time. Since I

was the only person coding most of the data, this temporal separation from it was important to ensure reliability and stability of coding. To further enhance this reliability, a small sample of interview and classroom observation data was reviewed a third time following completion of the first draft of this document. This final review provided further clarification of the distinction among the various codes and resulted in minor coding changes.

The quantitative data related to instructional practice appears in the responses of students and faculty to the survey questionnaire. Student responses were averaged across all participants and faculty and program director responses were averaged together. These two groups of data were visually compared for consistency of ratings between students and faculty. A comparison was made for each statement and then a conclusion was drawn about the comparability of the perceptions of faculty and students about how much each of these activities was required in the program.

Student Outcomes Data

The results of the CCTST and CCTDI for the cohort at each site included individual scores (both total and subscale) and group descriptive data. In addition, normative data was available for the skills test. Because the number of participants was unequal and lower at sites B and C than had been hoped for, statistical comparison of results was performed but does not serve as a foundation of the analysis. While differences in performance are seen among the various student groups based on descriptive statistics, these results can only be seen as suggestive of some possible differences. Therefore, type II errors are likely in this study.

Samples of student work were also available for analysis. These were primarily research papers, but included four in-class presentations as well. This data was analyzed for evidence of critical thinking and then coded using the APA categories for critical thinking skill (see Appendix A). The amount of data of this type that was available is quite small and so is limited in its ability to provide the ability to triangulate the findings for student outcomes.

Finally, the cross case analysis was used as a spring board for the most important question of all, "so what did you find?" As recommended by Miles and Huberman (1994), conceptually ordered displays were used to organize the data related to the major research questions. Similarities and differences among the various sites became obvious with this visual display of the data. This matrix was also used to connect the distinctions among my three sites back to the theories of instruction in critical thinking. The matrix was reduced to those conceptual areas that differentiate the three sites and is presented in Chapter 7.

CHAPTER 4

Whole Group Quantitative Results

This chapter will summarize the results of the instructional practices survey used as a basis for case study selection and the data from the two measures of critical thinking outcomes. This data will supplement that provided in the previous chapter to further explain site selection. In addition, it will serve as a preliminary explanation of the data provided by the two critical thinking measures, the California Critical Thikning Skills Test (CCTST) and the California Critical Thinking Disposition Inventory.

Survey Results

Eighty-three programs responded to the invitation to complete the web-based survey about instructional practices for critical thinking. The surveys provided data indicating how frequently the program director believed the program addressed each of 17 different critical thinking activities. In addition, demographic information about program size, selectivity, accreditation status and graduation date was collected. Program directors were also asked to indicate their interest in participating in the follow-up phase of the study.

A cumulative score for critical thinking instructional practices (CTIP) was calculated for each program. This score became the indicator of how much critical thinking instruction was occurring in each program. Programs reported CTIP scores ranging from 7 to 48, with a mean score of 30.63 and standard deviation of 8.36. For reference, a school reporting "a little" activity for each of the 17 prompts would score 17, one reporting "moderate" activity would score 34, and one reporting "a great deal" of activity on each would score 51.

The intention was to select programs demonstrating both high and low amounts of critical thinking instruction, so programs were rank ordered once the scores were calculated. In addition, programs of similar selectivity were desired, so each program was coded as being low, high or unknown selectivity.

Early analyses of CTIP scores were performed to assess potential differences among the various groups of respondents. The following questions were posed: Do programs with higher selectivity engage in more critical thinking instruction and therefore report higher CTIP scores? Do program directors willing to participate in the follow-up phase of the study come from high CTIP schools? Do those schools that are potential sites for follow up differ on their CTIP scores based on selectivity? The results of those analyses follow.

1. Selectivity: One-way ANOVA was used to test for differences in reported CTIP score among programs reporting high, low and unknown selectivity. While the more highly selective programs reported higher quantity of instructional practice use ($n = 19$, $M = 32.79$, $SD = 8.07$) than unknown ($n = 25$, $M = 30.20$, $SD = 8.07$) or low selectivity schools ($n = 38$, $M = 29.84$, $SD = 9.66$), CTIP scores did not differ significantly among the three groups, $F(2,79) = 0.831$, $p = 0.44$.

2. Willingness to participate in case: Survey respondents indicated either a willingness to participate in the case study phase, an unwillingness to participate further or a request for more information. Those reporting a willingness to participate or a request for more information were combined in a group of potential case study participants, while the non-potential group included both those specifically saying no to further participation and those that left the item

blank. Independent samples t-test was used to test for differences in CTIP score between the two groups. Those respondents in the potential case group ($n = 50$) reported a lower quantity of instructional practice use ($M = 30.02$, $SD = 8.78$), but the mean was not significantly different from the mean for those that were not potential cases ($M = 31.59$, $SD = 7.78$), $t(80)$, $p = 0.41$.

3. Selectivity of potential cases: The smaller group of respondents coded as potential participants in the case study phase ($n = 50$) were again tested for differences among reported CTIP score along the same levels of selectivity identified previously. Here again, highly selective programs ($n = 9$, $M = 32.22$, $SD = 6.89$) reported more CT instructional practice use, but not a statistically higher use than the other groups, $F(2, 47) = 0.339$, $p = 0.72$.

As a result of these analyses, the low selectivity group was chosen as the study population with reasonable confidence that they did not differ in predictable ways from the high selectivity group. The low selectivity group was chosen because it contained schools with a wider distribution of CTIP scores and therefore presented the greatest range of instructional practice variation for the study.

Student Outcomes for Critical Thinking

A total of 25 students took the California Critical Thinking Skills Test (CCTST) and California Critical Thinking Disposition Inventory (CCTDI), 12 from Site A, eight from Site B, and five from Site C. The results of the whole group on these two measures will be presented in this Chapter with individual program results reported in each case report of Chapter 5 and the cross case analysis in Chapter 6.

California Critical Thinking Skills Test

The CCTST is composed of 34 multiple choice questions and reports a total score as well as five subscale scores. The first three subscale scores follow the categories of the APA consensus definition on which the test is based. They include Analysis (which also includes the APA category of interpretation), Inference, and Evaluation (which also includes the APA category of explanation). The other two subscale scores report on the more traditional dimensions of deductive and inductive reasoning.

Table 4 contains the descriptive statistics for this group of students as well as comparison information from a national sample of baccalaureate level undergraduate students. Comparisons should be made with caution since the students in this study were near completion of their Associate level degrees, while the comparison group were completing baccalaureate degrees. This comparison is made in part because there has not been enough data collected as yet to provide comparisons for associate level students. In addition, as will be seen in Chapter 5, students completing the associate level of these radiography programs are more similar to junior status college students because of the programs' pre-requisite requirements as well as a high credit requirement for the associate level programs.

This group of students performed at approximately the same level as the baccalaureate level students on overall skill as well as in most subscales. A small difference is seen in the Analysis subscale with the radiography group scoring higher than the national sample. This study does not allow discrimination between two competing explanations: these radiography educational program produce greater analysis skills or individuals with a greater aptitude for analysis are attracted to these programs. In

Table 4

Comparison of Radiography Skills Results with National Data

	Study Group			National Sample[a]		
Scale	**Mean**	**Range**	**S.D.**	**Mean**	**Range**	**S.D**
Total	16.56	9-23	3.79	16.90	1-32	5.06
Analysis	4.76	2-7	1.20	4.44	0-7	1.41
Inference	8.04	4-13	2.21	7.85	0-15	2.68
Evaluation	3.76	2-8	1.73	4.52	0-11	2.14
Induction	9.56	7-13	2.81	9.53	0-17	2.82
Deduction	7.0	2-13	3.79	7.27	0-16	2.89

[a] n=2677 Four-year college students

the Evaluation subscale, the radiography groups scores quite a bit lower that the national sample, again indicating that perhaps either aptitude is lower or treatment effects are less effective in this area.

California Critical Thinking Disposition Inventory

The CCTDI consists of 75 questions that address an individual's tendency to think critically. The CCTDI reports a total score as well as seven scales: Truthseeking, Openmindedness, Analyticity, Systematicity, CT Self-confidence, Inquisitiveness and Maturity. These scales are further defined in Appendix A. Each scale has a potential range from 10 to 60 and the total score from 70 to 420.

A cut score of 40 for each scale and 280 for total disposition has been established by the publisher. Scale scores falling at 30 or below are considered to represent negative disposition, while those in the 31-39 range are considered ambivalent and those 40 and

above positive. The exam booklet also suggests a target score of 50 for each of the scales. By simple arithmetic, one can extrapolate to the total disposition score of 210 or below as negatively disposed, 211-279 as ambivalent, 280 and above as positive and a target of 350 (P. Facinone, N. Facione & Giancarlo, 2000).

This group of students demonstrated a positive overall disposition, as well as in each subscale except that of Truthseeking. The ranking of individual disposition scores from highest to lowest begins with Inquisitiveness, then Analyticity, CT self-confidence, Maturity, Systematicity, Openmindedness and ending with Truthseeking (Table 5). This is consistent with data reported for undergraduate students that indicates that students are most likely to score below 40 and least likely to score above 50 in the subscale of Truthseeking as well as being least likely to score below 40 and most likely to score above 50 in the subscale of Inquisitiveness.

There are two sets of data that can be used for gauging the performance of this group of radiography students. The test publisher supplies comparative information for a group of 267 undergraduate students (P. Facione, N. Facione & Giancarlo, 2000). The aggregate nursing study (N. Facione, 1997) provides percentile scores for each class of nursing students. Junior class information is used for comparison given that these programs approach 90 credits when pre-requisite courses are counted.

This group of radiography students is nearly equal in disposition to both comparison groups in Confidence and total disposition and slightly more disposed to Analyticity than the nursing group. They score more moderately (greater proportion between 40 and 50 and fewer above and below this range) in the scales of Inquisitiveness and Maturity. They are less disposed to Openmindedness than either comparison group.

While the radiography students show a greater disposition to Systematicity than the general college population, they are somewhat less disposed than the nursing students. Truthseeking disposition was particularly low in this population of nursing juniors and so radiography students show a little stronger disposition here, but with reference to the national sample show more extreme scores, not necessarily higher or lower.

Table 5

Comparison of Radiography Student CCTDI Scores to Two Other Samples

	Radiography group			National sample			Nursing estimates[a]		
Scale	Low [b]	Moderate[c]	High [d]	Low	Moderate	High	Low	Moderate	High
Truth	64%	28%	8%	60%	38%	2%	70%	20%	10%
Open	32%	64%	4%	15%	57%	28%	20%	70%	10%
Anal.	20%	64%	16%	23%	61%	16%	20%	70%	10%
System	28%	60%	12%	44%	45%	11%	20%	70%	10%
Conf	24%	60%	16%	25%	56%	19%	20%	70%	>10%
Inquis	4%	68%	28%	14%	45%	41%	<10%	50%	40%
Maturity	20%	68%	12%	17%	54%	29%	<20%	60%	>20%
Total	20%	76%	4%	22%	72%	6%	<20%	70%	<10%

[a] Estimated based on percentile score reports
[b] Scores below 40 in each scale or below 280 in Total score
[c] Scores between 40 and 50 for each scale and between 280 and 350 for Total scores
[d] Scores above 50 in each scale or above 350 in Total score

Correlations

The relation between these two critical thinking outcomes measures are of interest in this study as an indicator that the instrument behaves with this sample as it has in empirical tests of the tools themselves. Again two sources of data are available: that

reported by the test developer (Blohm, Howard & Giancarlo, 1998) and the results of the large scale nursing study (N. Facione, 1997). Table 6 reports those correlations along with those found with this group of radiography students. The radiography group demonstrated correlations consistent with those of the other two studies in these comparisons.

Table 6

Correlations of CCTDI and CCTST

	Radiography		Nursing		Test Manual	
	Pearson Correlation	Significance (two-tailed)	Pearson Correlation	Significance (two-tailed)	Pearson Correlation	Significance (two-tailed)
CCTST w/ CCTDI	.464	<.05	Entry: .201 Exit: .169	<.001 <.001	.201 .41	<.001 <.05

The nursing study also reported significant correlations between the individual skill subscales and the dispositions scales, with the exception of two combinations. The disposition scale of CT Confidence did not correlate significantly with the skill subscales of Analysis and Evaluation. However, the results of this study show quite different results. The only significant correlations between individual skill subscales and dispositions are as follows: Analysis skill with Analyticity disposition, Inference Skill with CT Confidence Disposition and Deduction skill with CT Confidence disposition. While the correlation coefficients for the radiography group exceeded those in the nursing study in most areas, the larger number of participants in the nursing study (1300-

1400) allows any correlation greater than 0.05 to represent a significant finding. A full report of correlations for the radiography group is included in Appendix G.

Summary

On the average, radiography programs report using moderate amounts of instructional activity directed to critical thinking. This frequency of use does not change when the programs selectivity changes, nor did it influence the program's willingness to participate in the second phase of this research study.

This group of radiography students performed at par with other groups available for comparison in many ways. Performance appears somewhat higher than comparison groups in the skill of Analysis and lower in the skill of Evaluation. These radiography students displayed lower inclination toward the disposition of Openmindedness and greater inclination toward Systematicity. While the comparisons must be interpreted cautiously because of differences in class level and degree aspirations, they do provide an indication of the approximate level of these radiography graduates.

CHAPTER 5

Case Reports

Site A – A Recreational Jogger

So you have decided to take up jogging…either because you want to or because you have to. Either way, everyone knows how to jog. You put one foot in front of the other, farther and faster than you do if you are walking. There is lots of information out there about the training, the equipment, the routes and the technique. But you really can "Just do it," to quote the Nike ad campaign. Without the benefit of this information however, you risk failure, injury and getting lost or on an inappropriate route. You may or may not be effective in acquiring the benefits that jogging promises. You have some jogging sessions that really work and inspire you and you have some that make you struggle and believe you can't do this.

So it is with the first case study—a recreational jogger in the critical thinking realm. Working on intuition and common knowledge of what critical thinking is…just doing it. There is little formal planning within or between courses and little use of available information resources. They have tried some new approaches…some worked, some did not and they haven't really thought about why. They are working on critical thinking, but it is not entirely clear where the finish line is. Faculty don't know if students are getting to the desired end point for critical thinking and students don't know either. Some activities and practices are success stories, but others are missed opportunities.

Site A is just at the beginning of its own development of instructional practices, planning and culture building for critical thinking. A summary of its features related to the research questions follows.

Table 7

Site A Summary of Findings

Question	**Finding**
Planning Method	Informal, student centered Not CT focused
Planning Resources	Minimal
Curriculum	Some infusion (direct instruction within RT)
Assessment Definition & Importance	Goal exists, no definition Very important
Communication	Print and discussion
Assessment Methods	Clinical Professional Evaluation, competency evaluation, employer and alumni survey
Program Fosters	Hard to identify, little agreement
Program Limitations	ARRT exam, time
Instructional Activities	Case scenarios & film critique
CT Processes	High: interpretation and inference Low: evaluation, analysis, self-regulation
Student Outcomes	Skills: Best = analysis, Worst = evaluation [a]Dispositions: Negative = T Low = T, O, S, C High = A, I, M
Implementation Strategies	Focus on activity design and instructor delivery

[a]Scales of the CT Disposition Inventory: T=truthseeking, O=openmindedness, S=systematicity, C=Self-confidence, A=analyticity, I=inquistiveness, M=maturity

Site Description

Site A is a community college in a moderately sized metropolitan area. The radiography program is one of eight allied health and nursing programs in the Health Sciences Division. The program currently has an enrollment of 27 students in two classes combined. The program is accredited by the Joint Review Committee on Education in Radiologic Technology.

Program faculty consists of a full-time program director, a full-time clinical coordinator, a half-time faculty member, and several adjunct faculty members whose sole responsibility is clinical instruction. The program director has filled that role for approximately one year, but has taught in the program for eight years. The Clinical Coordinator is new in the job this year and has no previous teaching experience. The faculty member with the greatest experience is the one that teaches half time (10 years).

Students must take 28 pre-requisite credits, including medical terminology, human anatomy & pathology, English Composition and first aid prior to acceptance into the program. Once accepted, the curriculum is a two-year program, including two eight week summer sessions. The total number of credits, including pre-requisite courses is 87.

Site A was classified as low selectivity (average or minimum SAT/ACT score below the national mean or students accepted from the top half of the high school graduating class) based on data provided in the screening survey. It was also classified as providing few instructional activities to develop students' critical thinking skills or dispositions, scoring 7 of a possible 51 points as reported by the program director on the screening survey.

All faculty participated in the study, as did all second year students in the program. Nearly all first year students consented to classroom observations. Six first year and six second year students participated in the focus group. All second year students took the California Critical Thinking Skills Test and Disposition Inventory.

Planning

Method

Planning at Site A is informal for most program operations. The Program Director assumes primary responsibility for planning and seeks feedback from the faculty. Formal faculty meetings are frequent and regular. These involve both didactic and clinical faculty and are focused primarily on discussing individual student performance and progression in course material. Yet, much of the discussion related to program planning occurs through informal hallway chats and individual discussions.

> What ends up happening is I talk to [Faculty 1] and then I'll talk to [Faculty 2] and we'll talk about things that need to be discussed and then we'll bring them up again in the clinical meeting so that they'll be in the minutes. The thing is, when things come up, you don't just wait until the faculty meeting. I just run next door....We're just so close, we all talk really well and so it's difficult to wait. The only reason we do it is just so we have minutes.

Here the program director describes what s/he sees as a typical mode of communication among faculty. This method is used both for problem solving as implied here and for more typical planning activities.

Yet, the informal planning does not necessarily address critical thinking. Further, one faculty member believes that this lack of planning is a limitation to the development of critical thinking skills in their students.

> Well, I don't think that we sit down when we do our syllabi or our outlines and really think about and address critical thinking skills. I think we don't look at like a percentage of what we teach addresses that. I don't think

> that we have a goal – I don't think it's something that we talk about. We as teachers don't say – I do this and I think it's a good critical thinking exercise. I don't think we think about it. At least, I don't that much.

This response was to a question about what limits the development of critical thinking at this site. Here the faculty member suggests that more formal planning around critical thinking might be helpful.

Resources

While faculty talked about a variety of sources that helped them with teaching in general (on campus workshops, formal coursework, books and articles), none were able to identify anything specifically related to critical thinking. The Program Director used one reference book that was focused on critical thinking in radiography.

The faculty has not consulted with colleagues in any other allied health programs, the nursing program, or the psychology or philosophy departments. The Program Director did consult with the College's Office of Institutional Research, but did not receive any helpful assistance from this resource. As a result of this absence of professional development and consultation, the faculty members are teaching for critical thinking in a very intuitive manner.

Curriculum

As is typical in radiography programs, there are a number of pre-requisite courses and general education courses taken concurrently with the radiography curriculum. Beyond this, the curriculum organization is unusual. Each course contains multiple mini-courses that may be unrelated to one another (for instance advanced radiographic exposure and facial positioning). Each mini-course functions as a separate unit, has

separate grading and is often taught by different instructors. The mini-course grades combine together to be recorded as the official course grade.

There appears to be little attention given to planning specifically for critical thinking progression or development throughout the curriculum. Faculty are not familiar with the content or approach of pre-requisite or general education courses. Faculty also had little knowledge of each other's courses. While they were able to talk about how their own courses did or did not help in critical thinking development, they were only able to talk about others' with respect to the potential of the content to lend itself to critical thinking, rather than on specific knowledge of the instruction that is occurring. Direct instruction for a four-step approach to problem solving is provided in both the ethics/laws and trauma/special procedures mini-courses.

Planning for clinical instruction follows a minimalist approach. Planning for critical thinking focuses on evaluation more than it does instruction. Two evaluation tools form the core of the instructional and assessment plan. Students are required to complete clinical competency evaluations on 45 radiographic examinations. Each of these evaluations requires that the student critique the resulting radiographs with the clinical instructor. This provides opportunities for instruction, assessment and evaluation of the student as s/he makes judgments about film quality and possible modifications.
The second evaluation tool is the Professional Clinical Evaluation that is completed by the supervising faculty member once each semester. Different rubrics are used to evaluate first year and second year students.

Assessment

Definition and importance.

One of four program goals is to "Develop the student's communication, problem solving, and critical thinking skills so that they may function competently as part of the health care team." Further definition of critical thinking skills or their differentiation from problem solving skills has not occurred. However, there is a general consensus among faculty and students as to what comprises these two areas. The primary area of focus is the ability to adapt standard protocol to accommodate the patient and environment. Several supporting skills are also commonly mentioned: applying theory, considering options, and making decisions/choices. In addition, the critique and correction of radiographs is commonly included in discussions of critical thinking.

It is difficult to determine how important critical thinking is to this particular program because there is little agreement. The Program Director believes that the goal containing critical thinking is equal in importance to two other goals focused on professional competence in ethics, patient care and radiation safety. This may result from the belief that these other two rely on the student's critical thinking abilities. Most students believe that critical thinking is the second most important goal, but there is not agreement among them about what the most important goal is (knowing facts, passing tests and low program attrition were commonly mentioned). One faculty member believes that critical thinking is the least important goal of those established for the program.

> Well, we're giving them a body of information that we hope they'll assimilate and basically memorize and then add to that. And a lot of it to me is based on their own abilities and some people can critically think on their feet or imagine or put into practice different scenarios or situations that may come up, and some people can't.

This is not a view commonly held by faculty or students at this site, but illustrates the variation in perceptions of importance of CT here.

A number of inconsistencies related to importance of critical thinking are seen. While the Program Director and students believe that critical thinking is highly important, few could identify how the program develops critical thinking through its characteristics, culture, curriculum or instructional activities. The importance may be artificially elevated as a result of a recent re-accreditation evaluation in which the program was cited for its instruction and assessment related to critical thinking, as well as my presence to conduct this research. Secondly, the faculty member who considers critical thinking to be the least important program goal actually includes more instructional activities that call on critical thinking than other faculty. S/he also has been more creative in trying different approaches to engage students in activities that would develop their critical thinking.

Communication of goals.

Despite the lack of definition and variation in perceived importance, students and faculty alike are clear about communicating critical thinking goals to students. The goals are included in the student handbook and are discussed with students at the outset of the program. In addition, individual course syllabi include objectives that establish specific performance areas related to critical thinking (although they are not clearly labeled as such). Students also perceive that they learn about critical thinking priorities (being able

to adapt and to critique films) from the technologists and experiences that they encounter in their clinical rotations. Despite the fact that students had difficulty when specifically asked to define critical thinking, their discussions about what promoted it and hindered it were free flowing and illustrative of their common understanding of that definition.

Assessment of goals.

The program goal specific to critical thinking is directly assessed only in the clinical courses, not in the classroom setting. The primary measurement is student performance on the Professional Clinical Evaluation completed by supervising staff at the clinical site and by the faculty member responsible for that site. Indirect assessment data are also collected from employer surveys and alumni surveys completed 6 months and 3 years after graduation. The program documents indicate that student performance on the American Registry of Radiologic Technologists' certification examination will provide evidence that this goal has been achieved. No research is available to support this claim.

The Professional Clinical Evaluation tool is a rubric that includes one category specific to "Critical Thinking and Problem Solving" with five performance levels. The tool used for first-year students focuses on the ability to modify protocol as needed to accommodate the patient and/or situation. The evaluation tool for second year students combines these criteria with that of organization and adds a second category specifically focused on adaptation to patients of different ages. The criterion statements in the rubrics provide basic performance criteria related to presence of the ability (can/cannot modify protocol) and then frequency of application (rarely, often, excellent), leaving room for interpretation by both faculty and students.

While not identified in the program's assessment plan as an indicator of critical thinking performance, the students' procedure Competency Evaluations also include elements of critical thinking. The performance measure requires students to evaluate film quality in nine different aspects that are graded as "done/not done." While this appears on an evaluation form, it seems to be used more for instruction and development of critical thinking than for assessment. The Program Director expressed confidence that s/he uses this activity to develop students' critical thinking, but was unsure about how other clinical faculty approach this activity.

Program Features

There is little agreement among faculty and students about features of the program that foster students' critical thinking development. Students focused strongly on clinically related activities such as adapting to different patient needs and analyzing and correcting radiographs (particularly when reviewing with a clinical instructor). Only one faculty member also mentioned patient activity in the clinic. Another faculty member suggested that requiring the students to apply a given theory in a number of different classes was a "fostering" feature and that the logical sequence of the curriculum was as well. Another thought that club activities provided opportunities for students to exercise their critical thinking skills in a different context. In general, faculty had difficulty identifying program features that foster critical thinking.

It was easier for both faculty and students to identify features of the program that *limited* students' ability to develop critical thinking. Both groups mentioned two features commonly: limited amount of time and teaching focused on passing the ARRT examination. These two items are likely related to one another as teaching the

information required by the test limits the time that program faculty have to spend on critical thinking or other instructional goals. It was also suggested that staff technologists could either be a help to students' development or a hindrance depending on how much they afford students the opportunity to develop their own thought processes. Students also mentioned rival goals of retention and making sure that students passed classes (which means they pass exams) rather than what they perceived to be a competing focus on thinking and learning.

> I think sometimes teachers get caught up in...they try to get you to pass this test or pass that or pass the program and sometimes in doing so they forget to help you learn critical thinking. They're thinking, we've got to graduate so many students, this one needs to pass that one, instead of getting in there and trying to help you rationalize or think this out, this particular area or question or whatever, they get caught in that sometimes, I think.

This student recognizes and verbalizes the conflict between knowing facts and being able to apply them that is prominently expressed by both students and faculty at this site.

Students perceive the clinical work environment to be an important tool for critical thinking development when they are allowed to: a) practice independently, b) think for themselves rather than being told exactly what to do, c) "practice" thinking about how to approach different situations/challenging patients and d) spend one-on-one time with clinical instructors to review films. The minimal structure associated with clinical practice leaves little assurance that these features will be present in any of the multiple clinical sites used by the program.

Instructional Activities

No course or mini-course is clearly focused on critical thinking development. Two of the three faculty members believe that Anatomy & Positioning classes (of which there are 5 mini-courses) provide the greatest opportunity for critical thinking development, while students focused on clinical activities. Both faculty and students discussed individual activities from the radiographic exposure, quality assurance and ethics/laws courses.

Faculty and students presented a variety of instructional activities as being connected to students' critical thinking development. These range from questioning techniques in class, to group goal setting, interpretation of graphs, role-playing and experimentation in the laboratory. The most common is the use of case scenarios related to ethics and law and film analysis.

Classroom visits allowed observation of faculty and students in action. On the faculty side, there were demonstrations of a variety of skills, dispositions and implementation strategies beyond the planned lesson. Faculty explicated their reasoning in coming to a conclusion, forced students to come up with multiple solutions for a problem, helped them to come to a conclusion, and asked probing questions. As well, there were a number of missed opportunities to call on students' CT. Students demonstrated self-correction of their thinking and an absence of Truthseeking disposition as they failed to correct an error in the instructor's calculations that they obviously noticed.

When comparing the students' perceptions of instructional practices as indicated by the survey questionnaire to that of the faculty members, there was little agreement.

Students typically reported that they were required to perform the instructional activities identified in the questionnaire more frequently than faculty did. The differential score for individual activities often exceed 0.5 on a 3-point scale and were found to be as much as 1.5 different. More detailed analysis and comparison with other programs is provided in Chapter 6.

Critical Thinking Processes

The activities used in this program primarily ask students to perform the cognitive activities of interpretation and inference, along with some explanation. The more specific skills of drawing conclusions (inference), clarifying meaning and decoding significance (interpretation) were most prominent within those categories. The categories of evaluation, analysis and self-regulation were rare or absent.

These instructional activities call on cognitive skills similar to those evidenced by the objectives included in course syllabi, although not necessarily in similar proportions (Figure 1). Course syllabi include extensive lists of performance objectives and minimal explanations of grading and assessment criteria. Few included broad goals, descriptions of assignments or specific evaluation criteria. Every course includes objectives that could promote critical thinking with the Patient Care and Advanced Exposure courses containing the greatest number.

When analyzed against the APA classification system, most objectives called on the category of interpretation with analysis and inference being seen slightly less frequently. The categories of evaluation and explanation were seen infrequently and self-regulation not at all. Objectives frequently asked students to compare and contrast

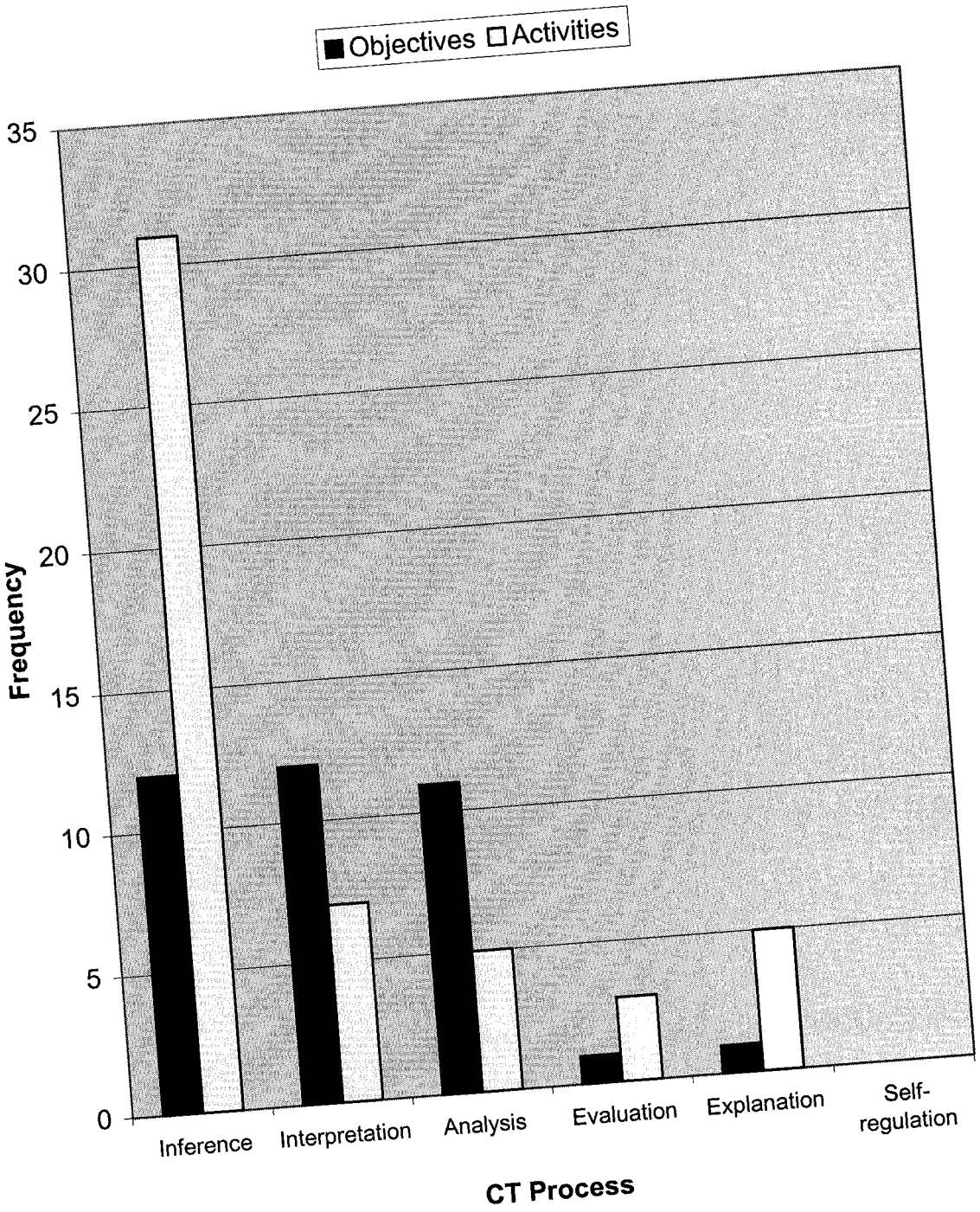

Figure 1. Site A. Comparison of CT processes indicated in course objectives with those called on via activities suggested by syllabi and faculty. In most categories, more activities are present than the objectives would suggest.

concepts (Analysis), interpret graphs and the significance of events (Interpretation) and determine how to modify a radiograph (Inference).

Outcomes

Given the emphasis on interpretation, analysis and inference in the program's learning activities and objectives, one might expect that students would perform better on these subscales than on the Evaluation subscale or the overall skills test. Overall, this program scored slightly lower (16.33) than the group mean (16.56). These students posted their best performance in the Analysis subscale and their worst in Evaluation. Figure 2 demonstrates the relationship between instructional practice and student performance for each of these subscales.

There were significant correlations between critical thinking skills test scores and college GPA ($r = 0.53$, $p = .05$) and major course GPA ($r = 0.68$, $p = .01$), suggesting that perhaps critical thinking is being recognized and rewarded in course grades, particularly in the major. Total score on the disposition inventory demonstrated a non-significant negative correlation ($r = -0.20$) with college GPA and a larger, but still non-significant positive correlation with major course GPA ($r = 0.46$). Significant correlations exist between the disposition of Truthseeking with Maturity as well as between Analyticity and total disposition. Each subscale of skills is significantly correlated with total skill, as is the subscale of Deduction with that of Inference and Analysis.

Results of the disposition inventory show that students in this program maintain positive attitudes toward critical thinking overall and in each of the subscales except Truthseeking. The mean Truthseeking score for this program is 39, which is just below the cut score for positive disposition (40). Students also scored low in relation to the other

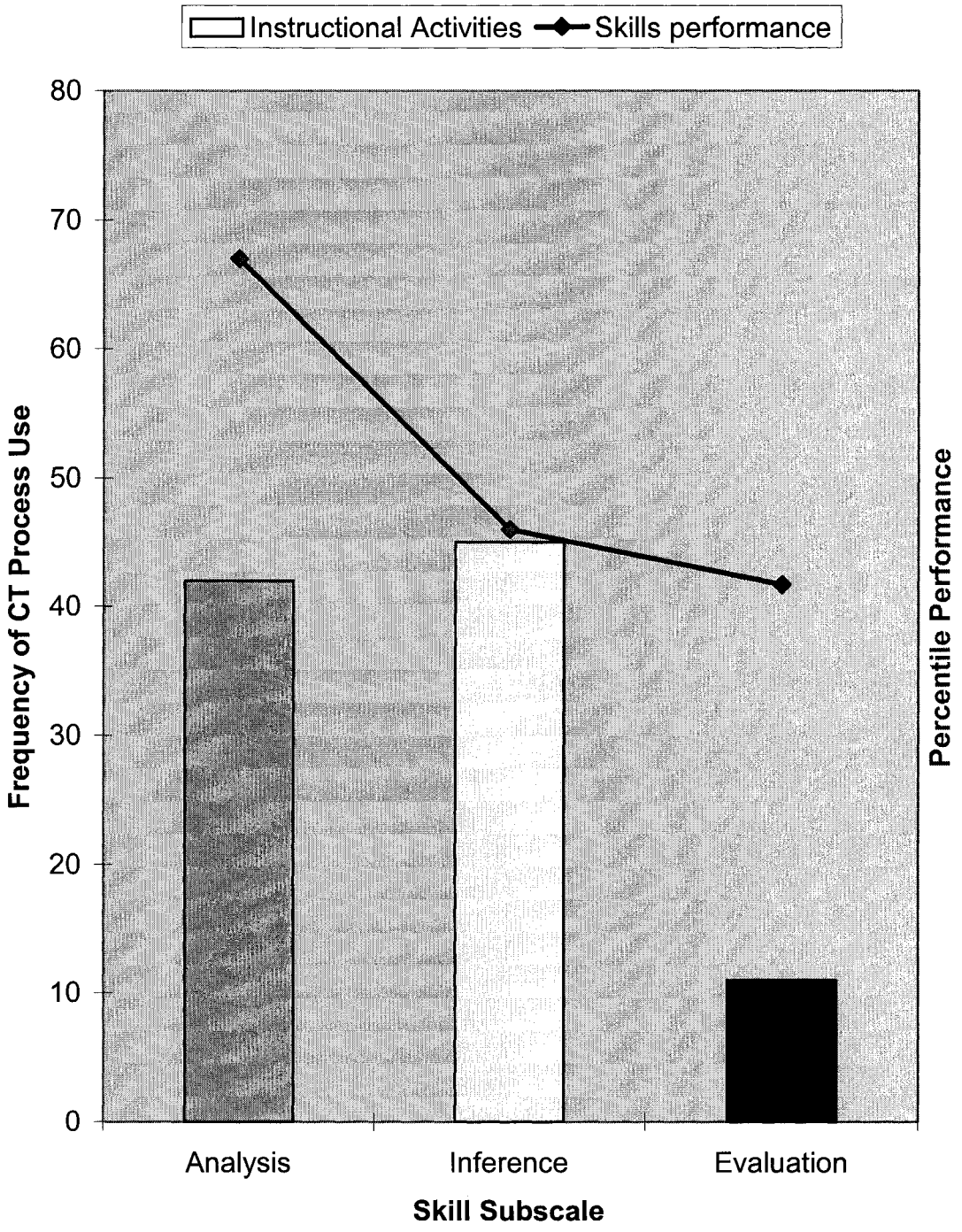

Figure 2. Site A. Comparison of instructional emphasis on each of the CT processes and performance on the associated CCTST Subscale. Performance trends match instructional emphasis only for evaluation subscale.

sites in 4 out of 7 subscales and total disposition. The greatest differences were demonstrated in the subscales of Open-mindedness, CT Self-confidence, and Inquisitiveness. Further evidence of low inquisitiveness is provided by these quotes from two different faculty members.

> I can remember going over anatomy once and having students, not all of them, I've had a couple of them, say "Uh, I don't want to be a radiologist." You know that's one of those people that I don't think should be in x-ray.
>
> I'll tell them a story and say, well, gee, what would you guys have done? Their reply was "I'm not going to do surgery, so I don't have to worry about it."

These quotes illustrate how student behaviors in the classroom have been consistent with the disposition inventory scores of these students, although we cannot be sure that the quotes refer to the same students who took the inventory measure.

Little student work was available for review. What was available was a series of papers written by students in the program during the years 1996-1999 that were award winners in state level competition among radiography students. Since these papers were not the work of these participating students and would be highly skewed to demonstrate the best work produced by the students at this school, they were not analyzed.

Implementation Strategies

Students in the focus group were asked to identify what makes an instructional strategy work to make them use their critical thinking and what makes an activity not work in that regard. They did not appear to understand the question well, because their answers were more closely related to the type of activity used, rather than what makes the strategy work or not. However, some messages came through: building concepts upon

one another, allowing enough time, requiring decisions, and limiting the amount of information to be considered.

The issue of time was one that faculty also agreed was important in developing students' critical thinking. Several faculty suggest that situations that do not have one obvious correct answer would be helpful for developing critical thinking. Individual faculty focused on motivating the student to be engaged in the task or on the dynamics required for activity completion. There was agreement about what made an activity not work—lack of time or too much information to be included. Other items suggested include both personal issues (strong personalities, lack of knowledge) and process issues (group process, lack of direction, not thinking broadly).

While individual faculty members mentioned a number of other features, only one faculty member was particularly reflective about what made an activity work. In reference to scenarios presented in an ethics class, s/he felt that the following were important features that made students think critically:

> I think these particular scenarios were effective because there was no obvious correct answer. I think it took critical thinking and they had to use things to justify their decisions. Even with the justifications enumerated and listed, there still could be another answer. And this really got them going. I think if there had been one exact correct answer, there wouldn't have been as much to have thought about. I mean, there being room for debate caused them to have to really think more about it. And then when they started arguing, oh boy…

> I think it gave them an opportunity to independently think about it – they weren't just in the group before they could make their decision. They independently had to work on it too and I think that caused the variety of opinions to be even stronger. I think if putting them in a group like we did – the one strong personality could have had more influence over other's thinking.

This faculty member shows considerable insight into how instructional activities might be designed and delivered in order to promote critical thinking. However, the faculty here did not frequently evidence this insight. In general, there was an emphasis on teacher talk at Site A rather than on student independent thinking. This is demonstrated by consideration of the six dimensions of the implementation strategies as demonstrated in Figure 3.

The distribution of strategies is heavily weighted toward the area of activity design, with a secondary emphasis on instructor delivery features. The design features included such strategies as the need to ask more questions, give more direction and provide the students with more opportunities for independent thinking. Most conversation about strategies were teacher-focused, but were aimed at getting students to be more active and involved in the learning activities.

One faculty member at this site presents some interesting findings related to beliefs and instructional activities. While expressing a deterministic belief about critical thinking ability (some students can and some cannot think critically), this faculty member was also very creative with instructional activities. Some of the more unusual approaches to instruction included:

- Completing all aspects of a research paper assignment along with the students and discussing the process with them
- Using popular film to study radiation therapy and the importance of attitudes about cancer, death and dying.
- Encouraging students in a trauma radiography class to identify their own areas of instructional need and help to arrange the class and guest speakers

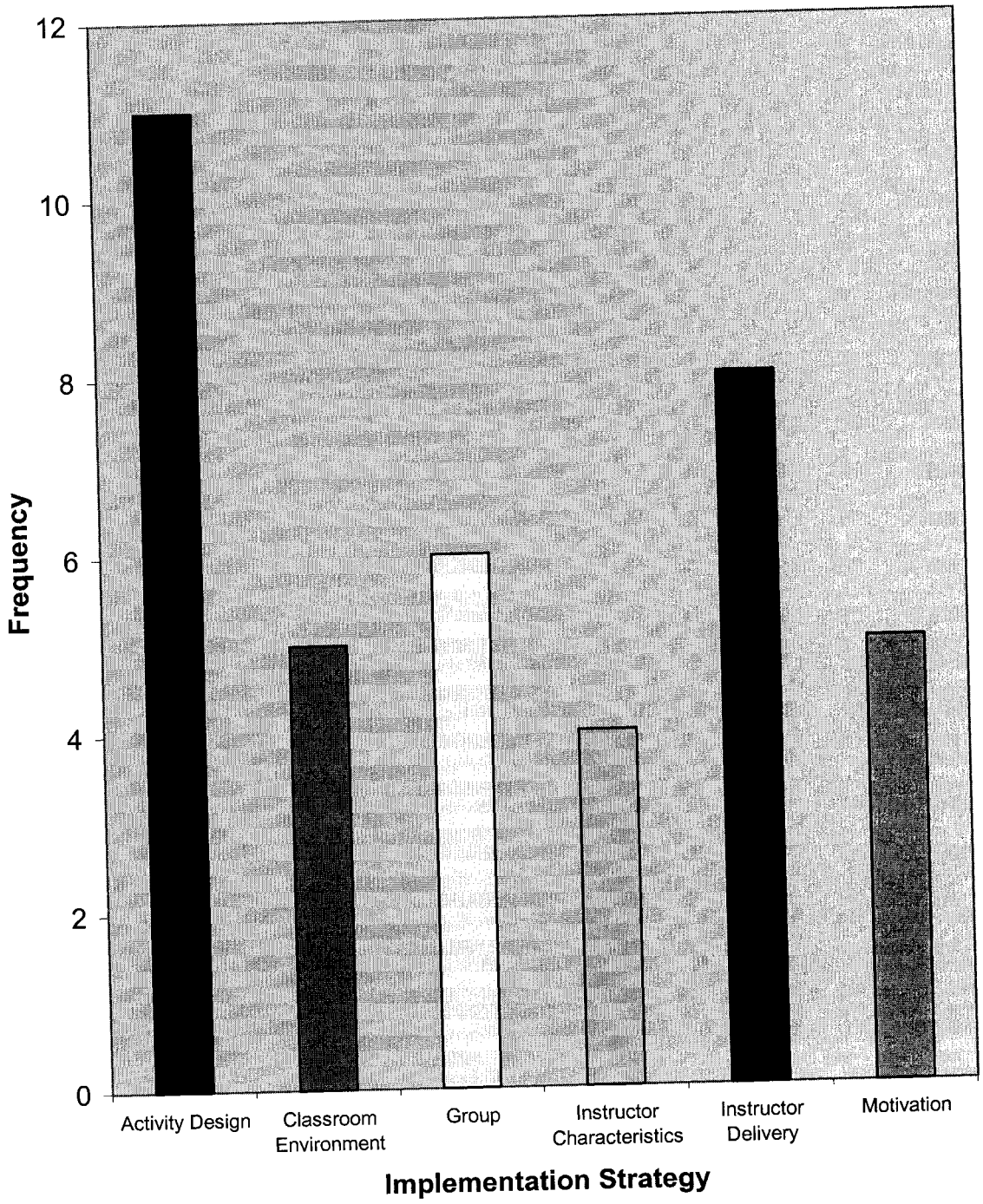

Figure 3. Site A. Distribution of implementation strategies. Strong emphasis is placed on Activity Design and Instructor Delivery. Faculty characteristics are not seen as an important feature related to critical thinking.

Each of these activities was used once or twice, initially with great success and typically with a lesser degree of success the second time. A third use was generally unsuccessful. When probed about why the activities worked at first and not as well in subsequent uses, the instructor offered student differences and faculty enthusiasm about the activity as potential explanations.

These activities demonstrate several key aspects of strategy implementation: instructor delivery and motivation in particular as well as attempts to try new methodologies. The faculty member's reference to student differences as being important in activity success may be related to a belief that critical thinking is (at least partially) innate, rather than a learned skill.

Summary

During the site visit it appeared that more instructional activities related to critical thinking were being used than had been initially reported by the program director (8 out of possible 51). The two other faculty members and the students all indicated that they believed more CT instruction was occurring than the program director had initially reported (average scores of 18 and 28 respectively). I completed the same survey to test this perception and arrived at a score of 17 for this program. This confirmed my perception that more critical thinking instruction was occurring in the program than had originally been suggested. While a score of 17 would have initially been considered a more moderate CTIP score, in fact, the manner in which the activities were implemented, rather than actual frequency is a more accurate indicator of CT instructional practice at this site.

The program has established critical thinking and problem solving skills as one of the goals for the program (as required by the JRCERT). However, the program does not have a formal definition of critical thinking or specific goals that serve as a basis for its assessment of student skill development or program effectiveness. Review of the program documents reveals that the focus for this program is on modification of procedures to accommodate different patient conditions and to critique and correct radiographs.

Classroom activities that were thought by both groups to be helpful in developing critical thinking include case scenarios, role-playing, interpretation of graphs and experimentation (both scientific and procedural). However there was little agreement about what makes a particular CT activity work. There was agreement about what made an activity not work—lack of time or too much information to be included.

Faculty and students alike were hesitant when asked about program goals for critical thinking. Yet, there was consensus that critical thinking includes adapting to the patient and various situations/environments, critiquing radiographic quality, considering options for correcting film quality and making decisions (including value & situational choices). While most thought CT was highly important (ranking 1 or 2 on a 5 point scale), one faculty member thought it was of lowest priority.

Planning for critical thinking instruction and assessment is minimal. Faculty do not specifically plan for instruction in this area at either the program or course level, even though some course level goals include elements of critical thinking. This was thought to be a deterrent to students' development of CT by one faculty member. Assessment of critical thinking occurs in the clinical environment and indirectly through the use of graduate and employer surveys.

As a result, it was difficult for anyone to identify features of the program that foster critical thinking. Faculty tended to list their own courses as having an impact but few that other faculty members teach. There was more agreement about the program's limitations in developing critical thinking (at least between the program director and the students)—time, teaching to the national board examination, and the clinical staff.

Given the slight amount of instructional attention to critical thinking initially reported by the program director, one would expect the students to perform poorly on the CT skills test and disposition inventory. Students scored slightly, but not significantly, below the whole group mean in critical thinking disposition and skill. There was also more variability in scores for this program's students than at other sites. In the skills test, students at this site scored from the 12^{th} to the 97^{th} percentiles when compared with a sample set of two-year college students.

This program has focused more of its attention on assessing students' critical thinking performance than on development of critical thinking skills. While a moderate amount of instructional activity that has the potential to impact students' critical thinking is occurring, it may not be as effective as it might be if more attention were paid to planning and implementing these activities.

Overall, Site A does not follow many of the suggestions in the critical thinking literature. They are newly focused on critical thinking and so their instructional practices are intuitive rather than deliberative.

Site B – A Weekend Warrior

After jogging recreationally for a while, you learn things…you learn the routes, you learn the language, you learn who else in your neighborhood jogs. You start to talk to other joggers, maybe even work out with a regular group. You talk about shoes and clothes, how far and how fast to jog. You pick up pointers on technique, you build up speed and endurance. Maybe you even check out some running web sites, magazines, books, or seminars. One day someone suggests that you enter a race. A race! That means some serious training and commitment. It takes planning, and record keeping and particular types of running…some to build speed, others to build distance and stamina. But you're still learning. You get injured sometimes. You analyze your training, talk to friends, and do some research to try to figure out the best training program for you.

Site B resembles a weekend warrior when it comes to critical thinking instruction. Faculty know the language, they consult with colleagues, and they work on it regularly. Courses and lesson plans are constructed with attention to critical thinking. Exams focus on critical thinking at some points in the program, and not at others. They know what instructional practices should work in their environment and they regularly implement them and refine them. Faculty are confident that a lot of instruction for critical thinking is happening, but students don't necessarily see its application or effect.

This second case study illustrates a program that is more developed in its ability to help its students achieve critical thinking outcomes. Table 8 summarizes its features related to the research question.

Table 8

Site B Summary of Findings

Question	**Finding**
Planning Method	Formal and informal, syllabus-centered Not CT focused
Planning Resources	Books and allied health colleagues
Curriculum	Humanities elective may address CT
Assessment Definition & Importance	No definition Most important
Communication	Student orientation
Assessment Methods	Essay exams, research paper, procedures & competency evaluation, skills checklist, employer evaluation
Program Fosters	Students organize a continuing education seminar, clinical & clinical conferences
Program Limitations	Home environment
Instructional Activities	Film critique, research, case scenarios
CT Processes	High: interpretation, inference and evaluation Low: explanation, analysis, self-regulation
Student Outcomes	Skills: Best = inference, Worst = evaluation [a]Dispositions: Negative = T Low = T, O, S High = A, I, M, C
Implementation Strategies	Focus on activity design and instructor delivery

[a]Scales of the CT Disposition Inventory: T=truthseeking, O=openmindedness, S=systematicity, C=Self-confidence, A=analyticity, I=inquistiveness, M=maturity

Site Description

This site is a community college in a rural area. The Radiography program is part of the Allied Health and Nursing division and is housed at a site separate from the main campus, but near the community's primary hospital. The program accepts 15 students per class and enrolled its first students in the 1990's. JRCERT accreditation has not been sought for this program, but the college is accredited by a regional association.

Program faculty consists of a full-time program director, a full-time clinical coordinator and an adjunct faculty member. The program director established the program and has many years of teaching experience. The clinical coordinator has been in the position for one year and is an early graduate of the program. The adjunct faculty member is "on-loan" from the nearby community hospital in a temporary assignment to support the program.

Prior to admission, students must take 14 credits in math, science, English composition, and medical terminology and achieve a minimum score of 19 on the composite ACT examination. Once accepted, the curriculum spans two years, including two summer sessions. The total number of credits required for graduation from the program is 71. A large percentage of the student population is of Hispanic decent and many students are first generation college students.

Site B was classified as low selectivity based on its minimum admission requirement of ACT composite score of 19. The program director's responses to the screening survey indicated that this program required students to participate in a large number of critical thinking instructional activities. Of a possible score of 51 on this survey, this program scored 48.

All faculty participated in the study, providing documents and interview time. Interviews with the adjunct faculty member were limited and thorough analysis of the courses that s/he teaches were not attainable. Four first year students participated in a focus group interview along with three of the second year students. A total of eight second-year students completed the testing phase and four allowed observation and tape recording of their class presentations.

Planning

Method

Program planning includes both formal and informal activities. While these planning activities are not specifically focused on critical thinking they do provide opportunities for the topic to arise. Formal activities include an annual advisory board meeting that includes a formal curriculum review, admissions review and analysis of graduate performance. Graduate performance is evaluated by employers 6 months after graduation and includes one item specifically related to critical thinking and problem solving. Employers are asked to rate their employees on this criterion on a four-point satisfaction scale. Since most advisory board members are also employers, they could provide insights about student performance to supplement the survey rankings.

Another opportunity for formal planning arises twice each semester when all faculty meet formally to review courses based on the syllabus and objectives. While not a specific goal of this meeting, the opportunity to discuss critical thinking in terms of individual course objectives is present. It was not clear whether these planning meetings also include discussions of instructional strategies and student progress. Informal planning occurs between faculty members on an impromptu basis as they work closely

with one another, both physically and functionally. There seems to be a common focus on active learning techniques between these two faculty members and I wonder how much they talk with one another in planning these activities.

Resources

Faculty in this program rely heavily on other faculty as resources in their instructional planning for critical thinking. They work in the same building as the nursing and other allied health faculty and have consulted with them frequently about instruction for critical thinking. In addition, they consult regularly with other radiologic technology colleagues both through seminars and personal contacts. Faculty members seek advice from with the program director, while s/he consults with other educators in the field.

The program director has used several print resources to become familiar with critical thinking pedagogy: (a) *Engaging Ideas: The Professor's Guide to Integrating Writing, Critical Thinking and Active Learning in the Classroom* by John Bean, (b) *Critical Thinking Skills for Higher Education Students* and (c) articles shared by the Vice-President. In addition, s/he found that courses in a Masters degree program were helpful in the areas of needs assessment and program planning.

Curriculum

The program follows a typical curriculum structure for radiography programs. After completion of the pre-requisite courses, the program covers six semesters. There are progressions of three procedures courses, three imaging/science courses, and five clinical practicum experiences. General education requirements are interspersed throughout the curriculum and include a humanities requirement in the fifth semester. This requirement may be met by taking one of three courses: Ethics, Introduction to

Logic, or Introduction to Humanities. The faculty advise students to take either Ethics or Introduction to Logic and believe these would contribute to CT development.

It is not obvious from course syllabi, objectives, or interviews how students' critical thinking skills would be progressively developed in the three series of courses identified above. The objectives listed in the syllabus are essentially the same across all levels of the course. There is an increase in complexity and depth of assignments, specifically papers, as students progress through the program.

The courses that are viewed as most helpful in developing critical thinking skills are the radiographic imaging equipment course and the clinical practicum courses. Both faculty members also view radiographic exposure courses as helpful, but disagree about the usefulness of the radiation biology course. There has been no direct instruction in critical thinking skills in the past. However, this year, the orientation program will include a component that introduces students to the concept of critical thinking and its application in radiography.

Clinical practicum courses provide minimal structure related to critical thinking. There is close interaction between college-based faculty and the students and their clinical supervisors. The structure of the practicum courses provides for development and assessment of critical thinking through the procedure and competency evaluation system. Both technologists and clinical instructors assess the students' performance in the areas of adaptation to the patient and film critique as part of competency evaluation.

Assessment

Definition & importance.

The program has not established a formal definition of critical thinking. There is agreement among the various persons interviewed that the program's focus is on application of knowledge in the clinical practice environment. Several individuals elaborate on this basic premise to stress the importance of students understanding the underlying explanations of why and how things happen.

> ...explain to them the "whys," which will make them more valuable as technologists. It will make them be technologists and not just someone from the street that came into a department to work and didn't know what they were talking about, didn't know what was going on...be able to have some kind of method where they can, after being educated in all these factors, be able to make decisions about where they can set up techniques and be able to know what the basic technique involved—what it does and how they can correct it.

This passage is representative of how all the faculty at Site B spoke about their goals for students in the area of critical thinking. These faculty members use the term critical thinking interchangeably with higher order thinking. Only the students emphasize the importance of being able to adapt to new situations and critique and correct radiographs.

There was broad agreement that critical thinking was the most important goal of radiography education. Competing goals included foundational knowledge as a base for critical thinking and specific implementation of thinking skills in performance and attitudinal areas.

Communication of goals.

All parties agreed that the primary method of communication to students about the critical thinking goals of the program is the new student orientation program. This two-day program occurs prior to the official beginning of the fall semester. Here students

are familiarized with the policies and procedures of the program and its expectations of them. In addition, the faculty believe that they communicate these goals during pre-admission advising and in the brochures and application materials. Apparently the students do not remember the goals coming up in advising since they only mentioned the orientation session. The printed program materials that I had to review did not include any mention of critical thinking.

Assessment of goals.

One way that critical thinking is assessed in the classroom is through the use of essay examinations. As an example, the basic level procedures class would include essay questions such as: (a) discuss the importance of having the patient.... or (b) discuss the reason(s) why the patient is positioned _____. The examinations for the advanced level procedures course contain more multiple choice questions (as students prepare for their board examination, which is multiple choice), but also include such questions as: "How could you use this position another way to demonstrate anatomy other than what is intended?" A question such as this is intended to require the students to be creative and to apply their knowledge of the position and patient anatomy to a new problem.

Another didactic approach to assessing critical thinking skills is through the pathology course whose evaluation is entirely based on the completion of a research paper and its presentation to the class. The students are instructed to write a research paper on a particular disease process and receive directions about length (minimum of 25 pages), source choice, citation style, organization and contents (to include epidemiology, pioneering research and case studies from their clinical experience). Similar detail is given regarding presentation requirements. They spend the entire semester working on

the paper, including required review of multiple drafts. Both the paper and the presentation are evaluated by the instructor and thought to be indicators of the students' critical thinking skill. The grading criteria used by the instructor include content, writing style, presentation style, and use of technology, but do not specifically address critical thinking in any way.

Most instructional activities described by the faculty include a feedback component, even if the activity is not evaluated or graded. Students would receive either verbal or written feedback about their completion of that activity that would address their thinking as well as their knowledge of the subject matter.

The clinical courses also provide opportunities for assessment of critical thinking. Here, two specific evaluation tools are used. The first is the procedures and competency evaluation that includes assessment of students' ability to (a) adapt to the patient and environment, (b) provide patient education through explanation and communication, and (c) critique the resulting films and suggest improvements. In each of these areas, the students are evaluated as to whether they can or cannot perform these functions; yes and no are the only choices.

The second means of clinical evaluation is the skills checklist that is completed twice each semester by the clinical instructor supervising the student. This evaluation includes one item specifically targeted to critical thinking and defined as: "good safety practices for the patient, other team members and self. Effectively solves technical problems independently and exhibits logical thought in making decisions and recommendations." This definition is similar to that provided by the faculty during interviews, but goes beyond it in the areas of problem solving, logic and decision making.

A second item addresses the student's self image and may be related to the self-regulatory component of critical thinking as evidenced in its definition: "awareness of own strengths & weaknesses and makes changes to effectively improve technical and communication skills." This clinical evaluation would be performed twice each semester throughout the program (5 semesters of clinical practica) and therefore provides both assessment and evaluative functions.

Finally, the program assesses critical thinking indirectly through employer evaluation. Employers are asked to evaluate graduate performance within six months of the students' graduation. One item on the survey specifically asks employers to rate (on a 4-point scale) their satisfaction with the level critical thinking/problem solving skill that the student brought to the job. The program's Advisory Board considers the results of this survey as one element in the annual curriculum and admissions policies review and revision.

Program Features

Students and faculty agree that one of the most important features of the program in developing student critical thinking is a co-curricular activity. The Student Organization of Radiologic Technologists organizes and presents seminars to provide continuing education for area radiographers. The freshman are primarily responsible for the seminar and the seniors coach them, having done it the previous year. They are required to put together the program, obtain the speakers, seek donations, organize the refreshments, etc. They develop a brochure and mail it to technologists in the state. Faculty see this as a way for students to develop their CT skills because it requires diverse people to come together to accomplish a goal.

Students also find the clinical portion of the program to be an important feature that develops critical thinking skills. Two students described how being involved in certain radiographic exams requires critical thinking to adapt to the patient:

> ...trauma has a lot to do with critical thinking. You go in there and you see somebody's arm opened up and you go, 'OK how am I going to do this? How am I going to handle him?' What not to do, like rotating his arm...
>
> You've got to be on your toes. When there's a car accident or something, you've got to think ahead of everybody else...so that way you get your work done....That requires a lot of critical thinking.

The program's clinical coordinator agrees and focuses on the clinical conferences that accompany the practicum courses, providing students the opportunity to present cases and problems and troubleshoot with one another about their resolution.

> We also have something that I feel is important, that I've added, I call them clinical sessions. What we do is talk about problems they are having, any areas where they need to work on. That's why we have them, any problems they might be having. If they have a special case, I let them go in front of the class and tell us the history on the patient (of course the patient remains anonymous) and they go in there, they get to show their films, they get to show what they did, what they learned. And they kind of shine. Plus it gets them in front of the class as well. They give sort of a presentation type of thing. And that's really nice. And we keep close communication that way. And in whatever area, we can troubleshoot whatever areas they might be having problems with.

These faculty and student quotes illustrate that the clinical environment is an important feature of the educational plan with respect to critical thinking development. This program has attempted to provide greater structure to the clinical component through its use of clinical conferences that allow students to process and analyze their clinical practice.

Both students and the program director also indicate that the way that faculty teach fosters students' CT development. Students indicate that they like a particular

faculty member's approach because s/he gives them all the information they need and then expects them to apply it in clinical practice and on examinations. The program director also stresses the importance of using these thinking skills outside of the classroom, in the clinic and at home and work.

Interestingly, students see that the clinical environment can serve as a limitation to their critical thinking development as well as help develop it. Students spend large amounts of time working under the direct supervision of a staff technologist and when asked what limits their ability to develop critical thinking say:

> I think having to work with a tech. I know the liability and everything, but it seems like you have to really really apply your critical thinking skills when you're on your own without a tech under their supervision....You're more dependent on them.
>
> ...Telling us how to do things step by step instead of letting us think. Like maybe giving us a protocol and saying you're going to do it like this and this. That doesn't help us a lot.

They emphasize the importance of working independently of their supervising technologist as a means to force them to use their own critical thinking rather than rely on the expertise of their professional supervisors. First and second year students disagree about how much of this independence they are allowed at the clinical sites. Naturally, closer supervision is provided when students are just beginning their clinical practice and more independence is allowed in later stages.

The program director feels that one of the limitations on the program's ability to develop critical thinking skills is the home environment of the students in the program.

> So what limits them then on the opposite hand is everything else that's out there. Because most of their families don't speak English. Or if they speak, limited English and they don't hold work outside the home,

> especially the women. You're not going to find a whole lot of push or a whole lot of thinking beyond what you really need to know in the home environment or in the outside environment. Now, if parents happen to be, I would say, working outside of the home on another kind of a level, or maybe higher educated parents outside, you'll find that happening a lot. But the hindrance would be, I would think, a lot of their environment.

Many students are first generation college students. They may be having their first experience with serious academic pursuits and the supports at home may not be as strong as in some other environments. This effect may be more pronounced for women in the program than men because women in the work force and in higher education is less prominent in the local culture than for men.

Instructional Activities

Direct instruction for critical thinking has not occurred in this program. As previously indicated, there will be a small unit on critical thinking added to the new student orientation program for the class beginning Fall 2002. As stated previously, the faculty do not feel that there is a particular course that is best suited to developing critical thinking. In fact, most courses include some instructional activities related to critical thinking as indicated in an analysis conducted for the state higher education board (as well as in interviews).

A large number of instructional strategies are used in various portions of the program to develop critical thinking. They range from experiments and other laboratory activities to structured experiences in the clinical setting to mind mapping and classroom discussions. Students tended to focus on clinical and hands on types of activities as being useful instructional strategies: experiments, film critique & correction, performing procedures on trauma patients, and disassembling the processor. Faculty had a more

didactic focus, including such activities as term papers, journal article discussions, in-class research, and essay quizzes.

Discussion seems to be a large component of every course, even those that are primarily lecture. The faculty use an interactive lecture approach in a variety of ways to keep students engaged and thinking rather than being passive learners. It is common for faculty to share their personal experiences with students and then ask the students to suggest ways of addressing the particular situation or to provide a critique of how they had handled it. Students are encouraged to present alternative approaches to the problem. Probing questions are used regularly in order to delve deeper into the students' thought processes about the subject. For instance, the program director indicated the following questions would be used in an introductory procedures class after presenting a particular scenario: "What would you do? Why would you do it like that? Is there another way? Have you seen this done other ways?"

Critical Thinking Processes

As mentioned previously, the stated objectives for many of the courses were the same and therefore all courses have objectives that call on critical thinking to approximately equal degrees. These objectives require the cognitive activities of interpretation, inference and evaluation most commonly, with analysis, explanation and self-regulation seen much less frequently.

When comparing objectives with the instructional activities described by faculty for their specific courses, there is a general lack of correspondence (see Figure 4). More instructional activities call on inference (common in objectives) than on interpretation and on explanation more than on evaluation, contrary to objectives. It is relatively

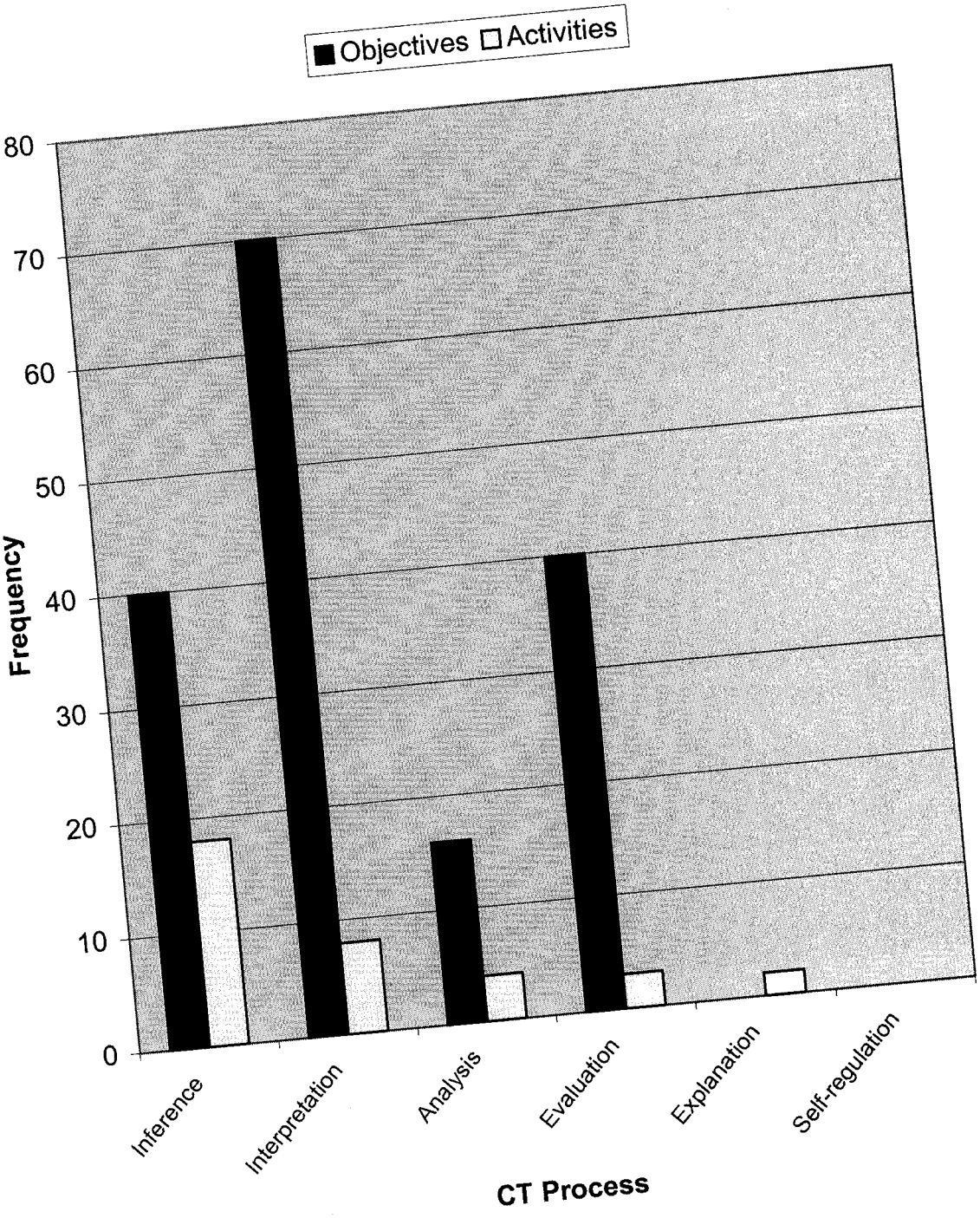

Figure 4. Site B. Comparison of CT processes indicated in course objectives with those called on via activities suggested by syllabi and faculty. Few activities are present to support stated objectives in most categories.

common for instructional activities to require the students to use a cognitive skill that is not suggested by the course objectives.

The clinical course shows the greatest degree of correspondence between its objectives and its structured activities. Much of this course is unstructured as students and faculty alike must adapt to the demands of the clinical environment. However, its procedure and competency evaluation process and clinical skills evaluation, along with its clinical conferences, provide instructional strategies that require cognitive processes consistent with its objectives.

Outcomes

No student admission or GPA data is available for comparison with CCTST and CCTDI data. This school scored very close to the group mean (16.38 versus 16.56 for the group) on the CCTST overall and on the CCTDI (305.3 versus 303.3 for the group). Both CCTST and CCTDI subscale scores were consistently around the group mean with approximately equal numbers slightly above and below the group. All outcomes measures for these students showed less variance than other programs studied. In the skills test, students at this site scored from the 54^{th} to the 96^{th} percentiles when compared with a sample set of two-year college students, with five of eight participants scoring in the 61^{st} –69^{th} percentile range. This school posted its best performance level in the Inference subscale and its worst in the Evaluation subscale (based on percentile scores).

This level of performance is somewhat consistent with the program's instructional activities (Figure 5). The Evaluation subscale includes both Evaluation and Explanation, which are the least common types of activities in the program. Inference is more common, but not so much so that frequency alone could account for the dramatic

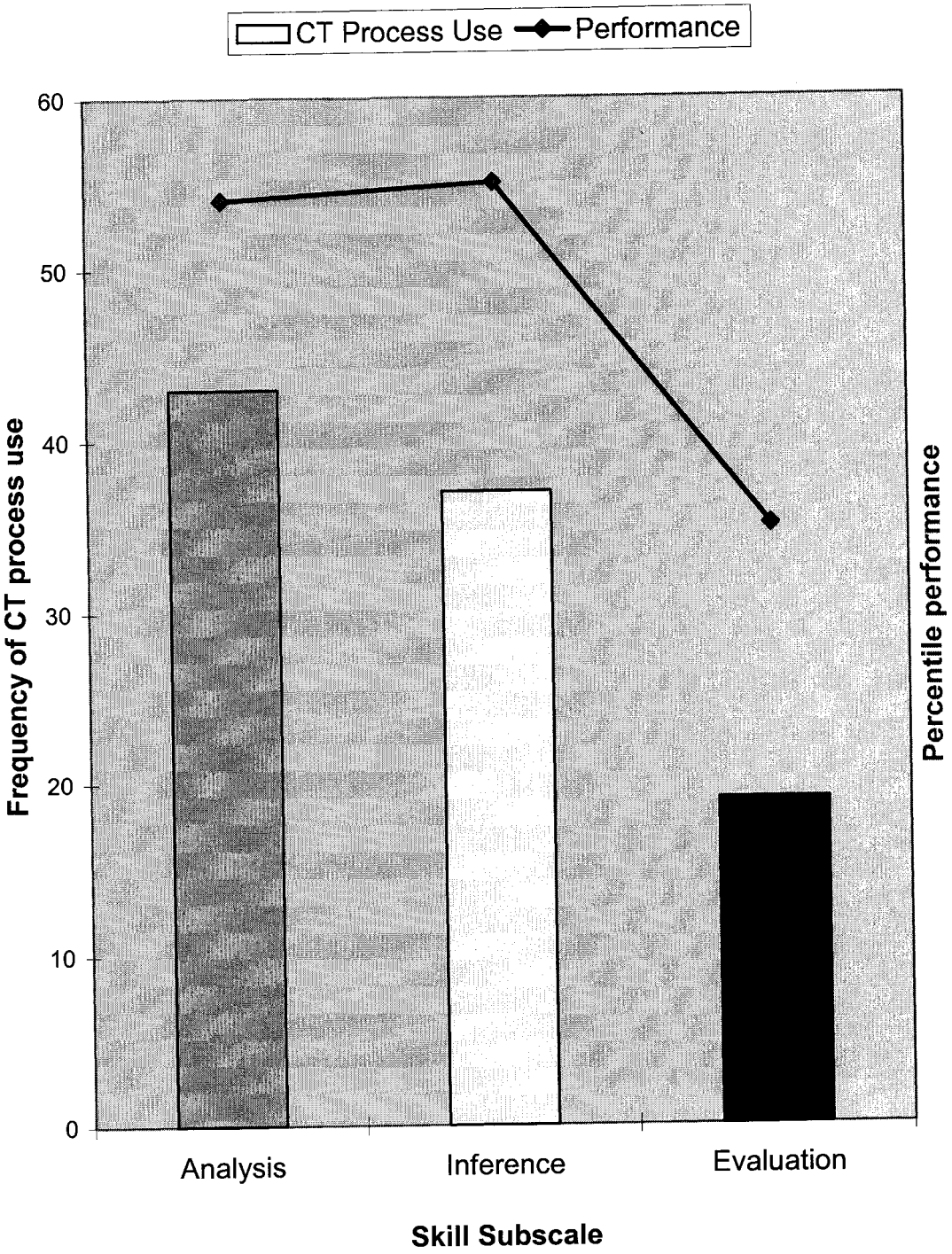

Figure 5. Site B. Comparison of instructional emphasis on each of the CT Processes and associated performance on the CCTST Subscale. Performance trends are similar to instructional emphasis.

difference in student performance on these two subscales. The Analysis subscale encompasses both analysis and interpretation functions and might be expected to be the area of best performance for this group of students, but is slightly below that of inference.

In the dispositions area, group performance in the Truth-seeking subscale (37) was the only one to fall below the target score of 40, indicating an overall positive attitude toward critical thinking. The group score for the subscale of Systematicity was on the low end in comparison to other programs, while CT Self-confidence was on the high end. The remainder of scores were in the middle of the range. The subscale of Inquisitiveness (48) approached the target score of 50; this is consistent with undergraduates overall, where 41% score above 50.

Significant correlations were seen between the disposition scales of Open-mindedness and Systematicity with total disposition. On the skills side, significant correlations ($p < 0.001$, one-tailed) were seen between the total skills score and the subscales of Inference and Deduction as well as between the subscales of Deduction and Inference. There were also large correlations (but significant at the lesser $p < 0.05$ level) between a number of disposition subscales as well as with the total disposition score. There were no significant correlations between dispositions and skills. Interestingly, one skills subscale, Analysis, was slightly negatively correlated with nearly all dispositions, including the disposition subscale of Analyticity.

Student work was reviewed in the form of observation of presentations and review of the associated papers. Presentations and papers were evaluated for the presence of CT, which was then classified using the APA system. It was common for students to use paraphrasing in their work and less frequently to compare and contrast perspectives

or concepts. As instructed in the assignments, students considered the significance or importance of events or facts and used patient cases to illustrate the point that they were trying to make. The best student work included all of these as well as offering creative and original alternative points of view or problem solutions.

Of the four student presenters that were observed (and accompanying papers read), three also participated in the testing phase of the study. In this small group, it appears that disposition scores are more consistent with paper and presentation rankings than skill scores are. The student with the highest disposition score also had the highest paper ranking and second highest presentation ranking, while the student with the highest skill score ranked fourth of five on the paper and last in the presentation.

Implementation Strategies

Students in the focus group were asked to think about a particular activity that faculty use to make them think critically. Then they were asked what causes that activity to work to get them use their critical thinking skills and what would make that same activity not work. The answers obtained from this question again indicated that students did not really understand the question because their answers were more about types of activities than about what made them work.

However, you can infer from some of the answers how one might design instructional activities to call on critical thinking. They should be hands on and provide clear instructions about the end point, but not the process. They should involve situations that are new to the student and should require students to work independently to think through the situation. Finally, the instructor or supervisor makes a difference when s/he

supports the student to use his/her own thinking rather than providing the answers or doing the work for them.

Faculty also focused some on the types of activities rather than on their implementation, but not to the degree that the students did. In their eyes, the most important feature for faculty to consider in planning is the students' motivation. This was evidenced in the following comments by several faculty members:

> So I went from eliminating the test taking – which has worked better because they're more relaxed in class – they're asking me lots more questions about the subject because they're truly interested in the subjects.
>
> I think when it becomes interactive and you can actually voice your opinion or come up with alternative ideas or say I think this might work a little bit better as opposed to this. I think the interaction is the part that makes it work.
>
> I think those controversial videos just spur tons of things...Because they're real life situations...And I ask those questions when we're done. What are your thoughts on this? How would you react if you were in that situation? So tell me what you're thinking.
>
> Like I've told them, no answer is a wrong answer...But, I feel like once you break the ice with the kids, that they're able to actually want to answer these questions and they – it's like anything – there's competition between them.

A variety of approaches to motivation are represented here: instrinsic motivation based on inquisitiveness, keeping students actively engaged, using controversy, and providing an environment where competition is used to motivate students.

Faculty also claimed that activities would be unsuccessful if attention was *not* paid to instructor preparation and timing (to ensure needed knowledge, experience and skills), and the culture of the program to expect that students are thinking rather than focusing on memorization.

In addition to considering faculty and student perceptions of successful techniques for strategy use, the instructional activities were analyzed for their characteristics along the following dimensions: graded, mode of expression, individual/group, degree of structure, and presence of feedback. In this program, most activities were ungraded, verbal, individual, planned and provided feedback. There were also a significant number of group activities.

When comparing this program's activities with its perceptions of what will work, they are matched on individuality and planning and perhaps on competition (verbal report). However, they do not match with respect to grades. Faculty say that grading should reflect the importance of critical thinking, but most activities are ungraded. It is not clear whether the other motivational factors identified by the faculty are consistently applied in these instructional activities.

Site B placed a greater emphasis on teacher questioning and active learning techniques. The faculty all spoke about using probing and open-ended questions. They talked about using challenging questions and series of questions that kept probing until they got to the underlying principles. There was quite a bit of consideration given to instructional delivery—how a particular activity was implemented in the classroom or clinic or laboratory. Figure 6 demonstrates that this site placed the greatest emphasis on the strategies of activity design, with instructional delivery nearly as frequent.

Summary

During the site visit it appeared that fewer instructional activities related to critical thinking were being used than had been initially reported by the program director (reporting a score of 48 out of a possible 51). While faculty indicated substantial

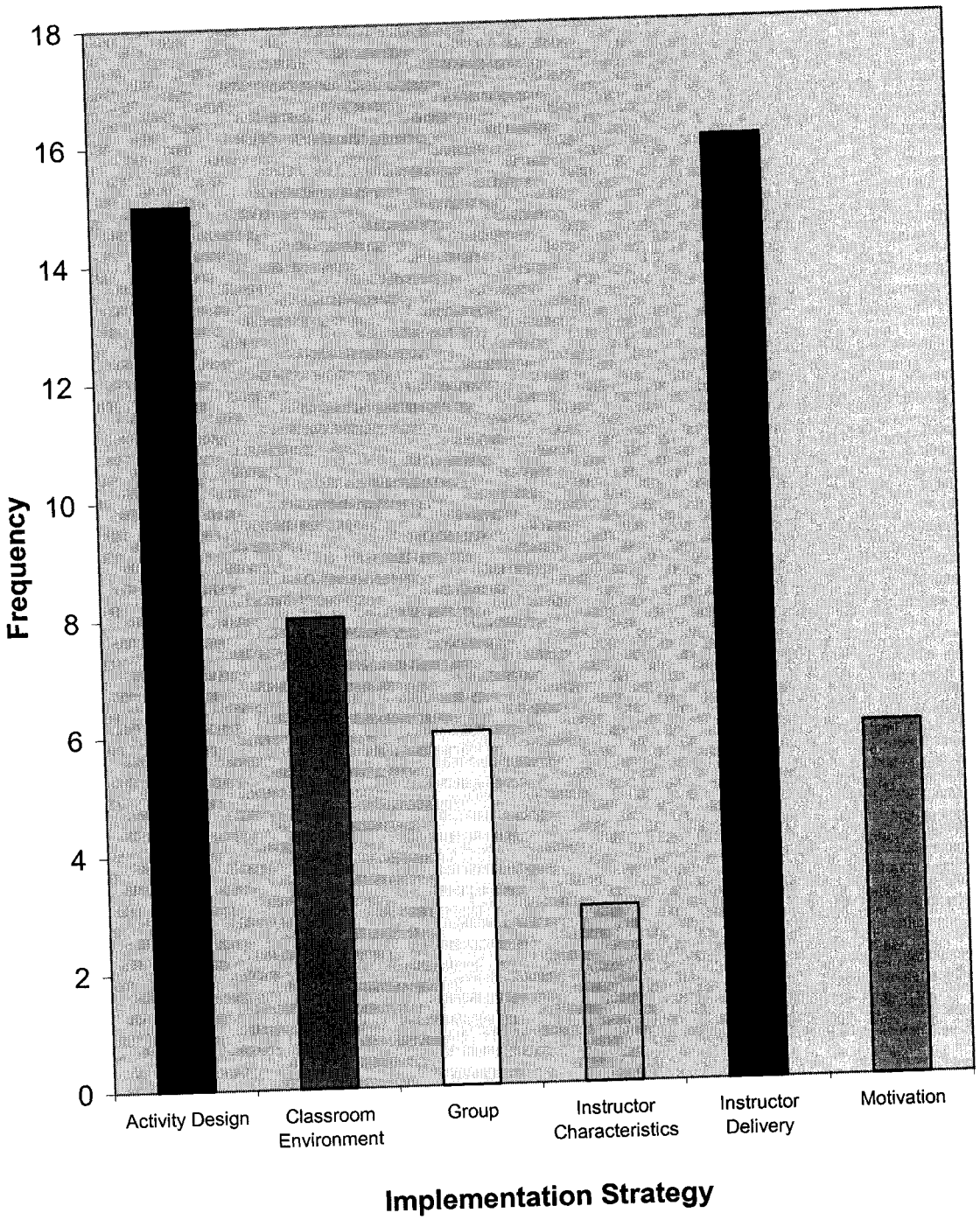

Figure 6. Site B. Distribution of implementation strategies. Emphasis is placed on Activity Design and Instructor Delivery. Faculty characteristics are not commonly seen as an important feature related to critical thinking.

agreement with the program director on the survey (average CT score 48.33), students reported that less critical thinking was occurring than the faculty believed (average CT score = 37.25). After review of all data sources, I completed the same survey and arrived at a score of 30 for this program. This allowed me to quantify my perception that less critical thinking instruction was occurring in the program than had originally been reported.

A phenomenon that is perhaps related is a lack of clarity and consistency in the faculty and students' use of the term critical thinking. Faculty descriptions of critical thinking goals for the program do not match the criteria that are used in evaluation of critical thinking. Evaluation is directed at problem solving, decision-making and logic, while the faculty descriptions emphasize application of theory to practice. Students have yet another perception of critical thinking that focuses on adaptation to new situations and critiquing and correcting radiographs. Despite their lack of consensus of what critical thinking is, all parties believe that it is the most important goal.

This importance is evident in some aspects of the curriculum and instructional planning. Instruction for critical thinking is being added to the orientation session for the program. Faculty encourage students to use their humanities elective in a way that would enhance their critical thinking skills. The student organization is required to plan and deliver continuing education for professionals in the community. Both students and faculty find that this experience serves not only as a community service, but also to develop the students' critical thinking skills in action.

The instructional approach of the entire faculty is focused on interactive lectures. Whole class and small group discussions are a prominent feature of the instructional

planning and are often focused around the typical "story-telling" that occurs in the radiography classroom. The faculty uses their experiences as informal—albeit planned—case studies for the students. Rather than telling the students how they handled a particular situation, they provide situational details and ask the students to provide the solution or perhaps an alternative to their own solution.

The activities that are used throughout this program have an emphasis on the cognitive skills of inference and interpretation, specifically drawing conclusions and clarifying meaning. Assignments appear to become more cognitively complex over the course of the program. Students are required to present an argument or defend an action or statement much more often than would be expected by reviewing the published course objectives. This emphasis is reflected somewhat in the skills test scores of this program where students performed their best in the inference sub-scale and their worst on the evaluation subscale.

While student disposition did not correlate with overall or subscale scores on the skills test, they did appear to make a difference in student work. When a small number of student papers were read and presentations were reviewed, the best student work was produced by the student with the highest disposition score.

While not measured on the disposition inventory, this group of students consistently indicated the importance of working and thinking independently as an important element of instructional design for successful critical thinking development. Whether it was in the clinical, laboratory, or classroom environment or even in their co-curricular activities, the common theme was the importance of being allowed to work toward a clearly defined goal with the assistance of a coach that was not quick to tell

them exactly what to do. Faculty, on the other hand did not emphasize this independence at all when talking about instructional planning. They may in fact provide it as a result of their beliefs about critical thinking, but did not consciously identify it as an important element for implementation. Their primary focus was on student motivation to engage in the task, primarily by attending to student interest through the use of controversial or real-life topics or problems.

This program attends to many of the practices that are encouraged for CT instruction. Yet, faculty and students may not be running toward the same critical thinking destination.

Site C—An Elite Runner

An elite runner has a totally different approach to the sport than either the recreational jogger or the weekend warrior. Running is not something that they *do*, it is *who they are*. While a weekend warrior keeps track of running mileage and time, the elite runner pays attention to the weather, food, and emotional and physical feelings before, during and after the run. The elite runner notices the subtleties—that a run at 43 degrees requires tights and long sleeves, but no gloves. While the recreational jogger schedules running in around other more important activities, the elite runner schedules running first. Training may occur in groups, where there is competition, camaraderie, motivation and support. A coach organizes the group for maximum benefit, provides individual feedback on performance, and establishes both individual and team goals.

My final case study is comparably an elite runner. While planning is less well developed than the analogy would imply, there is greater attention to the subtleties and there is a coach. Critical thinking is part of the fabric of the instructional environment. Testing on the more fact-based aspects of the curriculum is done outside the classroom, because the classroom is for working with the team. The team consists of both the faculty and fellow students and everyone has something to offer. Attention is paid to how to ask the question and how much direction to give in an assignment. Students are asked to evaluate themselves as well as be evaluated by others. Attention is paid to the disposition to think critically as well as the skills themselves.

Well-developed in its approach to critical thinking instruction, Site C resembles the elite runner described above. Specific findings related to the research questions follow in Table 9.

Table 9

Site C Summary of Findings

Question	**Finding**
Planning Method	Mostly formal, Group planning CT focused, individual planning includes CT
Planning Resources	Seminars and Program Director
Curriculum	Higher concentration of "hands on"
Assessment Definition & Importance	No definition, embedded in other outcomes Most important to faculty, second to students
Communication	Program director; disagreement between faculty and students about source
Assessment Methods	Homework, class discussion research paper, Clinical Evaluation form, self-evaluation
Program Fosters	Hands on, faculty, group study
Program Limitations	Little agreement
Instructional Activities	Case scenarios, film critique, clinical
CT Processes	High: interpretation, inference and analysis Low: explanation, evaluation, self-regulation
Student Outcomes	Skills: Best = analysis, Worst = evaluation [a]Dispositions: Low = T, O, M High = A, S, C, I
Implementation Strategies	Focus on classroom environment and use of groups

[a]Scales of the CT Disposition Inventory: T=truthseeking, O=openmindedness, S=systematicity, C=Self-confidence, A=analyticity, I=inquistiveness, M=maturity

Site Description

Site C is a community college in a small city in the U.S. The radiography program is housed in a dedicated allied health education building along with seven other allied health programs. The program enrolls a maximum of 16 students per year and currently has 16 second year and 15 first year students. The program is accredited by the Joint Review Committee on Education in Radiologic Technology.

Program faculty consists of a full-time program director, a full-time clinical coordinator, and two adjunct faculty. The program director has been at the institution for 16 years, while the other faculty have either been associated with the program long term or they are very new.

Prior to admission, students are required to complete 12 hours of pre-requisite courses (anatomy, medical terminology, psychology and computer literacy), pass skills tests in mathematics and typing, and complete 100 hours of experience in a radiology department. Once accepted, the program is a 67-hour certificate program. Students may also earn an associate degree if they complete the general education requirements of the college.

This site was classified as low selectivity (students accepted from the top half of the high school graduating class) based on data provided on the screening survey. According to this same survey, the program was classified as providing a moderate amount of instructional activities to develop students' critical thinking skills or dispositions, scoring 32 of a possible 51 points as reported by the program director. The program director reports that students in this program are some of the top performers in

the nation on the certification examination of the American Registry of Radiologic Technologists, scoring a 93 program average on last year's exam.

All faculty participated in the study, as did all students to varying degrees. Both first and second year classes were observed and all second year students completed a survey. Five second-year and five first-year students participated in the focus group and the same five second-year students took the California Critical Thinking Skills Test and Disposition Inventory.

Planning

Method

Program planning occurs at two different levels, the faculty as a whole and individually with the program director. Faculty meeting minutes were reviewed and no specific mention of planning for critical thinking was seen. There was mention of a department sponsored professional development seminar in which clinical staff were asked to bring in a problem from their instructional experiences with students in the clinic for discussion. It is possible that this activity would have included some discussion of how to teach for critical thinking in the hospital, but this cannot be determined from the notes or assured by this activity.

The program director appears to have a great deal of influence on the instructional practices of other faculty members. S/he reviews their course plans for convergence between the objectives, the homework and the assessments. Faculty are asked to reinforce highly important issues, such as CT, in every course. Faculty are not given guidelines in advance as to how to address CT, or what aspects to address, the program director simply

discusses these with the faculty member to ensure that the plans will contribute to meeting the program goals.

Resources

This faculty identified several sources that helped them to be better teachers that may have related to critical thinking. No one had specifically studied the theory of critical thinking either formally or at professional development seminars directed to good teaching. Two faculty members recognized their graduate degree programs (in management and organizational behavior) as having contributed to their perspectives about instructing for critical thinking. Two others reported that the College had provided a number of professional development activities related to good teaching that were helpful, although not specifically directed to critical thinking. Faculty also credit the program director as being a source of information and personal development for them.

No books, theoretical sources, or radiologic technology sources were cited as methods for faculty preparation to teach for critical thinking. Nor was there any mention of consultation with colleagues outside of the department, either in the nearby allied health and nursing faculty or with psychology or philosophy faculty.

Curriculum

The curriculum is structured over two calendar years following completion of the pre-requisite courses. Its structure is typical, with concurrent clinical and didactic instruction over the entire time. The curriculum includes a three-semester positioning sequence, a two semester physics sequence, and six clinical experiences that provide for 1850 hours of practice. There is no direct instruction for critical thinking anywhere in the

program or pre-requisite curriculum, although occasionally a student takes a critical thinking class as an elective.

The faculty do not agree about which courses in the program are most likely to develop students' critical thinking. Each tends to believe that a course that s/he teaches is the most helpful, although that is not true of one faculty member. Two courses, physics and patient care, are considered by different faculty to be both the most helpful and the least helpful. The clinical experience was not mentioned at all as a contributor here (perhaps because faculty did not consider it a course). The greatest amount of agreement centered on the belief that all courses contribute to students' CT development and that positioning courses were among the most helpful.

The syllabi do not specifically identify an area where critical thinking is instructed as a stand-alone unit. A developmental approach to critical thinking skill or disposition is not evidenced in any of the relevant course syllabi. However, the clinical objectives that serve as the basis for the professional evaluation do have a developmental sequence. As a student progresses through the program, different levels of expectation with respect to critical thinking occur in various categories. These objectives form the basis for the clinical evaluation system and hopefully guide the clinical instructors toward use of instructional activities that are developmentally appropriate.

The clinical structure is typically informal. There are no specific assignments or activities that students are required to do that would necessarily provide for their critical thinking development. Three faculty members mentioned conducting film analysis sessions with students when they were visiting the sites. This would help to develop critical thinking, but is not a requirement of the clinical program. Students are involved in

whatever activities are occurring in the clinical site, will work independently after competency assessment and are supervised by a clinical instructor at each site. The use of instructional approaches that develop critical thinking in the clinical setting is left to each faculty member or clinical instructor and are not planned in advance.

Assessment

Definition and importance.

The program has not developed a formal definition of critical thinking. There is broad agreement that an important aspect of critical thinking is the ability to adapt protocols to a particular patient and situation. It is common for the faculty to discuss the importance of applying theory to practice in descriptions about critical thinking. The faculty also stress the importance of understanding the theory and being able to explain why something works as it does. Students included decision-making and creativity in their definition of critical thinking.

The program identifies a number of learning outcomes and goals for the program. Critical thinking is not explicitly included in any of these learning outcomes, but rather is embedded in a number of others such as:

1. Modify standard procedures to accommodate for patient condition and other variables.
2. Adjust exposure factors for various patient conditions, equipment, accessories and contrast media to maintain appropriate radiographic quality.
3. Evaluate radiographic images for appropriate positioning and image quality.
4. Evaluate the performance of radiographic systems

There is agreement among the faculty that critical thinking is the most important program instructional goal. Secondary goals include: basic knowledge, communication skills, following policy and procedure, and experiencing active learning. Students, on the other hand, were more inclined to say that critical thinking is the second most important goal, with general knowledge of technique and patient care being more important. Several students made the case that basic knowledge was a pre-requisite to critical thinking and so was more important, even though the critical thinking was the ultimate goal.

> You feel like a baby as a first year student developing that critical thinking…I just want to be where that tech is that's been there for 25 years who can assess that situation quickly and be creative. You can't be creative until you've got that knowledge down.

It was important for this student to move quickly to develop the critical thinking skills, but s/he felt hampered by the ability to master the foundational knowledge necessary to proceed.

Communication of goals.

Faculty are inclined to believe that critical thinking goals are communicated to the students through course syllabi. However, students do not mention the course syllabi at all. They identified the program director as the primary source of their knowledge about the program's critical thinking goals. Two other faculty members also think that the program director is an important feature of this communication. In addition, students believed that their textbooks and their clinical practice helped to expose the importance of CT in this discipline.

Assessment of goals.

There was little agreement among the faculty about how critical thinking goals are assessed. Included in the variety of responses from interviews are: homework, film critiques, case scenarios, clinical evaluation, in-class questioning, presentations and projects, among others. It may be that faculty were answering the question about how they evaluate CT in their own individual courses. If this were the case, you would not expect much overlap except in the clinical area where all teach. Even in this area there was either no mention or no agreement about what aspect of clinical evaluation addresses critical thinking. The Clinical Evaluation was specifically mentioned by one faculty member as a means of assessing critical thinking and specifically denied by another because of its inherent subjectivity.

Examination of syllabi and course level interviews with faculty reveal that there are a number of ways in which CT is evaluated at this campus. Homework assignments include short answer questions, some of which call on critical thinking. Similar questions are used on examinations and in class discussions where assessment is more informal. Papers and presentations are commonly used in the program, but there does not appear to be an element of critical thinking assessment embedded in the student feedback mechanism. Student performance on film critique assignments are prime indicators of critical thinking as students are asked to evaluate, compare and contrast, justify their answers, etc. Other than grading these homeworks, these assignments are not used as an indicator of student critical thinking ability in any formal way. The positioning class final exams are case-based and require the student to adapt to the patient situation that they are presented with by their classmate (from a script written/identified by the instructor).

The Clinical Evaluation Form includes ten to eleven areas of performance evaluation, some of which include critical thinking. The faculty agree that critical thinking is included in the areas of: professional judgment, application of knowledge, film critique, and initiative. This belief is confirmed by review of the sub skill statements for each area. This student evaluation is used at the end of each clinical semester (six in all).

Students are also asked to complete a self-evaluation at the end of each clinical semester. The forms change from semester to semester and request that the student reflect on and write about their comfort level with various technical and academic skills as well as their impending place as a professional in the field. One would expect that most students engage in critical thinking to complete this evaluation, but the questions don't generally call on specific CT skills of the classification system. The fifth semester self-evaluation does specifically ask the students to discuss how well they are able to complete two objectives (that are CT): adjusting technical factors and procedures to the patient condition and adjusting to unforeseen problems that arise.

Program Features

Faculty and students agree that the hands on nature of the program facilitates students' development of critical thinking. This is thought to be true of both the clinical and laboratory portions of the program. Of 16 courses required in the program, seven include laboratory components and six are clinical courses. Students and a single faculty member both mentioned that group study and considering content from multiple perspectives, either through various contexts or faculty, are important in CT development.

Students acknowledge that faculty, particularly the program director, encourage them to participate in activities that will help develop their critical thinking, e.g. difficult or unusual cases, arguing about exam questions/answers, and comparison of procedures as taught versus as practiced.

> In many cases if you had a different answer than what was the answer on a quiz or any type of test, if it was marked wrong and you disagreed with that, if you had a good explanation of your answer, [faculty] would take that into consideration and not mark you wrong if you could explain yourself. So that was a good way…

Faculty also believe that they have an important impact on the students' development of critical thinking. While one believes this is because students experience five different faculty members' perspectives, another focuses on the tendency of instructors to ask "what if" questions.

> Faculty 1: We are constantly throwing out, "What if this happens? What if your patient doesn't cooperate the way you want them to?" We are always throwing out scenarios for them so that they can think of what the reality will be.

> Faculty 2: …just the very setup with the particular faculty we have, because we each have really unique teaching styles. We have one faculty member who was trained in Europe so s/he has totally different ideas about how to figure out technique and so I think it's great for them…So, I think that's great when we have different faculty so we're not all on the same page every semester—we're actually coming from different places.

Both examples reinforce the responsibility that faculty have for creating an environment where authentic problems are being solved and emphasis is placed on a multiplicity of potential solutions. All faculty members at Site C mentioned that both of these features were important aspects of instruction for critical thinking.

Group study is important in this program. The development of study groups outside of class is listed as an item in the student handbook as one of the strategies for

success. It is required by assignments and projects and is the methodology for conducting laboratory experiences. The students frequently raised the concept of group study and learning in the focus group session as an important feature of their critical thinking development as evidenced in the following quote:

> Just having six different people, so there's six different ways of looking at it so you could kind of take three of the different ways and put it together and have it work. And we all learn differently so having it explained in all the different ways, you're bound to get it eventually.

Students appreciate the benefits of studying together as well as taking advantage of the variety of experiences and perceptions represented by a small group of peers.

One faculty member also mentioned the importance of studying a particular concept from different perspectives, but s/he was referring to consideration of a single concept in multiple classes--for instance, the concept of film critique and correction from the perspectives of positioning and the science of film production as well as from radiation protection.

> Where you have that didactic material that has to be applied, you have to go back and forth between concept and application. In that sense it's built in. And then we do have classes that overlap information. The positioning classes taught by different faculty, then the classes on the physics and accessories and so there's application between going to the positioning class, looking at films, being told the technique and then going to a different class talking about technique and not positioning. And – yah there's a lot of it built into the program.
>
> So, with a new batch of students in the fall, I might be talking about contrast and density and then, in their positioning class, they might be being shown a hand and they're told that they have contrast and density and they would probably be told a technique the hand was done at.

Again, this illustrates the common perception across faculty and students that critical thinking instruction benefits when topics are viewed from multiple perspectives.

Faculty believe that student and faculty involvement in the life of the campus is a support for students to develop critical thinking as well. Whether talking about student involvement in the campus government association or faculty participation in campus-wide professional development, it was clear that this program is an integral part of a wider campus community. By my experience, this is relatively uncommon for college/university-based radiography programs.

General education requirements are thought by one faculty member to be a contributor to CT development, as is the College's focus on educating adults that can go out into the workplace and handle their jobs, "the philosophy that I've come across as far as the college goes is that they are trying to foster adults that can go out there and face life in any situation." This supports the importance that is placed on instruction for critical thinking at this institution.

There is little agreement about features of the program or the institution that would limit student ability to develop critical thinking. One faculty member mentioned teaching to the registry exam, a concept closely related to another's reference to using a predominance of multiple choice test questions at some phases of the program. The students disagreed about whether stress, pressure, and fear of failure were enhancements or limitations to their CT development. In response to a question about characteristics of the program that might limit their critical thinking development, the following exchange occurred among the students.

> 14: The pressure. Especially in the first year, this constant feeling of I'm not going to make it, what did I get myself into? Just because it's a whole new thing and you have to think in such different terms than you would ever normally think in.
>
> 9: Pressure or fear?

> 14: Well kind of both. And then all of a sudden it just clicks and you realize, what a minute, I'm doing all this. I'm not behind, I'm not an idiot or whatever feelings you have.
>
> 8: I would tend to say that the pressure and the stress almost forces one to become a critical thinker because if you don't you're not going to make it. You've got to figure out your schedule, you've got to figure out your study time you've got figure out your clinical time and then when you get to clinical you've got to look like you know what you're doing. And the whole thing is a life exercise of critical thinking, not just radiology.

This passage reflects students' broad definition of critical thinking and is consistent with institutional mission.

Instructional Activities

The program's use of case scenarios as the most common instructional activity to develop students' critical thinking is consistent with the institutional focus of developing individuals who can use critical thinking in a variety of situations. The various faculty members and the students talked about these in different language, but referred to the same type of activity. Case scenarios are used in patient care and ethics classes as well as physics courses focusing on technical factor selection. The positioning classes use them in didactic and laboratory instruction, as well as in a case-based final laboratory examination. The students also described the faculty's use of real-life stories in which they were asked to develop a plan of action or critique the actions actually taken.

The next most commonly mentioned activity was the use of group work, including laboratory-based experiments. Students were not specific about a particular group project, but included laboratory experiments, creative projects, in-class activities, and their own study groups. Instructors were often general as well, including any activity that includes give and take in small groups. The program director went so far as to say

that s/he believes that critical thinking cannot develop in the absence of interaction with another. At least one specific group activity required students to answer multiple-choice mock board questions as a group and to think out loud as they considered each answer. Students believed that *learning* to think critically was better in a group, but that *practicing or using* their critical thinking was better done independently.

The use of research papers as a strategy to develop critical thinking was controversial in the student group. While several faculty included research projects in their instructional activity bag, only some students found this helpful. Those who did find it helpful commented on the depth of their learning through this process and their consideration of how this would impact their clinical practice. Those who did not find it helpful expressed concern about the writing process itself interfering with the ability to focus on the thinking behind the paper.

> I think writing can be good, but for me it's too much stress. Cause I'm not a type of person to write so I don't look at the aspect of learning something new. I look at it like, "Oh my goodness, I have to sit down and actually think and write a paper."

There did not seem to be a consensus of opinion among the students in the focus group about whether writing was a helpful tool for critical thinking development. A number of students subscribed to each of these disparate views.

Less commonly mentioned, but brought up by the students and at least one faculty member are the activities of film critique and the use of open-ended questions. In fact, the use of open-ended questions was one of the activities first mentioned by students and specifically focused on those that have more than one answer. Students appreciated that the process of critiquing a film and having to explain the cause of any errors on the film were CT developing activities. This is both a didactic and a clinical activity and occurs in

both structured exercises (like an analysis of repeat films) and the unplanned performance of any radiographic examination in the clinical.

The program director was the only one to mention the use of the portfolio as a means to develop students' critical thinking. This is the only program that used a portfolio process and so deserves consideration here even though it was not consistently regarded as important to critical thinking. The purpose of this portfolio is for the student to gather professionally relevant materials as a means of presenting him/herself to a potential employer. The outline of the portfolio requirements includes three aspects that would foster the use of CT: a personal reflection, selection of scenarios that demonstrate the student's use of critical thinking and problem solving skills, and the selection of their best piece of work (paper, project, radiograph). Students are provided with samples of previous student's portfolios to use as an example and are free to discuss the portfolio with the instructor. Little class time is spent in discussion or development of the portfolio. It does not appear that the portfolios are used as an indicator of the student's critical thinking ability nor does the evaluation of this project include items related to critical thinking.

Activities related to critical thinking dispositions were also discussed and demonstrated. Three of five faculty members either described examples of or demonstrated role modeling of critical thinking for the students. Most also discussed the importance of motivating the student to be involved in the activity. For example, the following works on the disposition of Open-mindedness.

> ...very often, maybe 3 times a day, I will make at least one inappropriate comment, on anything I can come up with. Typically in the arena of sexual harassment, comment on patient's odor, comment on co-workers behavior and using bad words, so SOB. I use that a lot, shortness of

> breath. And so I just say SOB and write it on the board and leave it. And some will take a look and some will ask, "Who wrote that? Did you write it?" "Yea, I did." "Why did you do that?" And I explain that it means shortness of breath. That's the first clinical sign that you need to understand when you read the request. So you've got to think twice about whatever you read and be open to other meanings of it.

The faculty addressed several other dispositions as they described their instructional approach and plans (CT self-confidence and open-mindedness) or behaviors demonstrated by students in the classroom observations (inquisitiveness) as seen in the following description by a faculty member.

> I do it with humor and basically say, "Well that's another point of view but remember that this person is seeing things from their perspective." Trying to foster again that idea of being open. Just because this person sees it that way doesn't mean that person is going to see it that way and they're both correct and they're both wrong. But nobody is more right than another. However, I also couch it within the norms of our field, and say you are allowed to think whatever you want, but behaviorally, this would not be acceptable. For you to act on that would not be OK.

Here faculty are both modeling critical thinking dispositions and discussing their place in the classroom and profession.

In classroom observations (totaling 3 Carnegie hours), two different faculty members demonstrated very active classroom logistics. In the class with first-year students, a new faculty member regularly directed questions of individual students back to the group as a whole for answers. S/he guided them to ask probing questions and led their thinking in the right direction with hints and his own questions (although sometimes memory based). S/he commonly asked students to justify their answers and explain their thinking as well as consider alternative approaches to the procedure.

The second year classroom observations revealed many instances of students questioning the faculty member and each other and catching one another' errors of

judgment or memory. There were multiple times when the whole group would spontaneously break into smaller group discussions with those sitting around them. The instructor did not have to encourage this; practically every time s/he paused in directing the class, the groups began discussion. S/he really was like a director that was guiding the students' performance rather than being the performer him/herself.

Critical Thinking Processes

The learning outcomes stated in course syllabi suggest that this program places the greatest emphasis on the CT processes of inference, interpretation and analysis. There is considerably less attention paid to the skills of evaluation, explanation and self-examination. Specifically, the sub skills of drawing conclusions (Inference) and decoding significance (Interpretation) were most highly used. A substantial amount of attention was also focused on the students' ability to examine ideas (Analysis), typically by comparing and contrasting concepts or comparing experimental results with the theory or a set of standards.

Instructional activities were most likely to call on the processes of inference and interpretation. A second group of activities that were frequently used asked students to do explanation, analysis and self-regulation. The least used process was that of evaluation, showing up in only one activity. At a finer level of detail, the sub skills most frequently used do match those of the objectives: drawing conclusions and decoding significance, along with examining ideas. As well, a common subskill seen in activities is that of self-examination, where students are asked to examine their own thinking and performance and is primarily seen in the clinical and capstone courses.

In general the activities reported in syllabi, course materials, instructor interviews and classroom observations supported the stated objectives and went beyond them. In every course that I examined comprehensively, the activities called on CT processes that were not evident in the objectives. Therefore the breakdown of categories and subcategories for the instructional activities differs somewhat from that of the objectives (see Figure 7).

Outcomes

Only five out of 16 second year students participated in the testing phase of this study. In an effort to assess whether these students were representative of the student group at this site, the variables of age, college GPA and program GPA were compared between the groups. No statistically significant differences were found using an independent samples t-test on these three variables. The only obvious difference between the groups is that of gender. The participants were 40% male, whereas the whole class is only 25% male.

Since neither the skills test nor the disposition inventory has been known to have a gender bias, there is no reason to believe that this difference impacted the outcomes.

No statistically significant correlations were found between college GPA or program GPA and either the skills or disposition total score. A moderate correlation (r = 0.499) is seen between program GPA and total score on the skills test, but with an n of only 5, this is not a significant finding.

Students in this program scored higher (M = 17.40, SD = 3.44) than the group mean (M = 16.56, SD = 3.79) on the CCTST overall and also higher (M = 317, SD =

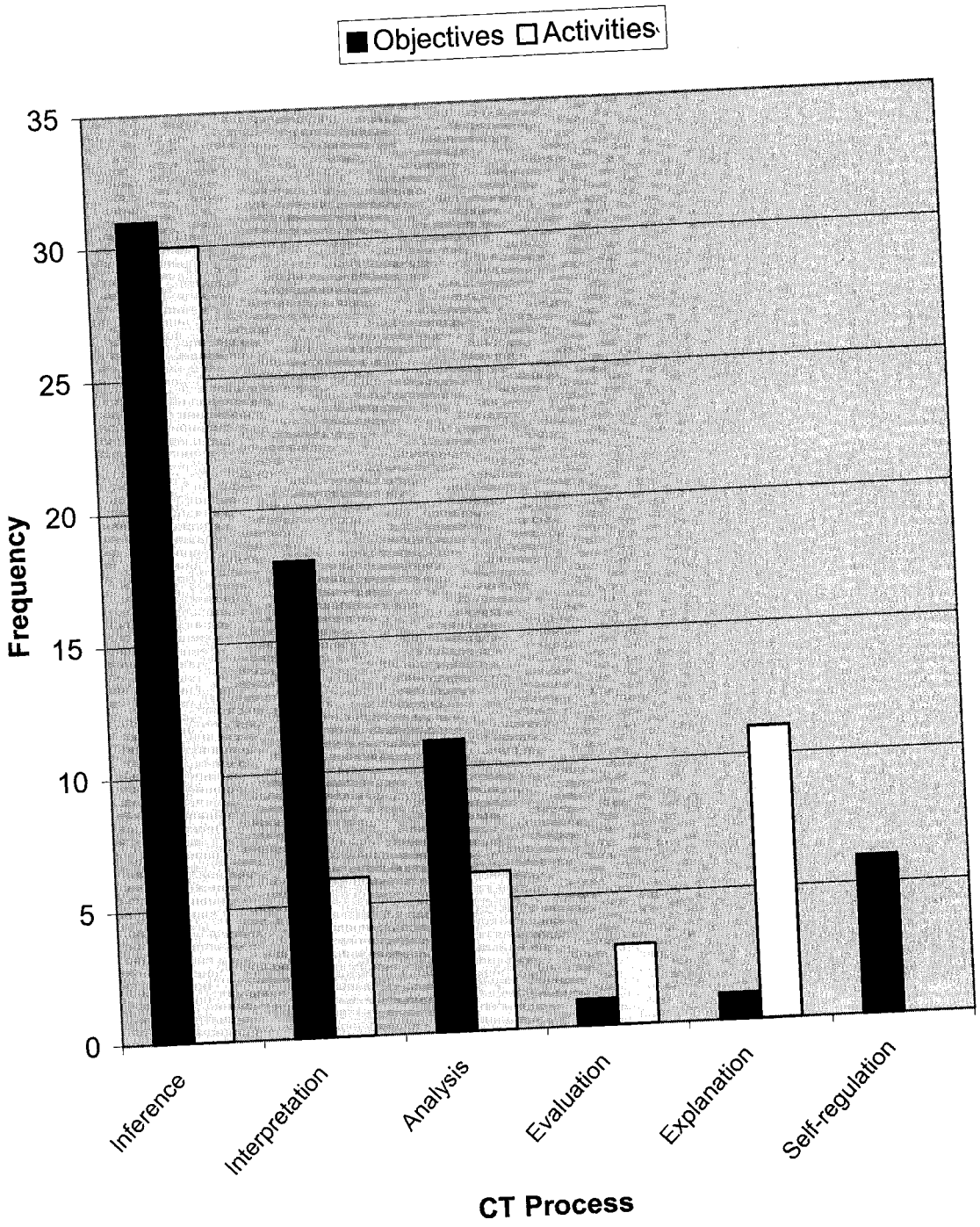

Figure 7. Site C. Comparison of CT processes indicated in course objectives with those called on via activities suggested by syllabi and faculty. Inference activities are closely matched with objectives. In other categories, sometimes activities and objectives are out of balance with one another.

34.99) than the group mean ($M = 303$, $SD = 25.41$) on the CCTDI, but these differences are not significant. CCTDI subscale scores were slightly above the mean in all areas except Systematicity where the program score ($M = 48$, $SD = 3.97$) exceeded the group mean ($M = 43$, $SD = 7.15$) by a larger margin. The only disposition subscale scoring below the group mean was on the Maturity subscale, where the program scored a 41 ($SD = 8.34$) in comparison to the group mean of 43.56 ($SD = 6.95$). In the Truth-seeking subscale, this program exhibited significantly greater variation in scores compared to other programs. Disposition scales indicate that the students are positively inclined in all areas of disposition and nearly reach the target score of 50 in the area of Inquisitiveness and in Systematicity where only 11% of undergraduates score above this target score.

On the subscales of the skills test, students in this program out-performed the group mean in all areas except Evaluation. Student scores in this area were very consistent compared to the group as a whole. When compared to the performance of nearly 3000 four-year college students on this form of the skills test, this program's students performed best in the sub skill of Analysis (scoring at the 75^{th} percentile) and worst in Evaluation.

As shown in Figure 8, this level of performance is inconsistent with the program's instructional activities. The evaluation subscale includes both evaluation and explanation, which are the least common types of activities in the program. Inference is more common, and student performance is better in this area. The analysis subscale encompasses both analysis and interpretation functions and would be expected to be the area of best performance for this group of students given the instructional activities that are commonly used.

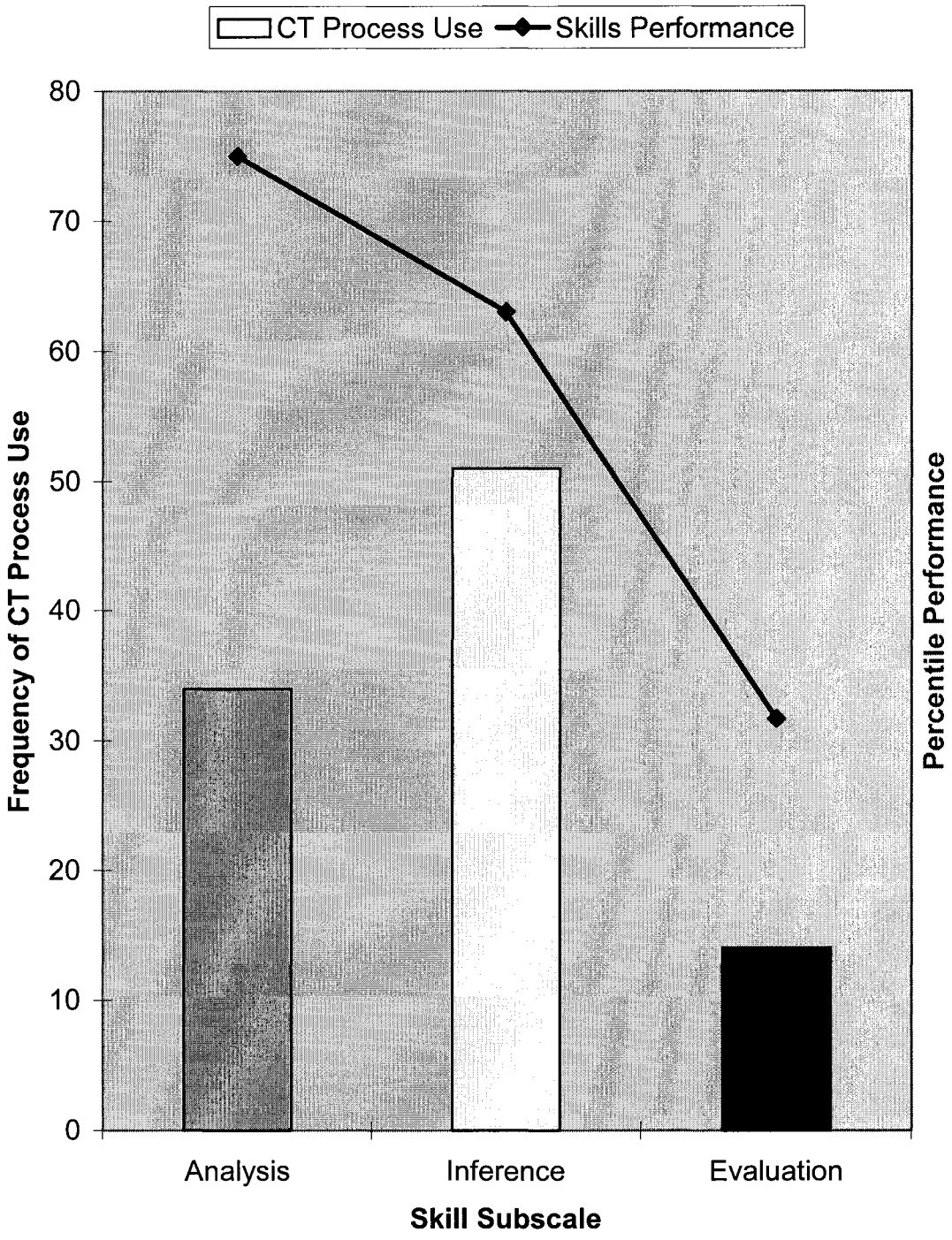

Figure 8. Site C. Comparison of instructional emphasis on each of the CT Processes and associated performance on the CCTST Subscale. Performance trends are similar only in the subscale of evaluation.

Significant correlations ($p<0.01$, one-tailed) were seen between the total skills score and the CT Self-confidence subscale ($r = 0.978$), as well as the sub skills of induction ($r = 0.994$) and deduction ($r = 0.992$). There were also large correlations (but significant at the lesser $p<0.05$ level) between the total disposition score and the total skills score ($r = 0.857$) as well as with the analyticity sub skill ($r = 0.814$) and induction subscale ($r = 0.901$). There were additional strong correlations at this level of significance among a few disposition and skills subscales, as well as between a few dispositions and skills. Only the disposition subscale of Systematicity was not correlated with any other disposition or skill. This is particularly interesting since this was the subscale on which these students scored surprisingly high.

Five student portfolios were examined as evidence of student work. These were portfolios from the graduating classes of 2000 and 2001, not the senior class that was tested. These findings are presented only as an indication of the type of critical thinking skills that are seen in the portfolios of this program. The portfolios included a number of research papers as selections of the students' best work and so some insight into the student papers as evidence of CT skills is available.

Three sections of the portfolio were reviewed: personal reflection, examples of critical thinking and problem solving, and the papers selected as evidence of the student's best work. Personal reflections showed no evidence of CT. Examples of critical thinking and problem solving consistently presented the theme of adaptation to the patient condition and environment in the scenarios that were described. This is further evidence of the strong consensus in the program that perhaps the most important element of critical thinking is this ability to adapt to situations. If one counts paraphrasing in a research

paper as critical thinking, then all papers showed evidence of CT. The only evidence of CT beyond this was seen in two examples of the same research paper assignment, to compare and contrast two imaging methods. These two papers explained the results of the students' examination of these two methods and presented similarities and differences between the two.

Three hours of classroom observations of both first and second-year students reveals an active group of students. In the first year class, students have more instances of talking than does the teacher. In the second year class, a session that was billed as a lecture to review radiographic science material turns out to be very interactive for the students. In both classes, it was quite common for students to demonstrate CT behaviors spontaneously, that is bringing up a topic or asking a question that took the conversation to greater depth or breadth. Second year students regularly challenged both the teacher and each other when they disagreed with a point of view or needed clarification. There was evidence of the dispositions of truthseeking and inquisitiveness as well as a variety of sub skills.

Implementation Strategies

Faculty interviews and the student focus group both provided suggestions for the design of strategies to promote critical thinking development. This information comes both from direct questions and from answers to other related questions. This particular group of faculty and students are most consistent in their belief that activities that require students to work in groups are effective. A variety of reasons are provided in support of these beliefs: opportunities to argue or discuss, a less stressful environment in which to verbalize your thinking, and the opportunity to be exposed to different perspectives from

a variety of students. They also emphasized the importance of an environment and relationships that allow them to feel safe in trying out their naïve thoughts and voices without the risk of being demeaned by faculty or peers. One faculty member expressed this in terms of building the students' confidence.

> ...then I'll start calling on students that I know have the idea but they are afraid to speak. Because there's always a few of those who know it but they just don't want to say it, so I'll start calling on some of those students. And kind of guiding them so it will increase their confidence level that they DO know what they're talking about that they just need to be able to say it. And so I'll kind of guide the conversation in that sense.

And a student explained the benefits of group work and study.

> I think in small groups is beneficial to help me think critically because I'm not nervous and stressed out about it and I can talk it out and bounce it off someone and maybe if I'm not saying it correctly they'll repeat it how they understand it and then it will be like, "Oh, OK." So just having small groups and a relaxed situation for me makes me think critically. Well you can do it this way.

Figure 9 quantifies the importance that faculty and students attribute to group study and learning and illustrates the high degree of emphasis placed on group work and classroom environment at this site.

Faculty and students also indicated the importance of allowing for creativity and being open to new ideas and points of view, albeit with less consensus. This was evidenced in various ways from the use of intentionally vague classroom questions to the inclusion of creativity as a grading criterion for projects. The faculty, but not the students, also found it important to spark interest in the students by using real life examples and trying to engage the students' personal interest. On the flip side, there was not as much agreement about what prevents activities designed to promote CT from working well, although ideas were offered related to relationships, stress, structure, and content.

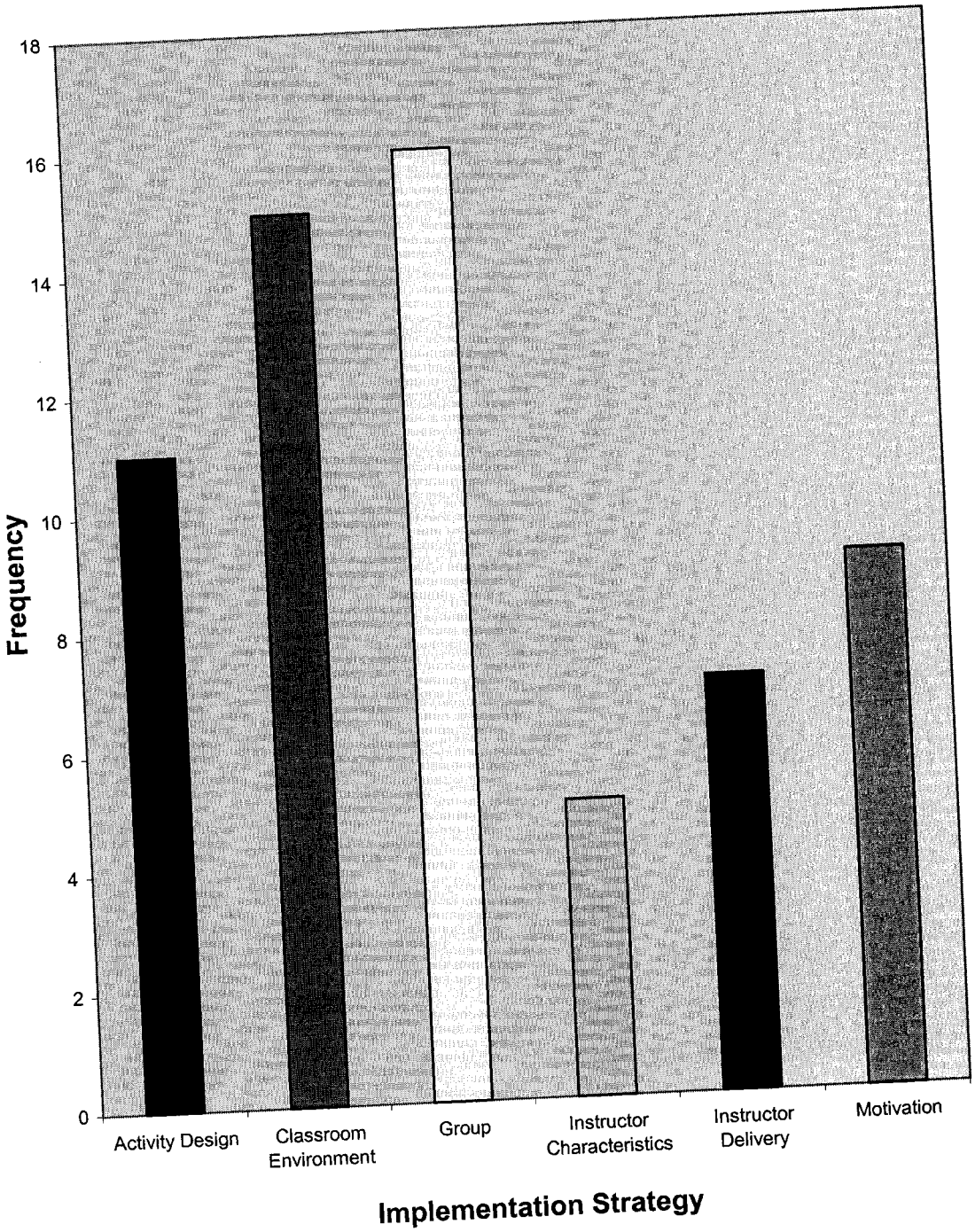

Figure 9. Site C. Distribution of implementation strategies. Emphasis is placed on Classroom Environment and Group strategies. Faculty characteristics are not seen as an important feature related to critical thinking.

This site places a greater emphasis on the importance of multiple points of view, a feature reported by students and faculty alike. As a result, learning in groups from peers is key strategy applied not only to developing content understanding, but also recognized as a critical thinking builder. However, there is a recognition that study and thought can not always be in groups, students need opportunities and encouragement to work and think independently as well.

> Faculty: I would spend some time so everyone has a verbal answer…And I find those who don't participate first, and get those to come out of their shells, until the 16 of them come up with some verbal answer. Then we come up with the best answer [as a group].

> Student: …thinking on my own because working in a group, that like helps get me started on the idea so when I've been in school, I've gotten all these ideas from other people, but in order for me to think it critically through, I have to have that situation [by myself].

Both students and faculty are conscious of the interplay between expressing their ideas in groups and talking things through as well as the need to rely on one's own thought processes in making decisions about what to believe or do.

Summary

It was obvious to me when I conducted my site visit that this program had a different approach or attitude about critical thinking instruction than the other programs that I visited. It seemed to be more a part of the fabric of the program than I had previously seen. I was very cautious during data processing to be sure that I was not skewing my analysis to confirm that perception. It was not until I completed the analysis of my data that I was able to piece together elements that might explain my perception.

Of course there were findings that were not consistent with my initial impression. Even though they see critical thinking as highly important, both students and faculty have

difficulty defining critical thinking. Yet, they talk about it in a very similar fashion when they are pushed to explain their understanding of CT. There is little formal planning about critical thinking instruction and its approach to assessment is not particularly well developed. Faculty have not studied how to teach for critical thinking either formally or through professional development activities. Direct instruction is not included anywhere within the radiography curriculum. Rather, film critiques and case scenarios form the cornerstone of the instructional approach.

But there were many more instances of how the program really *was* different from the others that I had studied. First, it is more connected to its campus community. A number of faculty talked about their participation in campus-wide professional development in instructional methodology. One of the faculty members was very involved. Students are involved in the Student Government Association. This is not particularly common for radiography students who spend a great deal of time off campus at their clinical education sites.

While all radiography programs would be considered "hands on" as a result of the usually substantial clinical experience, this program exceeds the norm. Only three classes in the radiography curriculum are purely classroom experiences. Students and faculty alike perceive these practical experiences as important in critical thinking development. Students commented that their ability to practice thinking in the lab before going to the clinic was an important element of their instructional program. It also appears that the laboratory experiences are less mechanical and more situation-based, a feature that may impact the development of critical thinking.

There is also a strong emphasis on the use of groups in instructional, study and practice environments. Students are encouraged at the outset to form study groups with one another. The schedule of classes encourages this as students have most of their classes in one day on campus and study together during breaks. Many homework assignments and projects are assigned and graded in groups. Some laboratory experiences also require students to perform experiments as part of a lab group. Both students and faculty acknowledge the importance of this activity to thinking development.

The instructional activities used by this program are typical of others in many ways. However, there is a pervasiveness about their use that is not seen in other sites. More projects, more writing, and more critical thinking questions appear in the homework. Film critiques are a laboratory and homework activity, in addition to a clinical activity seen in other sites. Procedures laboratory sessions and examinations are case-based in many instances. This serves to bring the variety and adaptation needed in the clinical environment into the more controlled laboratory environment. Here students have the time and support necessary to think about the adaptations that are required and faculty have the opportunity to encourage students to bring the underlying theories into their deliberation about how to adapt.

In addition a number of unique activities are also seen. Each student in the review seminar class develops a professional portfolio. Students select works that represent their best work, provide examples of critical thinking and problem solving scenarios and reflect on their journey through the program as they approach professional status.

Perhaps the most significant difference at this site is its attention to some of the dispositions of critical thinking. Faculty used different approaches to student motivation,

including the use of controversial statements and videotapes to get students to disagree with one another, defend their point of view, and interact with others who think differently. Several also paid attention to helping to develop the students' sense of confidence about their thinking. This was done mostly by asking appropriate questions and then following through with one individual until they were able to work through the cognitive challenge. Role modeling CT was not only discussed by faculty members, but was also demonstrated during my classroom observations.

The primary cognitive processes used by the instructional activities in this program are inference, interpretation, and analysis—the ones I might expect. This program asks students to do more self-regulatory activity than might be expected. Self-evaluations are used in clinical and the portfolio requires some reflection and analysis as well. Strategies are implemented through a relatively balanced use of graded and ungraded, written and verbal, and group and individual work.

Given the instructional focus on certain CT processes, attention to disposition and my perception that the CT instruction here was more pervasive, higher level performance on the skills test and disposition inventory were expected. The mean scores for this program do exceed the overall mean in almost every area, but not with statistical significance. This lack of significance may be a type II error given that the number of students participating in testing at this school was quite small (n=5). Since this group of students did not vary from the overall population of students in the program in any significant way, it seems likely that with a larger number of participants, a statistically significant finding would appear.

Scores on one skill subscale and one disposition subscale fell below the overall mean for this group. The skill of evaluation and the dispositional attribute of maturity were lower in this program. Very little instructional attention was paid to evaluation, perhaps explaining the skill score. The dispositional attribute of maturity favors students who are better able to tolerate ambiguity and is not easily explained by the observations and study as designed. One of the disposition subscales was also found to be highly evident in this group of students, that of Systematicity. Likewise, there is nothing in this study that provides a plausible explanation of why these students are more likely to approach problems in an orderly and focused manner. In fact, this may be a selection effect.

The following chapter presents a comparison among the three sites related to the research questions.

CHAPTER 6

Cross Case Analysis

In order to answer the research question, two very broad comparisons must be made. Did the three programs approach critical thinking instruction differently and were the students' critical thinking outcomes different? The answer to the first question is definitely yes, instruction for critical thinking is different. Each section of this chapter will describe both the similarities and the differences in instructional approach. The second question is more difficult to answer because of limited participation in the outcomes testing at two of the three sites. Small and uneven numbers of participants at the three sites limit the usefulness of statistical comparison of the means.

While the previous chapter focused on painting a comprehensive picture of each of the case study sites, this chapter will outline how the three sites compare with one another on each of the foundational variables in the study. Similarities and differences are noted and patterns are explained where possible.

Planning

The most basic feature of planning for critical thinking development is to specify a definition, goals and outcome measures for critical thinking. None of the sites has planned around all three aspects. None has an explicit definition and only one has identified a goal, yet all have identified both direct and indirect outcome measures. A summary of findings in the area of planning is presented in Table 10.

Table 10

Comparison of Program Features Related to Planning

Feature	Site A	Site B	Site C
Method	Mostly informal Student-centered	Formal and informal Syllabus-centered	Mostly formal Faculty-centered
Resources	Minimal	Books and allied health colleagues	Seminars Program Director
Curriculum	Some direct instruction No progression	Elective course may include CT No progression	More "hands on" Limited progression

Method

All sites use both formal and informal methods for program planning including that related to pedagogy in general. The formal methods of planning include regular faculty meetings at all sites and advisory board meetings at two of the three sites. However, there was not evidence at any of the sites that planning specific to critical thinking occurred on anything other than an informal basis. Critical thinking was not mentioned in the minutes of any faculty or advisory board meetings.

Differences are seen among the sites with regard to the focus of the planning activities. Site A centers on individual student performance, Site B uses its advisory board for curricular level planning and its faculty for course level planning, and Site C integrates course level and program level planning. Site C provides greater evidence that faculty have considered how each course fits into the overall curriculum with respect to

both content and specific skills. Site A does not appear to intentionally review its courses or curriculum.

Resources

Overall, the faculty have not leveraged the available research related to definition, instruction or assessment of critical thinking. Faculty at site A appear to be the most passive about seeking or using instructional resources related to critical thinking. Site B makes the best use of resources by calling on printed materials (book and articles) as well as allied health and radiology colleagues. Faculty at Site C have been involved in a number of institution-sponsored professional development activities centered on teaching strategies, although not specifically critical thinking. Since critical thinking is a focus at this institution, it is likely that CT was included in some of these, although the faculty could not recall anything specific. Only one of four faculty members at Site C has used any specific resources at all and none have consulted with allied health faculty. A number of faculty across all three sites recognized their graduate degree programs as being helpful in their teaching for critical thinking, although none has specifically studied educational methodology at the graduate level.

Curriculum

These sites do not seem to believe that curricular structure is an important feature of planning for critical thinking development. There is no obvious planning for progression of critical thinking. Large amounts of clinical practice time could be more effectively structured for critical thinking development. Only Site A uses direct instruction related to critical thinking. A course in logic is one of three courses that Site B students may choose to meet their humanities requirement.

More often than not, faculty do not agree about which courses in the curriculum provide the greatest emphasis on critical thinking. Faculty at Sites A and C tended to be familiar with and acknowledge the contributions of only the courses that they teach, while there was a bit more agreement at site B.

While these curricula are by nature quite cohesive and sequential with respect to content and disciplinary skill development, little attention is given to cognitive skill development. Courses within the major are tightly sequenced and so opportunity exists to consider carefully the pre-requisite skill level and development within the course, but no site explicitly addressed this. There were two aspects of curricular development at site C that addressed progressive development of skills: complexity of writing assignments and progression of skill level in clinical performance. The clinical performance measure does include some embedded elements of critical thinking and so progression may be indirectly included here.

Assessment

Given the JRCERT and regional accreditation mandates, programs should be planning for critical thinking using a model of goal setting and assessing results against that goal. The following section looks at the programs' development in this model and is summarized in Table 11. Communication of goals is added based on principles of good practice in assessment, which state that the students must be aware of the goals against which they will be assessed. Obviously the instructional practices interceding between goals and assessment are also of critical importance and will be discussed in depth later in this section.

Table 11

Comparison of Program Features Related to Assessment

Feature	Site A	Site B	Site C
Definition	Goal, no definition	No definition	No definition
Importance	Very important	Most important	Most or very important
Communication	Print and discussion Most effective	Student orientation Least effective	Program Director Source not clear
Assessment Methods	Clinical (2) Employer survey Alumni survey	Clinical (2) Employer survey Essay exams Research paper	Clinical (2) Homework Class discussion Research papers

Definition and importance.

None of the three programs has established a formal definition for critical thinking in the program. Site A has established a goal related to critical thinking and problem solving as required by the accrediting agency, but does not accompany that goal with a specific definition. However, even without a written definition, the programs could be functioning with a common language and understanding related to critical thinking that would be discovered from dialog with program members and review of documents. This is, in fact, the case.

Despite the absence of formal definitions, agreement exists between faculty and students about what the program means by critical thinking. Naturally, the degree to

which faculty and students share a language and understanding varies among the sites. Site A presents the most consistent definition, while site B presents the most focused definition. Site C presents a more broad view of critical thinking and includes a core where faculty and students agree and then branches where there is less agreement. Across the programs, the features of adapting to different patient situations, application of theory to practice, the ability to make decisions and justify them, and creativity are common features.

One would expect that these programs would place a high emphasis on critical thinking since it is specifically targeted by the accrediting agency. There was not as much agreement about this as one would expect. Site A had faculty rating the importance of critical thinking at both the highest and lowest levels. Site B was consistent across faculty and students in rating critical thinking as most important. Faculty at Site C thought critical thinking to be the most important program goal, while students leaned toward identifying CT as the second most important goal. There was broad agreement among students that the relation of critical thinking to content knowledge was important to consider.

> I put the critical thinking as number 2 because they teach us how to take the x-rays, how to actually produce the image and if you don't know that, I don't know how you could even start to do the critical thinking without it. You have to have some sort of knowledge to think from for your situation. So that's why I put it as number 2.

This quote from a student at Site C illustrates similar perceptions of about half of the students interviewed at all sites.

Faculty and students across all sites expressed the conflict between critical thinking as a goal and other important disciplinary goals such as patient care, good

communication and radiation safety. Since participants were asked to give a relative ranking of critical thinking in comparison to all the program goals they might have, it is not surprising that these disciplinary features were raised on level with critical thinking.

> Our goals are pretty, pretty broad. There are only four and they pretty much cover everything that is the important stuff. I can't say that patient care is the most important thing...the whole thing about patient care is that means you do the very best x-rays so the doctor can diagnose it. It's one big picture. You can't take one thing out and say this is more important than any other. Because to maintain high standards of ethics, patient care and radiation safety, those still are going to take critical thinking skills just like it will take problem solving and good communication.

Some faculty acknowledge the need for using critical thinking in performing in these areas, and so had a difficult time rank ordering competing goals.

Communication of goals.

All programs plan for face-to-face communication of critical thinking goals through advising and orientation sessions. Written materials are also used in support at Sites A and C. If agreement between faculty and students about the definition of critical thinking is an indicator of effective communication, then Site A has the most effective communication program. Site B seems to have the least effective method of communicating its critical thinking goals since its students were the least able to express a coherent definition. Site C faculty believe that their written syllabi are a primary communicator of CT goals, but these were not mentioned by students at all. Rather, students saw the textbook and clinical practice sites as contributing more to their understanding of what aspects of critical thinking were important. Students at Site A also identified the clinical practice sites as a method of learning about program goals for critical thinking. Therefore it might be wise for the programs to include their clinical faculty and staff in their plans for communication about program goals.

Assessment of goals.

These programs make more attempts to directly assess student ability in critical thinking than might be seen in other disciplines. In addition to gathering indirect assessment data from employer surveys, all three sites use a clinical performance evaluation to directly assess student's critical thinking ability in the practice setting. Sites A and B specifically include an item related to critical thinking, while Site C embeds critical thinking in other items. Both B and C include some language that explains the critical thinking or other items, while A does not. The evaluation tools used by Site C change over the course of the program as performance expectations rise in later semesters.

Sites B and C described using classroom-based assessments of critical thinking as well. Site B uses essay exams in the early stages of the program as well as papers and presentations. Site C uses a wide variety of didactic assessment methods including performance assessments in the laboratory. Unfortunately, the criteria for grading papers at both Sites B and C do not include elements related to critical thinking. Only one faculty member (from Site C) used criteria for grading the presentation of projects that s/he believed had critical thinking elements embedded.

> They are going to be graded on how much depth of research is evident, how much new material did you present, how many new questions did you evoke out of the class, and how well prepared were you as a group.

The first and second criteria may be proxies for critical thinking.

All sites asked students to self-report about critical thinking, but took different approaches. Sites A and C both asked students to comment on their perceived ability, Site A on an alumni survey and Site C on the 5th semester

student self-evaluation. Site B asked alumni to rate how much the program contributed to their critical thinking development. Only Site C asks the question at a time when the educational program can attend to any perceived deficiencies.

Program Features

When asked what features of the program and/or institution helped foster or limited students' critical thinking development, the three sites responded quite differently. Most striking is the observation that both faculty and students had a difficult time identifying features of the program that fostered CT at Site A, while at Site C they had a difficult time identifying program limitations. Whether this represents differences in actual features, awareness, or simply attitude is not clear.

Two program features were mentioned both as being fostering characteristics and as potential limitations. Clinical practice provides a multitude of opportunities for students to encounter situations that require them to exercise their critical thinking. However, their ability to take advantage of the opportunity depends on the particular clinical site and its staff. If a site is very busy, understaffed or employs staff that do not care to teach, then the opportunities for student critical thinking are often lost as the staff are less likely to provide the time that novices require to think through situations. In addition, faculty and students alike recognize that not all staff will serve as positive role models for thinking as is true with other features of good practice. Secondly, students at Site C mentioned that stress was both a limiting factor and a helpful feature of their educational program. Some students found the pressure to perform and fear of failure to be debilitating, while others found that same stress to be motivating.

Faculty were mentioned as being an important feature of critical thinking development at both sites B and C. While the context varies between the two sites, students at both are expressing their recognition of how the faculty member guides their learning focus. Faculty are not mentioned as a "fostering feature" at Site A. To the contrary, students mention faculty actions that are specifically limitations to their CT development.

> Site A: They have so much information to teach that once you kind of grasp what they're teaching you go to something else. You don't have to use what you've been learning, you just go to something else and learn something new. And you forget what you've just learned 'cause you're learning something new.
> Site B: [The professor] gives us all the information and then [the professor] leaves it to us to take the initiative to apply it to our clinical site and to tests.
> Site C: Another thing [the professor's] done is encourage us to seek out the weird and the difficult exam because that adds to your ability to...it adds to your experience library, if you want to call it that.

While faculty at Site A are probably fostering critical thinking in some way, those positive actions did not come to mind when students were asked about features of their program, while the negative ones did.

I was surprised to find that all three programs involved students in extra/co-curricular activities for the purpose of fundraising. While the specific activities were different at the three sites, all faculty believed that these activities helped students to develop their critical thinking abilities. Site B students organize a substantial continuing education seminar for local professionals. Both faculty and students here recognize the value of this activity for developing students' critical thinking. In order to raise money, students at Site C must participate in a college-wide club system that requires them to interact with other student organizations. Students at Site A also raise money to fund their educational conference attendance and by doing so interact with their classmates in a

different set of circumstances that require them to solve problems together with classmates who may have different perspectives.

Instructional Activities

These programs recognize the entire instructional environment for its ability to contribute to student's critical thinking development. Instructional activities may be conducted inside or outside of the classroom. Activities have been considered for frequency of use as well as the way in which they provide evidence of students' critical thinking. Table 12 summarizes the findings at the three sites.

All three sites use case scenarios and film critiques as their most common instructional activities. In addition they all use clinical practice, laboratory experiments, research papers and homework or test questions to develop and/or assess students' critical thinking. Other activities, such as brainstorming, stories, reading assignments and a variety of projects, are seen at more than one site. Activities unique to each site are also seen. As previously mentioned, Site B uses the planning of a continuing education seminar as a CT development activity as well as the use of controversial topics (such as euthanasia) as the basis for subsequent discussion.

Site C requires students to complete a portfolio that not only requires the students to exercise their critical thinking in selecting pieces for the portfolio and writing a personal reflection, but also requires them to include documents that demonstrate their own critical thinking and problem solving ability. Most of these documents are student stories about clinical situations in which the student reports how they thought through a particular situation, sometimes supported by another student or technologist.

Table 12

Comparison of Program Features Related to Instructional Activities

Activity	Site A	Site B	Site C
Case scenarios	Broad use Perform, write, speak	Limited use Mostly oral	Primarily procedures Perform and oral
Film critique	Regular use	Regular use	Regular use Homework as well as clinical/laboratory
Procedures laboratory	No adaptation required	Adaptation discussed orally	Adaptation performance required
Laboratory experiments	Limited use	Regular use, appear unstructured	Regular use of structured labs
Research papers	Few, short essays	Few, lengthy	Many
Homework	Drill and practice		Open ended with justification required
Fund-raising	Used	Extensive	Requires participation in student government
Clinical	Little structure	Little structure	Little structure
Stories	Anecdotes	Students analyze	Students analyze
Portfolio			Used at program end
Think out loud			Used in review
Controversy		Videos with discussion	Used regularly

Another interesting activity is used at Site C as part of the registry review seminar. Students form two groups that each are responsible for answering a small set of review questions in class. When one group is engaged in answering the question, they are required to think out loud and discuss their thinking around the right and wrong choices. Meanwhile the other group is listening to their thinking. The faculty member who uses this activity likes it because s/he is able to hear how students' thoughts might be going wrong. The students did not mention this activity as a way to develop their critical thinking.

Again, group activity comes up as a central tenet of teaching for critical thinking at Site C. The program director goes so far as to say, "I believe that critical thinking cannot develop without another individual." Students in the focus group were in agreement with this statement, but went a bit further to distinguish between learning how to think critically and then practicing their own skills independently, as the following exchange between a first year and a second year student demonstrates.

> 2nd: I'd have to agree with him. Thinking on my own because working in a group, that like helps get me started on the idea so when I've been in school, I've gotten all these ideas from other people but in order for me to think it critically through I have to have that situation. I have to be there on my own without anybody else telling me, "why don't you try this, why don't you try that," because then its not really me thinking it through. It's me just doing what they're thinking through.
>
> 1st: I think learning, using a group is helping me to learn to think critically, right now in class because it gives me the other options of the students. Because right now I'm learning and I can't, I guess my thinking is still a little narrow. It's still within the box of what I've learned so far and how I interpret what I'm learning and what I'm seeing in clinical. But when I'm with the group I get these other viewpoints that I can take or if they sound good to me I'll use. But I still need that group right now. Hopefully by next spring, I'm giving myself that time to be able feel independent enough, to feel confident enough to do that critical thinking alone, independently, and go for those films say on a trauma patient or

> something. Right now I don't feel confident enough to be on the clinical side to do my own critical thinking for most series.

This dialog demonstrates that students have perhaps adopted the philosophy of the program director about the importance of the group setting to learning and critical thinking development, but they have taken it beyond this belief statement and considered how and why and when this is true for them personally. An example of critical thinking itself!

Stories are used in Sites B and C as a critical thinking activity, while at Site A they are not. As you might expect, faculty at all sites frequently share stories with the students about situations that they have encountered in their own professional practice. However, at Sites B and C, these stories are the cases around which students will focus their attention to either develop a plan of action for the particular situation or critique the actions that were taken. At Site A however, the stories are either presented as examples of a particular theory or concept, or they are used as an interesting anecdote. The students are not asked to use the stories as a basis for further thought.

Student generated stories are also used at all three sites in a similar fashion. Students are asked to call on their own clinical experiences and share a story that demonstrates a particular concept or theory. This does require the students to use a particular type of critical thinking. Site B takes this activity a little bit further when student stories are used in the discussion sessions that are attached to the clinical course and can be used to help students to solve problems that they have encountered in their clinical practice.

Instructional activities were coded for the type of evidence of CT that they provide. Oral responses were among the most common at all three sites. This was

particularly true at Site B where oral response accounted for a larger proportion of the total activity than it did at other sites. Performance-based responses to critical thinking were slightly more common at Site C. For example, the final examination in the radiographic positioning class is scenario-based and the student is graded on his/her ability to deal with the situation presented. Writing was also used in a greater proportion of the exercises here, accounting for about 27% of the activities, where at Sites A and B, the percentages were 13 and 16 respectively. Site C students write an average of 12 papers in the radiography classes during the course of the program whereas other sites require one or two.

More in-depth study of the two primary activities of case scenarios and film critiques reveal some minor differences in their use at the three sites. Case scenarios are consistently used to focus on the students' need to adapt to the particular situation presented and include the use of faculty stories as a basis for student consideration of the necessary adaptations. These are used much more broadly at Site A than they were at either Site B or site C. Here they are used in patient care, ethics, procedures, technical factor selection, in communication role-plays and by the clinical instructors at the clinical sites. Students at Site A are required to perform, write and speak about the situations both alone and in groups. In comparison, Site B used scenarios primarily in relation to performing procedures and primarily as an oral activity. Film critiques are used much more similarly among the three sites. One difference is seen at Site C where film critique is a homework assignment and students spend more time explaining their reasons for a particular critique decision.

Faculty activities

Questioning strategies were used at all three sites, both in class and on homework assignments. However, there was some difference in frequency of various questioning techniques, particularly in the classroom setting. Site B tended to use more probing questions with the students in the classroom, for example, "I try to ask questions that they won't be able to...answer real quick. They've got to sit and ponder and sometimes even then I don't get the answer and I have to keep digging." Site C tended to use more guiding questions such as, "In the beginning, they won't know the difference, so I take them back a little bit," or "They need to come up with the technique. So I will help them, to steer them." There were no specific trends in the types of questions that faculty at Site A were asking, other than they were content related, both factual and higher level.

Two faculty members at Site C also make use of controversy in order to challenge students' comfort with their own assumptions and models of thinking. One faculty member uses it regularly and more informally in the classroom as demonstrated by the following quotes: (a) "I will make at least one inappropriate comment," and (b) "I invite them to get into a conflict in thinking and then solve it." Faculty at Site B also use videotapes on controversial subjects to engage students in conversations about ethical decision making,

Overall, Site C makes use of the greatest variety of instructional activities for critical thinking. They use both student activities and instructor actions in taking advantage of many opportunities in the classroom and laboratory and to a lesser degree, the clinic. They place a greater emphasis on making students explain their decisions and actions and expect students to participate to a greater degree in active learning and group

activities. Site B's greater emphasis on oral activity could potentially allow some students to be less engaged in the cognitive activity than faculty are intending, without providing the performance requirement needed to motivate some students. Site A simply does not take advantage of many opportunities to develop critical thinking. It makes extensive use of case studies but is much more focused on the content of the discipline than on developing thinking skills. Students do little writing and express a greater emphasis on passing tests than on learning to think about the content in more cognitively challenging ways.

Critical Thinking Processes

The predominant critical thinking process emphasized by the activities that were described in syllabi and interviews was that of Inference. This is primarily seen in the case scenarios where students are asked to assess a particular situation, consider alternative plans of action and then come to a decision about the best approach. It is also the process used in film critique where students are required to interpret the findings on the film, compare them to a set of technical standards and then come to a decision about whether the film is acceptable or not, and if not, how it needs to be corrected (again, choosing among a set of alternatives).

Figure 10 demonstrates the variation among sites in the remaining CT process categories. While Sites A and C call on the CT process of inference most frequently, Site B asks students to use interpretation skills more often. Site B also places the greatest emphasis on Evaluation, but this data is skewed somewhat by a high proportion of course objectives related to evaluation. Site C asks students to explain the reasons for making the decisions in the case scenario and film critique activities. Self-regulation is the least

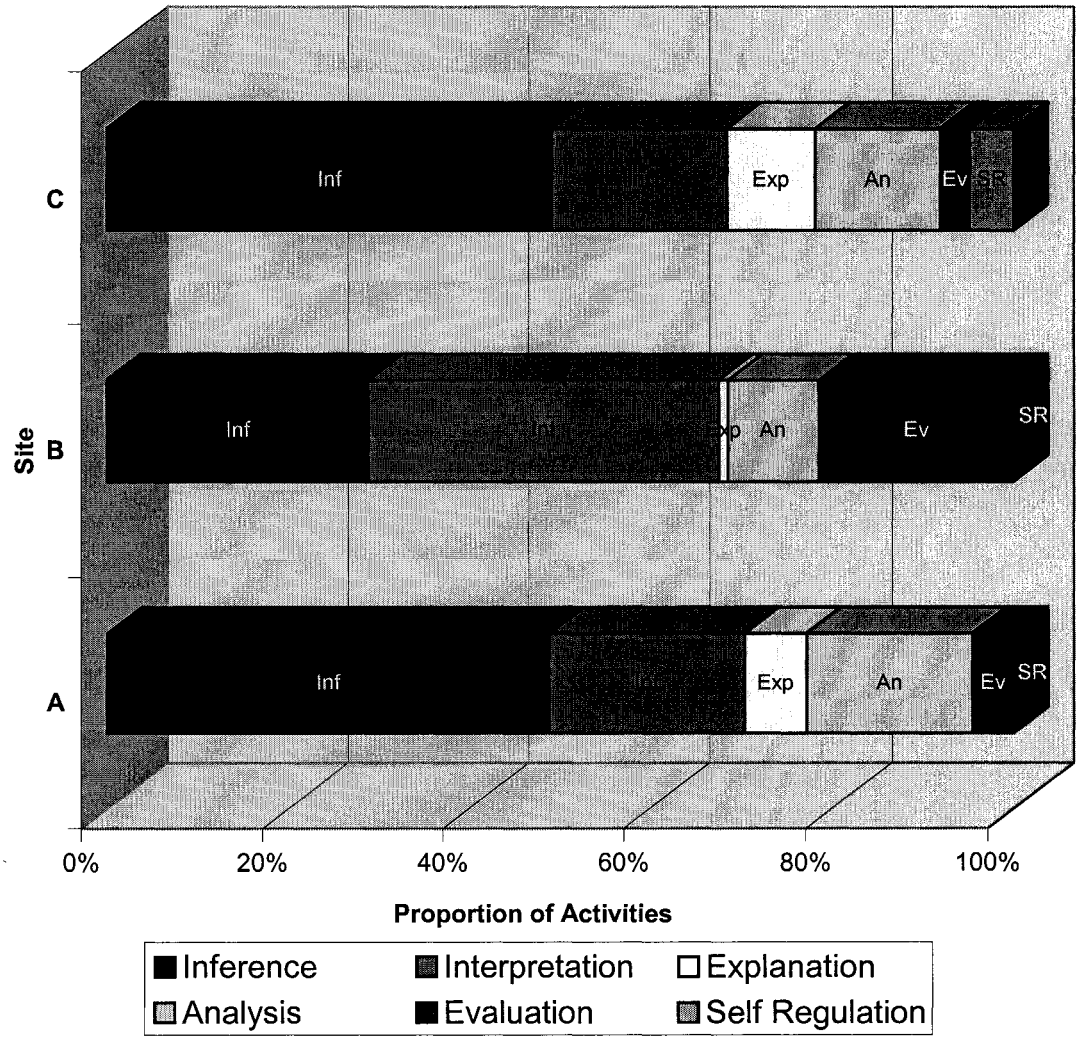

Figure 10. Compares the proportion of instructional activity calling on each of the six critical thinking processes of the APA Consensus Definition at each of the three sites. Numbers on the bar indicate frequency counts.

common activity and is not seen at all at Sites A and B, but does occur at Site C, being seen in six activities.

Implementation Strategies

Implementation strategies are methods of delivering the instructional activities described above. The strategies mentioned by faculty and students are considered along six dimensions: group activities, instructor delivery, instructor characteristics, activity design, classroom environment and motivation. Distinctions are drawn between instructor delivery and instructor characteristics. Items considered instructor delivery generally refer to a particular instructional activity and include such things as timing, phrasing and organization. Those included as instructor characteristics referred more to an instructor's general instructional approach, beliefs and attitudes. There is some overlap along these dimensions as instructor characteristics impact classroom environment and a number of categories can influence motivation. A more detailed explanation of the categories follows.

When examining the combination of all sites, the greatest emphasis is placed on activity design, instructor delivery, and group activities. However, there are differences among the sites in their attention to each of these areas (Figure 11). Site C emphasizes the nature of the classroom environment and group activities more than Sites A or B. Instructor delivery strategies are nearly twice as likely to be discussed at Site B than at either of the other sites. There is also a difference in attention to activity design with Site C faculty and students tending to address these features less than those at Sites A and B.

Group activity at all sites stresses the feature of multiple perspectives being shared among the students. At Site C this is particularly important as both faculty and

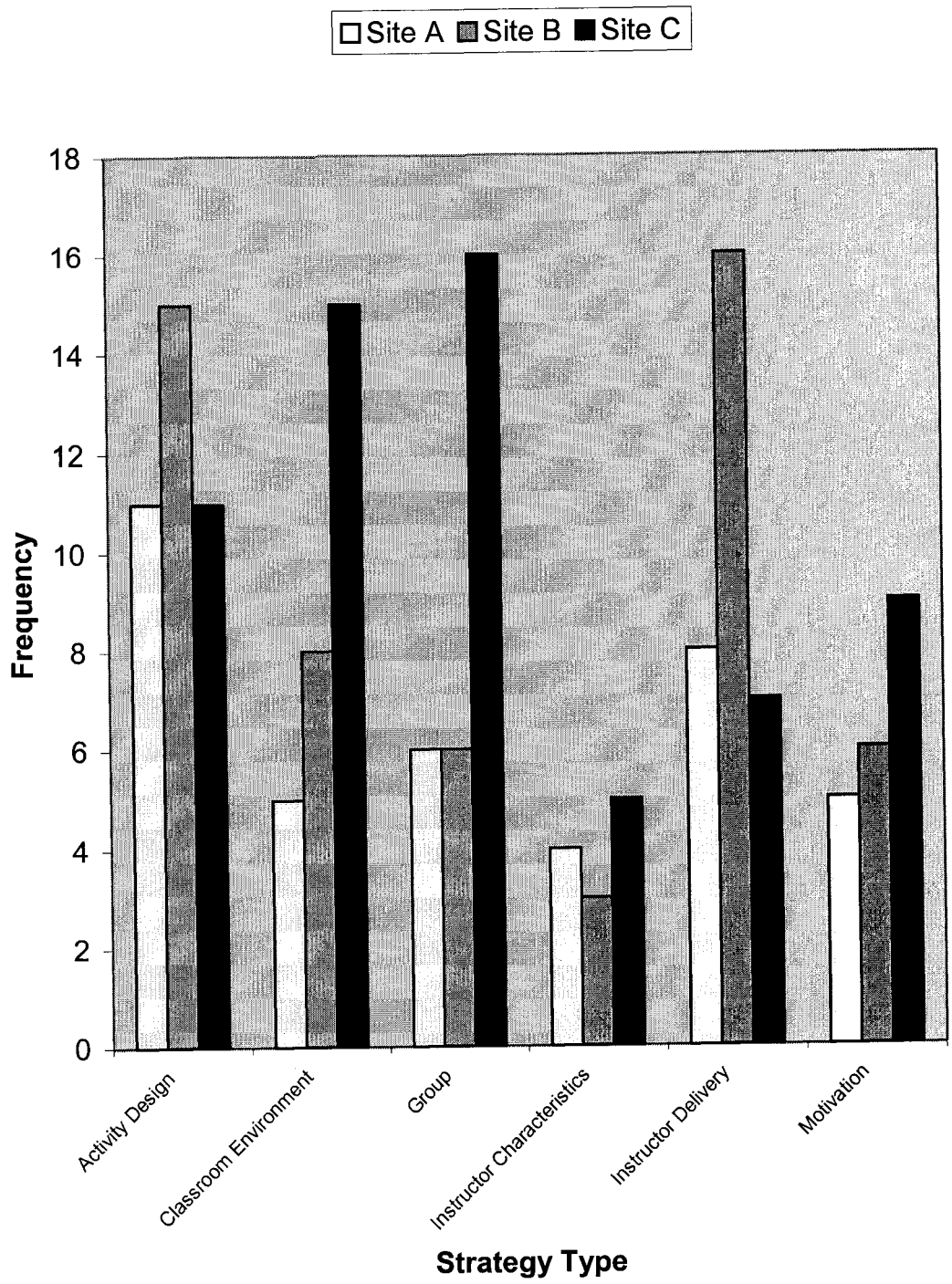

Figure 11. Compares the distribution of the various implementation strategies by site. Sites A and B focus on activity design and instructor delivery, while site C focuses on the classroom environment and group processes.

students discussed how this impacts students' willingness and ability to consider a different point of view.

> Faculty: But I just tend to hang back sometimes because what it does, is it generates, or sets the atmosphere I guess, for discussion and different points of view and them coming from a peer rather than coming from me saying, "Well have you thought about this?"
>
> Student: ...because even if I knew it really well it was like I was playing the teacher role and it reassured that I really do know this and to talk about it and tell somebody else. Well, then you also had six different viewpoints on it.

Site A is more likely to consider groups as a forum for problem solving activities that requires group generation of various solutions while Site B emphasizes group discussion of controversial issues.

Instructor delivery strategies include the themes of supporting the student through scaffolding and questioning and providing challenge to the student. Site B faculty pay the greatest attention to this dimension.

> I'm asking the open-ended questions – well why might you think that? What symptoms were present, and how can you relate that back to what we've talked about? So, it's a discussion, but I really prompt it with the open-ended questions.

Site A faculty are focused on making sure that they ask a question rather than giving information and also attend to allowing the student time to think about it before answering. One classroom observation at Site A included a considerable amount of instructor role modeling, not necessarily as a deliberate strategy, but as the instructor helped students to critique films, s/he "thought out loud" about the process of critique.

Activity design is also a primary focus of Site B. Across all sites the major features within this dimension consider how much direction a particular activity gives

students. No trend is evident among the faculty at any individual site. Some faculty believe that the *absence* of direction is important, while others describe critical thinking projects as failing because of lack of direction.

As well, there was much discussion about the balance of individual thought versus group brainstorm and sharing and how to work in both. Site A faculty talk about using both in one case scenario activity.

> I think it gave them an opportunity to independently think about it – they weren't just in the group before they could make their decision. They independently had to work on it too and I think that caused the variety of opinions to be even stronger. I think if putting them in a group like we did – the one strong personality could have had more influence over other's thinking.

In comparison, Site C uses whole class discussion in a way that blends both individual and groupthink.

> I would spend time so everyone has a verbal answer...And I find those who don't participate first, and get those to come out of their shells, until the 16 of them come up with some verbal answer. Then we come up with the best answer [as a group].

This dynamic balance is a key feature when course activities are implemented.

The classroom environment is described in two ways. The first considers how safe and secure the student would feel in the classroom. The issue of making the classroom a comfortable and safe place came up at each of the three sites. This implementation strategy is much more commonly addressed at Site C than either of the other sites. The other feature focuses on the role of the student in the classroom and how s/he is expected to behave and interact in it. Faculty at Site C are much more clear about their expectations that the students would be actively engaged in thought during class time.

> My philosophy in class is if you don't ask me questions, I ask you questions. And then when I ask you a question, you'd better come up with the answer because you're going to make a fool of yourself. So they come prepared or they ask me tons of questions, which I welcome, because to me that is their thinking... And if you ask the question, you must come up with the answer. I will not provide you answer until you come up with some lead to it.

While this particular quote is not consistent with the site's general focus toward a safe classroom environment, it is demonstrative of the expectation for thinking involvement that is expected of students.

Instructor characteristics are seen in essentially equal amounts at all three sites. This dimension is focused on the faculty role as expert versus facilitator and creator of a supportive classroom environment. There is little commonality within or across the three sites. A variety of approaches are discussed including inviting students to change the instructor's position and leaving the students to answer challenging questions without instructor guidance or support.

Finally, motivation is attended to most by Site C. Across all sites the most common feature is that of using real world examples and making the instructional activities grounded in the practice of the discipline, as well as taking advantage of these health care students' interest in helping others. All sites also mention the importance of motivating students by requiring an individual contribution from them even if the activity is group or whole-class based. While all sites consider motivation in similar ways, it was discussed most frequently at Site C.

Strategy Summary

Taking a holistic view of each site and how they address all six strategy dimensions in concert, there are also differences among the three sites A (Figure 11). Site

A places a greater emphasis on teacher talk than it does on student independent thinking. This is evidenced by its increased attention to activity design features and low attention to the classroom environment and motivation of the students as well as the use of group strategies. Site B places a greater emphasis on the teacher as questioner and participation by the students in more active learning techniques, but still teacher guided. There is some consideration of the value of working with peers and with groups, but much more attention is paid to instructional delivery and design aspects. Finally, Site C seems to have progressed to the point of relying more heavily on learning in peer groups. Site C attention now focuses on creating a classroom environment that is supportive and provides the opportunities for faculty and students to share their different perspectives on the issues. In addition, it is considering how to best balance the group benefits with the need for students to think independently.

Outcomes

Outcomes data falls into four categories: (a) skills test results, (b) disposition inventory results, (c) questionnaire results and (d) student work. Second year students participating in the testing phase of the research varied in number from 12 at Site A to eight at Site B to 5 at Site C.

With three groups to compare, ANOVA would be the statistical procedure of choice. However, most of the basic assumptions of the test are not met and so interpretation of results should proceed with caution. Momentarily ignoring the procedural difficulties with the use of ANOVA, no significant differences were found with an alpha of .05. If using a more relaxed alpha of .10, only the Self-Confidence disposition scale shows a significant difference among the programs with Site A students

scoring lower than the other two sites. Results of ANOVA for the skills and disposition data are included in Appendix H, but are not used in analysis of outcomes.

Table 13 summarizes the results of all the outcomes measures and shows that the greatest differences between the sites occur in the areas of dispositions and survey consistency.

Skills Test Results

Figure 12 demonstrates the patterns of scoring in the skills subscales at each site, while Table 14 provides the descriptive data. These data demonstrate that there is little difference among the three sites in the skills areas. The means for Site C tended to be among the highest and those at Site B tended to be in the middle. Scores from Site A were quite variable, being the highest of all programs in two subscales and the lowest of all programs in two others.

However, there were differences in variance in scores across the three sites. Site A showed the greatest variation in scores overall and for most of the individual subscales. This is also evidenced by the fact that in total skill, Site A students posted the three highest and the three lowest scores. Site B overall showed the tightest grouping of scores around the mean. Site C showed a larger standard deviation in the analysis subscale.

When compared to the performance of nearly 3000 fourth year undergraduate students (the only population available for comparison with these two year students), Site A students performed their best in the subscale of Analysis and their worst performance was in the Evaluation subscale. Site C students also performed their best in the Analysis subscale and their worst in Evaluation. Site B students performed their best in the

Table 13

Cross Case Analysis of Outcomes Measures

Measure	Site A	Site B	Site C
Total Skills	Lowest	Middle	Highest
Sub skills			
Analysis	Middle	Lowest	Highest
Inference	Lowest	Middle	Highest
Evaluation	Highest	Middle	Lowest
Induction	Highest	Lowest	Middle
Deduction	Lowest	Middle	Highest
Total Disposition	Lowest	Middle	Highest
Disposition Scales			
Truthseeking	Middle	Lowest	Highest
Openmindedness	Lowest	Middle	Highest
Analyticity	Lowest	Middle	Highest
Sytematicity	Middle	Lowest	Highest
Self-Confidence	Lowest	Middle	Highest
Inquisitiveness	Lowest	Middle	Highest
Maturity	Middle	Highest	Lowest
Survey Consistency	Inconsistent Students higher	Inconsistent Students lower	Consistent Students lower
Student Work	Interpretation only	Some analysis beyond interpretation	Analysis in specific assignments. Self-reflection in portfolio

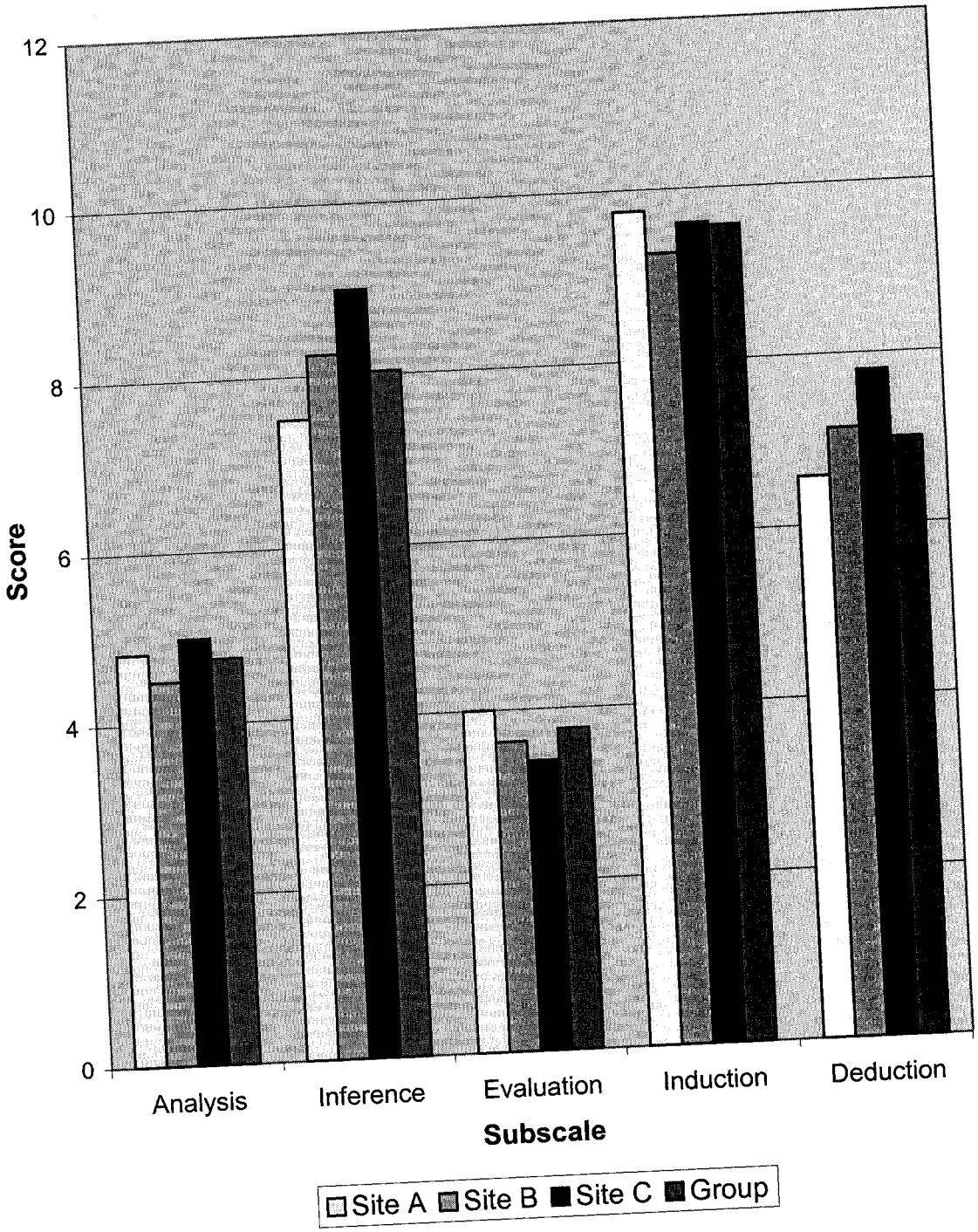

Figure 12. Compares the performance of each site against the group mean in each of the CCTST Skills Subscales. Differences among programs are quite small

Table 14

Cross Case Comparison of Skills Test Results

	Site A n=12		Site B n=8		Site C n=5		Whole Group n=25	
Scale	Mean	S.D.	Mean	S.D	Mean	S.D	Mean	S.D.
Analysis	4.83	1.03	4.50	0.93	5.0	2.0	4.76	1.2
Inference	7.5	2.47	8.25	2.12	9.0	1.58	8.04	2.21
Evaluation	4.0	2.04	3.63	1.06	3.4	0.89	3.76	1.56
Induction	9.75	2.05	9.25	1.28	9.6	1.82	9.56	1.73
Deduction	6.58	3.42	7.13	2.53	7.8	1.64	7.0	2.81
Total	16.33	4.74	16.38	2.56	17.4	3.44	16.56	3.79

Inference subscale and, like the others, their worst in Evaluation. None of these educational programs seem to be doing well at developing the critical thinking skill of evaluation, while they are more effective in the areas of Analysis and Inference.

Disposition Inventory Results

Descriptive data for dispositions suggest that there may be some differences among the sites worth noting (Table 15). Site C students appear to be consistently more disposed to Systematicity than students at either sites A or B as evidenced by both a higher mean score and lower variance. Students at Site A answered items such that they demonstrated less confidence in their critical thinking abilities than the students at either site B or C, although there is a larger variation among students at site C. One other

Table 15

Cross Case Comparison of Disposition Inventory Results

	Site A n=12		Site B n=8		Site C n=5		Whole Group n=25	
Scale	Mean	S.D.	Mean	S.D	Mean	S.D	Mean	S.D.
Truthseeking	39	6.31	37	3.02	40	11.49	38.56	6.65
Openmindedness	41.5	7.27	42.37	6.07	44.8	4.6	42.44	6.33
Analyticity	44.17	5.89	45.75	4.46	47	9.46	45.24	6.16
Systematicity	41.75	8.3	41.13	5.51	48.4	3.97	42.88	7.15
Self-Confidence	41.5	4.89	46.25	4.59	46.8	7.92	44.08	5.83
Inquisitiveness	44.75	8.59	47.75	4.89	49	3.74	46.56	6.82
Maturity	43.67	7.54	45	5.42	41	8.34	43.56	6.95
Total	296.33	22.59	305.25	22.15	317	34.99	303.32	25.41

disposition shows noteworthy differences only between the high and low scoring schools. The disposition toward Inquisitiveness was rather low at Site A when compared to Site C, although site B fell in between these two programs. The same is true of total disposition (Figure 13).

Further examination of total disposition scores by a ranking method demonstrates that site A tends to have a greater proportion of its students in the bottom half and proportionally fewer scoring in the top half while sites B and C are approximately equal. When looking at only the top five and bottom five scores, Site C holds three places in the top five but only 1 in the bottom five. From a variety of angles it seems safe to say that students at site A are less disposed to think critically and that perhaps site C students are

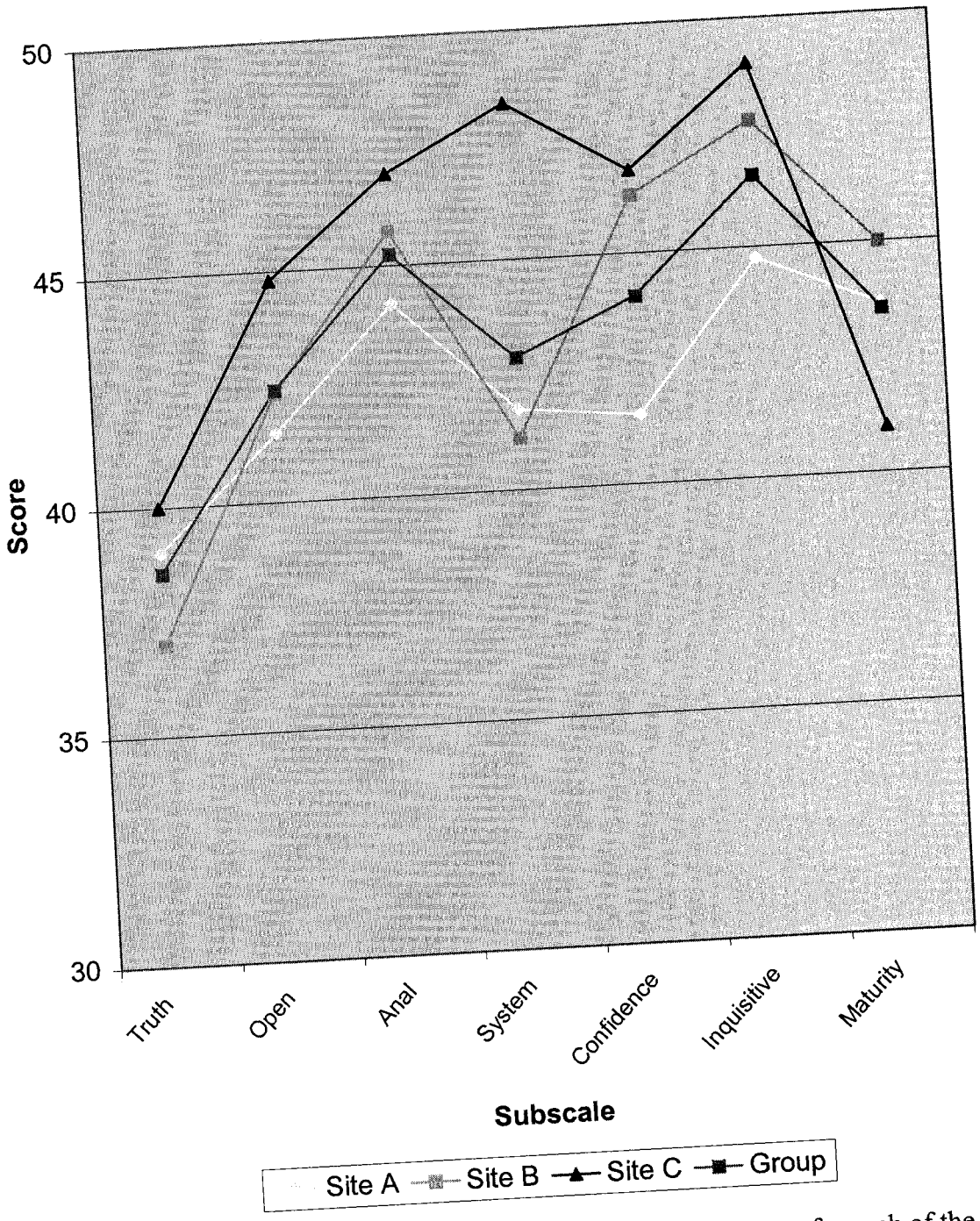

Figure 13. Compares the CCTDI disposition inventory subscale scores for each of the three sites.

more disposed, although the small number of students in this testing sample makes any generalizations about students at Site C risky.

In addition to the extremes of being least disposed to Truthseeking and most disposed to Inquisitiveness at all sites, there are some site specific high and low scores. Site A students display relatively low dispositions in Openmindedness, Systematicity and Self-Confidence. Site B students also display a low disposition to Systematicity, but a relatively high Self-Confidence. Site C students show quite a high Systematicity score, but less disposition toward Maturity. The disposition of Systematicity bears further exploration since it is a low scoring area for two sites but a high scoring area for Site C.

Survey Questionnaire Results

Initially the program director completed a questionnaire indicating how much the program emphasized a number of critical thinking tasks based on the APA definition of critical thinking. During the site visits, other faculty and second year students completed the same survey. Results of students' surveys were compared to faculty surveys (including that of the program director). In addition, the cumulative survey results were compared with the activities described in course syllabi and interviews for consistency within the categories of critical thinking. Agreement about the frequency with which an activity occurs is an indicator of the accuracy of their perceptions about what is *really* occurring at the site.

Student and faculty perceptions of how much the instructional activity prompts occurred were most consistent at Site C and least consistent at Site A. Of 17 possible activities, agreement within .50 or less (out of a possible 3 points) was achieved on 14 activities at Site C. In contrast, this level of agreement was seen on only five activities for

sites B and C. Frequency scores were less than .25 points discrepant on 11 activities at site C, four at Site A and two at Site B. Large disagreements (1.0 or greater) were absent at Site C and were seen twice at Site B and four times at Site A as shown in Table 16.

Students at Sites A and C tended to report that a particular instructional activity was used more than the faculty reported. Students at Site B reported less frequent use than the faculty. However, this pattern at both sites A and B are likely to represent a phenomenon similar to regression toward the mean. Site A faculty reported very low usage while Site B faculty reported very high usage. Student reports at both sites were more moderate than that of the faculty.

The proportion of activities reported on the survey does not match the evidence of activities found at the sites by interview and document analysis. Survey results indicate a much more uniform distribution across the various CT processes than was evidenced during the site visits. This is true for all sites. Not one survey shows the emphasis on inference that was found during the visits (Figure 10). However this is easily explained by the extensive use of case studies and film critiques that both use inferential CT processes but were not specifically mentioned on the initial survey questionnaire. Site B showed consistency in proportion of activity reported on the survey and seen on site, but its use of explanation and self-regulation was found to be much smaller than were indicated by survey responses. Evidence of self-regulatory activities was also minimal at sites A and C, even though survey results indicated that it should be present.

Two items on the survey questionnaire asked about specific activities that were not evidenced at either site. These are analyzing an argument and writing a paper arguing

Table 16

Comparison of Student and Faculty Perceptions About Instructional Practice

	Site A		Site B		Site C	
[a]Activity	[b]Difference		[b]Difference		[b]Difference	
1	.09		.29	+	.12	
2	1.17	+++	.75	++	.06	
3	.59	++	.62	++	.06	
4	1	+++	.29	+	.5	++
5	.7	++	.14		.06	
6	.92	++	.83	++	0	
7	1.16	+++	.75	++	.44	+
8	.66	++	.87	++	.19	
9	.5	++	.62	++	.19	
10	1.5	+++	0		.12	
11	.17		.87	++	.56	++
12	.45	+	.5	++	0	
13	1.17	+++	.79	++	.25	
14	0		1	+++	.63	++
15	.91	++	.37	+	.19	
16	1.38	+++	1.12	+++	.44	+
17	.09		.87	++	.12	

[a] CT activities presented in the initial survey (Appendix B)
[b] Differences between faculty and student ratings

\+ >=0.25 and <0.50
++ >=0.50 and <1.0
+++ >=1.0

for a particular position or procedure. While both faculty and students indicated that this was done at least a little bit, no evidence of this was found in interviews or document analyses. Students were less likely to report that these activities occurred than were faculty.

Student Work

A variety of student work was available for review at each of the sites. The primary source of data was students' research papers. Only Site B was able to provide the work of students who participated in the study, and then for only four students. This consisted of lengthy research papers and presentation of those papers to their classmates. Portfolios were available for review at Site C, but since the participating students had not yet finished their program, their portfolios were not available for review. The work that was available was from students in the previous two graduating classes in that program. The only work available at Site A was the research papers that had been submitted and accepted for publication by the state professional society. Obviously this is not a representative sample of student work. In addition, observation of student classes at Sites A and C are considered to be examples of student work.

For the most part, research papers presented little evidence of critical thinking beyond the interpretative skills used to paraphrase from sources used in the construction of the papers. There were a few additional examples worthy of mention. One research paper assignment at Site C asks students to compare and contrast two different imaging methods. Papers of this type show evidence of students' presenting their explanations of how the two methods are similar and different. These papers show evidence of the CT

processes of Analysis and Explanation. Papers from Site B were required to include a number of case studies related to the topic of the paper. While the case studies were in fact included, only rarely were the connections between the cases and the content of the paper explicitly made. This would have been an opportunity for the student to demonstrate critical thinking in explaining how the selection of the particular cases illustrated other aspects of the paper, but this was seen in only one paper. There was some evidence of analysis in these papers, generally comparing and contrasting one concept with another.

The papers and presentations from Site B were rank ordered based on evidence of critical thinking. These results were compared with the scores on the disposition inventory and skills test. There were only three students for which work was available in both categories. Looking at data for these three students suggests that perhaps disposition is more important than skill in demonstrating critical thinking in student work. The student whose paper was ranked as number one and whose presentation was ranked number two had the greatest disposition score among these students, but not the highest skill score. The student whose paper was ranked number four and presentation ranked number three scored the highest of this small group in skill but was 50 points lower than the top student in total disposition.

Other evidence of student dispositions came from the classroom observations and sometimes from interviews. The most striking differences again occur between sites A and C where I observed classrooms in action (observations at Site B were of student presentations described above). In classrooms at A, there was a greater focus on teacher talk. The teacher asked the questions, and students sometimes answered them, but more

often than not, the teacher answered the question. At Site C, the teachers rarely answered their own questions. As well, students asked more questions of the teacher and each other and carried the classroom interaction more than being directed by the teacher. Teachers role modeled critical thought process at both sites, but did not point out to students that this is what they were doing.

Summary

Despite the fact that radiography programs are required by their accrediting bodies to plan for critical thinking and assess its outcomes, little planning specific to critical thinking is seen. Even though little planning around this topic is occurring, instructional practices do focus on critical thinking as defined by each of the programs. The evidence does not support consistency among course objectives, instructional activities, and faculty or student perceptions about the frequency of their occurrence.

Instructional practices varied across the three sites in both frequency and type. While there was some consistency in the types of instructional activities used across all three sites, most notably case scenarios and film critiques, Site C used a greater variety of activities and also greater frequency. There was more and varied instruction for critical thinking at this site compared to the other two sites.

As well, the way that these activities were implemented in the classroom was different across the sites. Site A was much more teacher-centered than either sites B or C. Site B presented as somewhat evenly balanced between teacher and student focused, while Site C was more student focused. As a result, Sites A and B paid more attention to how specific tasks were designed in the aspects that the teacher could control, while Site

C was more focused on getting students to work together in groups and creating a learning environment that supported critical thinking development.

The results of these differences in instructional practices are noticed more in the area of dispositions than they are in student skills. Students at all three sites display nearly the same skill level, but it appears that students have more confidence in their ability to think critically at Sites B and C. In a very small sample of student work from Site B, those students displaying higher disposition scores also demonstrated more critical thinking in their writing and oral presentations. While other disposition scales did not display as great a difference among the sites, it is noteworthy that students at Site C scored the highest on all but one disposition scale (Maturity).

CHAPTER 7

Summary and Synthesis

The primary finding of this study is the differences between the programs as suggested in the analogies within the case reports. These three programs are at very different levels in how they instruct for critical thinking. Site A, the "recreational jogger," is at a very nascent stage in its instructional practices, characterized by an intuitive approach to critical thinking. By comparison, Site C, the "elite runner," is much more fully developed and uses instructional practices that are consistent with suggestions from the literature for development of critical thinking. Site B sits in the middle of those two extremes.

Table 17 summarizes the features on which there are important differences among the three programs. Here you can see a variety of instructional practices that are used differently at Site C than they are at sites A and B. It is not a matter of frequency, although that is sometimes true as well, the activities are structured and implemented differently. It is perhaps those qualitative differences in how the activities are used that has the greatest impact. Some of these features warrant further discussion here. Again, the student outcome differences seen in this study are more in the dispositional areas than in the skills area, although a Type II error regarding skills differences is also possible.

Planning method

While planning overall was surprisingly minimal, there was a difference in focus among the three sites. Site A focused its planning on specific students and their performance and progression through the program. Potentially a very powerful means to

Table 17

Cross Case Summary

	Site A	**Site B**	**Site C**
Planning method	Student-centered	Syllabus-centered	Faculty-centered
Film Critique			Homework with justification required
Procedures Lab	No adaptation	Verbal adaptation	Performance adaptation
Lab experiments	Limited	Regular, unstructured	Regular, structured
Research Papers	Few, short essays	Few, lengthy	Many, variety of lengths
Homework	Drill & practice		Open-ended with justification
Stories	Anecdotes	Students analyze	Students analyze
Think out loud			Used in student review class
Controversy		Video discussions	Used regularly & informally
CT Processes	Little Evaluation Little Analysis	Lots of Inference Lots of Evaluation	Lots of Analysis Little Evaluation
Skills	Best Analysis Worst Evaluation	Best Inference Worst Evaluation	Best Analysis Worst: Evaluation
Dispositions	Low Confidence		No negative Low Maturity High Systematicity
Implementation Strategies	Activity Design Instructor Delivery	Activity Design Instructor Delivery	Classroom Environment Groups

ensure student achievement, this approach is similar to an individualized instructional plan for each student. However, while planning meetings were focused on individual student performance, there was little evidence that this translated into varying instructional approaches for students with different needs.

The approach to planning at Site B was centered on courses, specifically their syllabi. Several times each semester, the faculty convened to discuss the course, its objectives and its instructional approach. These meetings were informal and documentation about their outcomes was not available. The faculty described the results of the meetings as discussion of what was, and was not, working about the delivery of the class.

Site C used both formal and informal planning as well, but focused its planning related to critical thinking on individual faculty members. Here the program director assumed a lead role via individual discussions with each faculty member on a regular basis. Again the meetings are not documented, but both participants report that the focus of the conversation is on how the course that is being taught fits into the curriculum and how it should be delivered to support the program's goals. While the approach is faculty centered, the result may be that a more cohesive and progressive curriculum is being delivered at this site.

These variations in approach to critical thinking planning are consistent with the findings of the N. Facione (1997) study where critical thinking outcomes were positively related to adopting a CT focus, faculty discussing CT and planning for curricular changes. Site A had recently adopted a focus on critical thinking, while there was a longer history of attention at sites B and C because of institutional requirements for

critical thinking. As a result, its faculty had not spent much time discussing critical thinking, nor had it planned its curriculum to develop these skills and dispositions. Site B was a relatively new program and so curricular changes were frequent. Site C had recently made a curriculum change that required the integration of basic science principles into a number of its courses, providing an opportunity to discuss the curriculum plans and approach.

Instructional Practices

Primary Activity Variations

Film Critique.

I have already reported that two instructional activities were used as the primary means of critical thinking development in these three programs: case scenarios and film critiques. The film critiques are used differently at the different sites. Again, this is a qualitative difference. Site A performs critiques primarily in the clinical sites. Here the students review films with the clinical staff and with the college faculty when they visit the site. However, there is not a consistent approach to how this review is completed. Some faculty take the lead role in the critique, pointing out key features to the students, while others take an approach that makes the student responsible for generating the critique and explaining results.

At Site B, there is more attention to film critique in the laboratory setting, as well as in the clinical setting. In the laboratory, students work in pairs or groups of three to critique a set of films, making notes about their findings and then reviewing them with the instructor. The process is somewhat informal in that no specific questions are prepared or forms used for the analysis.

A more structured and rigorous process occurs at Site C. Here film critique is a homework assignment associated with the procedures class and laboratory. Students (or student teams) must answer a series of specific questions. The questions are open-ended and frequently ask the student to explain how s/he came to the decision that is reported in the answer. The instructor evaluates these written critiques and students must correct any errors and resubmit them. In addition, film critique is also part of the clinical course, where a procedure similar to Site A is practiced.

These approaches incorporate a number of research findings for best practices in critical thinking instruction. Not only do the programs vary in how much "time on task" is devoted to this activity, but also the level of engagement in the task varies. In having to justify their decisions, Site C students are verbalizing their strategies for critique as recommended by McKeachie, Pintrich, Lin and Smith (1986) for developing critical thinking abilities. In addition, students are being conditioned to provide evidence in support of their arguments, an element of critical thinking in the Evaluation and Analysis categories of the APA model. Both Sites B and C have students working with their peers on these critiques and are following one of Smith's (1977) recommendations.

Case Scenarios

In many ways, all three programs use case scenarios similarly. However, there is one striking difference and that is how the three programs use stories differently. Radiography education tends to be practice-oriented and many of the faculty members are actively practicing the profession. This creates an atmosphere where practice-based stories are frequently used in the classroom. Site A tends to use these stories as anecdotes

that the teacher presents to the students as examples of theories or good (or bad) practice. Students receive the stories and try to incorporate them into content learning.

Faculty at sites B and C use the stories as a springboard for student interaction. They find that use of their own experiences is more motivating to students because they are more authentic. However, students are not just passive listeners. They are asked to solve the problems presented by the story, to offer alternative solutions, or to evaluate the actions taken by the radiographer in the scenario. The stories are used as the cases for students to analyze and solve. Faculty at Site A are missing the opportunity to use these real-case examples for critical thinking development.

Value Added from Laboratory Experiences

Radiography programs are, by their nature, hands on educational experiences. They incorporate classroom and laboratory instruction integrated with extensive clinical experiences. Differences were seen in the program's use of the laboratory setting. All three programs had an energized laboratory onsite, capable of making exposures on phantoms and developing films. All three conducted regular laboratory sessions for the purpose of practicing positioning on simulated patients (classmates), but these sessions were used in different ways.

All programs identified that a key component of critical thinking in the radiography discipline is the ability to adapt standard positioning protocols to the situation presented by a non-typical patient. Site A conducted its positioning laboratory sessions almost exclusively in simulation of a routine patient that does not present any unusual challenges. Site B focused on these challenging patients in the classroom and asked students in the laboratory to describe how they would approach a procedure

differently if a particular anomaly was presented. Site C laboratory experiences, both in practice and testing situations, required students to perform procedures on "patients" that were presenting challenges to them. The students here described one session where a classmate was placed in spinal immobilization as if in a motor vehicle accident, and the lab group had to figure out how to obtain a specific view.

Again, we see a progression from Site A through Site C of gradually more complex cognitive, and in this case psychomotor, challenges for the students. Students at Site C have to be more engaged in the process of solving the positioning problem before them. They have to be able to recall the theory, apply it, implement it, and in some cases, adjust their initial plans as a result of very practical feedback about their value. Site B students must recall the theory and apply it, but do not have the performance aspect and its potential for further adjustment. An emphasis on problem solving is also one of the recommendations that McKeachie, Pintrich, Lin and Smith (1986) make for developing critical thinkers.

It is also common for radiography programs to conduct laboratory experiments related to exposure controls, resulting film changes, and quality assurance. Site A conducts such experiments on a very limited basis. One faculty member described an experience with such a laboratory where it became difficult to maintain student interest and engagement and so such experiences were no longer used in the course. Laboratory experiments at Site B occur regularly, but appear unstructured. Descriptions by both the faculty member and the students indicated that students are highly engaged in the activities, which were allowed to evolve as the laboratory experience progressed. Students were given a general principle that they were to experiment with, but protocols

and follow-up was less well defined. Site C students followed specific laboratory protocols and wrote formal lab reports following the experiment sessions. Lab reports required interpretation and analysis of results and comparison with theoretical principles. Here as well, some instructors experienced difficulty in maintaining the interest of the students when a large group worked together on one project.

These laboratory experiences do not necessarily follow any particular research recommendations. There is some difference in frequency of occurrence, being used less frequently at Site A than at the other two sites. However, the difference between sites B and C is qualitative. The variation follows a general instructional design principle that if you want critical thinking to occur, you should specifically ask for it. Site C specifically directs students to perform the CT processes of interpretation, analysis and inference. It is not entirely clear what CT processes would be used in the laboratory experiments at Site B. They could be the same, but there is less assurance that they will engage every student. As well, some of the laboratory experiences used at both sites are problem-focused and again consistent with best practices suggestion for CT development (McKeachie, Pintrich, Lin & Smith, 1986).

Writing as a Tool for Thinking

Tsui (1999) recommends that writing be used as a tool for helping students to achieve gains in their perception of critical thinking ability. Differences in the use of writing in general, and research papers in particular are seen among the three sites. Students at Site A write very little. They take two research courses that require them to write an essay to be submitted for competition. Other than this requirement, hardly any writing is used in the program. Homework assignments are primarily drill and practice

and require little writing, and according to the students, no critical thought. Site B requires a more extensive research paper in the second year, a minimum of 25 pages. Students are required to submit multiple drafts of this paper, ensuring the practice of rewriting that Tsui (1999) also recommends. However, writing assignments in addition to this major paper are not commonly used.

Site C uses extensive writing throughout the program. Students write five short papers in an introductory course in the first semester, six longer papers in a special procedures class in the second year and a more comprehensive research paper for a pathology class, also in the second year. In addition, student homework is primarily open-ended questions requiring written answers of a few sentences because most require an explanation of the student's thoughts or justification for a decision. This more extensive use of writing is consistent with research findings related to critical thinking (Astin, 1993; Tsui, 1999).

Thinking Out Loud

McKeachie, Pintrich, Lin and Smith (1986) recommend that students be encouraged to verbalize their metacognitive strategies as a means for developing thinking skills. Logan (1976) also recommends that faculty model thinking practices for students as a means to promote good thinking habits. Role modeling is frequently suggested as a means to promote critical thinking development (Beyer, 1998; Brell, 1990; Chalupa & Sormunen, 1995; Logan, 1976; Tishman, Jay & Perkins, 1993). Only Site C makes deliberate use of such a strategy. While such role modeling by faculty was observed in the classroom at Site A, it was not planned for that purpose.

Earlier I reported on a review class strategy that requires students at Site C to think out loud as they are answering multiple-choice questions. The faculty member states specifically that this approach is used in order to find errors in the students' thought processes that should be corrected. Certainly some of these errors will be associated with misconceptions about content, but they also serve as practice and role modeling (either positive or negative) critical thought for the whole class.

Controversy That Stimulates Discussion

Sites B and C both use controversy as a teaching tool to promote discussion and debate in the classroom. Its use is more limited at Site B, primarily focused on the use of videos about controversial issues such as euthanasia to stimulate student discussion and debate. The instructor that uses these videos states that no particular planning is necessary in order to get students to think critically about multiple sides of the issues. Student discussion begins the minute the tape ends. However, management of the discussion by the faculty member to deal with the multiple perspectives in a critical way is an important aspect associated with success of this activity.

Faculty at Site C, particularly one faculty member, use controversy regularly in informal ways to stimulate critical thinking. As described previously, controversial statements are intentionally made on the first day of class and regularly throughout the program in order to stimulate student thinking. Its regular use early on also encourages students' willingness to engage each other and the instructor in dialogue about potentially contentious issues.

This use of controversy to promote critical thinking is recommended by Brell (1990), along with teacher modeling as a means of developing dispositions to think

critically, which he sees as the essential feature of transfer. Challenging student beliefs helps them to see the inadequacy of their approach and the need to consider another way of thinking.

A Progression of Instructional Development

At this point it should be clear that the three programs that participated in this study were instructing for critical thinking at different levels. It is not entirely clear from this study that these varied approaches made a difference in student outcomes, a result of the study's limitations.

The least developed program, Site A, follows few of the best practices evident in the critical thinking literature. More focus is placed on content than on developing thinking skills. More important than frequency of activity use, instructional activities that have the potential to develop critical thinking are often not implemented in ways that take advantage of that potential. Perhaps as a result, its students have lower confidence in their ability to think critically and a lower overall disposition. The measurable outcomes for students in this program showed the greatest variation of all the sites. It is conceivable that these variations are a result of differences in student ability upon entering the program and the educational experiences have had little impact on the students' critical thinking ability.

Site B sits at the midpoint on this instructional development continuum. More of the best practices are seen here, such as more writing and better use of stories and laboratory experiences. Students demonstrate greater dispositions for critical thinking, but not necessarily better skills. There is a greater consistency of student performance here, which may indicate a greater impact of the educational program. Yet, key practices

are missing. Students do not work in peer groups very much and verbalization of thinking strategies and controversy are less commonly used.

Site C is the furthest along the continuum. Most of the research recommendations for critical thinking development can be found here: peer interaction, extensive use of study groups, emphasis on problem solving, writing and rewriting, active learning techniques, challenging students, and encouraging student reflection. A culture supporting group study and learning both in and out of the classroom is seen. Faculty attend to the classroom environment so that critical thinking can be supported. Students here display higher levels of disposition in every scale except Maturity. Their skills are slightly higher than those at other schools, but with such a small group participating in testing it could be a result of error rather than a real difference.

While all three sites are primarily commuting schools, Site C has managed to create a culture that supports not only critical thinking, but also group learning. Students study together by choice and by design. Many projects and homework assignments are completed in pairs or larger groups. While some students do not participate in group study, many do as a result of encouragement by the faculty. This group interaction has been one of the most consistent findings in research related to critical thinking development (e.g. Astin, 1993; McKeachie, Pintrich, Lin & Smith, 1986; Pascarella & Terenzini, 1991; Smith 1977; Tsui, 1999). Others would do well to consider how this program has created such a climate as it serves to extend the instructional environment beyond the classroom.

Conclusions

This case study was an exploration of how the accumulation of instructional practices across faculty and courses and a two-year time span impacted critical thinking skill and disposition. As an exploratory study, its purpose was to identify areas that would be interesting for further, and perhaps more controlled, study. A holistic approach was applied in the context of a discipline that features an incentive to focus on critical thinking and a well-defined and structured curriculum. Findings suggest that there is a continuum of program development for critical thinking instruction.

Three sites were subjected to in-depth study of their instructional practices, faculty and student perceptions about critical thinking development, and student skills and dispositions toward critical thinking. Greater participation by students in the testing portion of the program would have provided the statistical power needed to have greater confidence in the impact of the learning environments. Nonetheless, the difference in instructional approach among the three sites is clear.

At one extreme is a site with a nascent view of critical thinking instruction characterized by intuitive practices and an awakening consciousness about how to adapt instructional practice to stimulate CT. At the other extreme is a program that incorporates many of the best practices for critical thinking development, including those that extend learning beyond the classroom. In the middle is a site that is consciously and regularly continuing to adapt classroom practice to improve its ability to encourage critical thinking among its students.

As a result of the low statistical power of this study with respect to critical thinking outcomes, specific recommendations for instructional practice are made with

great caution. If one accepts the suggestion that students at Site C were more disposed to critical thinking, then the differential practices at this site would be instructive with respect to disposition development. These practices include: (a) greater amounts of writing with attention to justifying claims and decisions, (b) use of controversy to stimulate discussion, (c) a focus on reality-based problem solving, (d) the use of "think out loud" exercises to reveal both good and poor habits of mind, (e) an emphasis on group work inside the classroom and group study outside the classroom, and (f) creation of a classroom environment that sets an expectation for critical thinking and is a safe place for students to experiment with it.

This study further suggests that dispositions are impacted not so much by a given quantity of practice, but rather the quality of practice. For instance, incorporating frequent use of case scenarios into instructional practice is not by itself an indicator of successful disposition development. It is important that the studies be implemented using a methodology that supports disposition development, such as an expectation that thinking be verbalized, decisions justified and actions supported by theory on a regular basis—regardless of the specific type of activity. Whether formal or informal, out loud or on paper, to peers or the teacher, the CT dispositions seem to be developed when the expectation is consistently applied by various faculty members in a variety of environments. It is this consistency of application and expectation that helps students to develop disposition—a tendency or habit to act or react consistently with critical thought.

In this respect, this qualitative, holistic approach to critical thinking research has confirmed many of the findings of previous research studies, as well as conceptual recommendations. It suggests that implementation of best practices makes a greater

impact on the students' disposition to use critical thinking skill than on the development of skills themselves. Perhaps its greatest contribution is to the professional community of radiography educators as a result of its analysis and explication of instructional practices within that community.

Future Research

This study does not reveal the cause of the particular differences. Do they exist somewhat by accident as a result of faculty hiring practices? Are they impacted by the larger institutional culture? How much influence and responsibility does the program director have on the focus of his/her program? As well, it is not clear how relevant this particular finding would be to disciplines with less structured curricula.

Nonetheless, the question of how to create a program culture that supports critical thinking is worth further exploration. A design that provides a larger number of student participants would enable the potential impact of such a culture to be more clear.

In addition to this general finding, the impact of individual student disposition on student work, particularly writing and speaking, is of interest. In a small subset of study participants, the papers and oral presentations demonstrating the greatest amount of critical thinking were produced by the student with the highest disposition, but with lower skill. With only three students in the group, this study can only suggest that this might be worth further exploration. Does disposition have a greater impact on student use of critical thinking than skill? If so, should attention be paid to developing disposition rather than skill? Are there some dispositions that are more critical than others?

This study demonstrated greater differences in disposition among the sites than it did in the skill area, particularly in the dispositions of Confidence, Systematicity and

Maturity. The dispositions of Systematicity and Maturity require further explanation. Systematicity concentrates on an organized and focused approach to working with complex issues that is thorough in its search for relevant information. Why were students at Site C more likely to present this disposition that those at the other two sites? This question cannot be answered by this current study, nor can the related question, "Why were students at Site C less likely to present the disposition of Maturity?" This disposition indicates an individual's comfort with uncertainty, willingness to suspend judgment and allow that some situations are ill structured and context-dependent. Finally, why were students at Site A less confident in their own abilities to think critically? Could it be because they did not have much opportunity to practice?

Aside from these particular dispositions, a more specific investigation of how to develop CT disposition in general would expand on the findings of this study. It is possible that the learning environment at Site C positively impacted most disposition scales. What are the specific features of that environment that fostered critical thinking development?

As an exploratory study, these questions related to disposition development represent the results of the study in that they provide direction for future research. The finding that dispositions are perhaps more impacted by a culture supportive of critical thinking was a surprise to me. I entered the study with an unstated, and perhaps unrecognized, interest in skill development, but discovered that the best practices suggested in the critical thinking literature may have a greater impact on disposition than on those skills.

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Appendix A

Skills and Dispositions of the APA Consensus Definition

Table A1

Critical Thinking Skills

Category	Brief Description
Interpretation	Comprehend and express meaning or significance of a wide variety of experiences, situations, data, events.
Analysis	Identify intended and actual inferential relationships among statements, questions, concepts, descriptions
Evaluation	Assess credibility of statements; Assess logical strength of relationships among statements.
Inference	Identify and secure elements needed to draw reasonable conclusions; Form conjectures and hypotheses; Consider relevant information.
Explanation	State results of one's reasoning and justify it; Present one's reasoning in the form of cogent arguments.
Self-regulation	Self-consciously monitor one's cognitive activities, elements used in those activities, and results deduced

Adapted from Critical Thinking: A Statement of Expert Consensus for Purposes of Educational Assessment and Instruction (P. Facione, 1990)

Table A2

Critical Thinking Dispositions

Category	Brief Description
Truthseeking	Eager to seek the truth, courageous about asking questions, honest & objective about pursuing inquiry even if the findings do not support one's interests or pre-conceived notions
Openmindedness	tolerant of divergent views with sensitivity to the possibility of one's own bias.....respects the rights of others to hold differing opinions
Analyticity	alert to potentially problematic situations, anticipating possible results or consequences and prizing the use of evidence even if the problem at hand turns out to be challenging or difficult
Systematicity	organized, orderly, focused, and diligent inquiry
Self-Confidence	level of trust one places in one's own reasoning processes
Inquisitiveness	values being well-informed, wants to know how things work, and values learning even if the immediate payoff is not directly evident
Maturity	disposed to approach problems, inquiry and decision making with a sense that some problems are ill-structured, some situations admit of more than one plausible option, and many times judgments are based on standards, contexts, and evidence which preclude certainty must be made

Appendix B

Critical Thinking Survey

INSTRUCTIONAL STRATEGIES

In answering the following question, please think about how all the courses in your program combine to provide the following experiences to students. Consider only courses within the radiography major, but include structured clinical and laboratory experiences as well as classroom experiences.

1. Please indicate how much your PROGRAM requires students to do the following:

	Not at all	A little	Moderately	A great deal
Determine which of several possible conclusions or choices of action is best supported by the evidence	☐	☐	☐	☐
Anticipate and respond to criticisms of their point of view or choice of action	☐	☐	☐	☐
Propose multiple alternatives for solving a problem	☐	☐	☐	☐
Categorize information according to a system	☐	☐	☐	☐
Explain the steps/strategies used in working through a problem or procedure	☐	☐	☐	☐
Analyze the structure of an argument	☐	☐	☐	☐
Revise work that contains factual or methodological errors and alter their position, findings or opinions if indicated	☐	☐	☐	☐
Identify where additional information is needed to support an argument or opinion	☐	☐	☐	☐
Determine if a given theoretical principle is applicable in making a decision	☐	☐	☐	☐
Interpret data from a procedure, piece of equipment or experiment	☐	☐	☐	☐
State their reasons for holding a particular point of view	☐	☐	☐	☐
Explain concepts or ideas in their own words	☐	☐	☐	☐
Write a paper arguing for a particular position or policy	☐	☐	☐	☐
Compare & contrast ideas, concepts or statements	☐	☐	☐	☐
Review their decision-making processes to look for errors in reasoning or fact	☐	☐	☐	☐
Agree/disagree with a claim based on the presence & credibility of the supporting evidence	☐	☐	☐	☐
Identify if any claims are being made and supported in a text	☐	☐	☐	☐

DEMOGRAPHIC INFORMATION

2. Program code: _ _ _ _

3. Is your program JRCERT accredited?

☐ Yes ☐ No

4. What is the total number of radiologic science courses required in your curriculum?

5. What is the total number of credit or clock hours devoted to radiologic sciences subjects in your program?

6. What level of education do graduates of your program complete before qualifying for the ARRT examination?

☐ Certificate
☐ Associate degree
☐ Baccalaureate degree

7. What level of education do students generally complete before leaving your institution?

☐ Certificate
☐ Associate degree
☐ Baccalaureate degree

8. Do you use SAT/ACT scores as an admission criterion?

☐ Yes ☐ No (skip to question 10)

9. What was the average combined SAT or composite ACT score for the class of students that will graduate from your program in 2002? *Skip to question 11.*

10. Are enrolled students more likely to have graduated from high school in the top:

- ☐ half of their class
- ☐ 25% of their class
- ☐ 10% of their class
- ☐ Other _____

11. How many students do you expect to graduate from your program this year?

12. When will students graduate from your program in 2002? Please provide the month and date.

13. How many faculty members (full-time or part-time) teach in the radiography program?

14. What is the average class size in your program?

15. What was your program's mean score on the ARRT exam in 2001?

Thank you very much for completing this survey. If you have questions about the survey or your participation, feel free to contact me.

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(802) 860-2728 (work)
lykkegrace@msn.com

Are you interested in having your program participate in follow-up research as a case study site?

☐ Yes ☐ No

If you would like to receive the results of this survey, please check the box below.

☐ please send me the report of survey results

Appendix C

Interview Protocol

Interview Protocol for Program Directors

- How does your program define critical thinking?
    - What are your program's goals?
    - How did you describe this area in your last self-study?
    - Relation with decision-making or problem solving?
- How was this definition developed?
    - How were your program goals developed?
- How do students find out about the program's goals for critical thinking development?
- How important are these goals in relation to other program goals (on a scale of 1-5, with 1 being most important)? Probe other, more important goals.
- Is there anything in this program that limits or fosters the development of students' critical thinking?
    - Is there anything else?
- Is there anything at this institution that limits or fosters the development of students' critical thinking?
    - Is there anything else?
- How have you and your faculty planned for critical thinking instruction and assessment?
    - What process was/is used?
    - Who was involved?

  - What resources were helpful?
- How have you prepared yourselves to provide instruction in this area?
  - Have you studied critical thinking, attended workshops, consulted with colleagues?
- Which courses in the program specifically address critical thinking instruction?
  - Which one(s) has(ve) the greatest impact?
  - Do any of the courses include modules or units that directly instruct for critical thinking skills?
- Do any courses outside the major also focus on critical thinking?
- Are clinical experiences structured to provide for development of critical thinking skills? If so, how?
- How do you assess critical thinking skills? Do you assess the affective elements of critical thinking? If yes, how?

Program Documents To Collect/Review

- Last Self Study
- Program Marketing Materials
- Program's Student or Faculty Handbook
- Curriculum Outline/Description
- Clinical Course Outlines (if they do not have a faculty rep.)
- Clinical Evaluation Plan

Interview Protocol For Faculty—Program Level

- What are the program's goals with respect to critical thinking? How important are these goals in relation to other goals (on a scale of 1-5 with1 being most important? Probe other, more important goals.
- How do students find out about these goals?
- Is there anything in this program that limits or fosters the development of students' critical thinking?
    - Is there anything else?
- Is there anything at this institution that limits or fosters the development of students' critical thinking?
    - Is there anything else?
- How have you prepared yourself to provide instruction in this area?
    - Have you studied critical thinking, attended workshops, consulted with colleagues?
- Which courses in the program specifically address critical thinking instruction? Which one(s) has(ve) the greatest impact? Do any of the courses include modules or units that directly instruct for critical thinking skills?
- Do any courses outside the major also focus on critical thinking?
- Are clinical experiences structured to provide for development of critical thinking skills? If so, how?
- How does the program assess critical thinking skills? Does it assess the affective elements of critical thinking? If yes, how?
- Complete program questionnaire.

Interview Protocol For Faculty—Course Level

- What are the goals and objectives for this course?
- How do you address critical thinking in this course? What instructional activities used in this course require students to use critical thinking?
- Provide examples of CT activities and ask: "Do you do anything similar to these in your course?" If yes, describe and ID time on task.
- Which activity used in this course is most effective in getting students to demonstrate their critical thinking abilities and dispositions? What makes it successful? What can cause it to fail?
- Which activity used in this course is least effective in getting students to demonstrate their critical thinking abilities and dispositions? What makes it fail? What could make it more successful?

Course Documents To Collect/Review

- Course syllabus
- Sample activities
- Most/least successful activities descriptions (what goes to students)
- Assessment tools

Student Focus Group Protocol

- What are the program's goals with respect to critical thinking? How do you find out about these goals? How important are these goals in relation to other program goals?
- Is there anything in this program that limits or fosters the development of your critical thinking?

- Is there anything at this institution that limits or fosters the development of your critical thinking?
- What types of assignments or in-class activities do faculty use to develop your critical thinking?
- What works the best to make you think critically? Why do you say that? What makes it work? What can make it fail?
- What doesn't work well to make you think critically? Why do you say that?
- Do any courses outside the major also focus on critical thinking?
- Are clinical experiences structured to provide for development of critical thinking skills? If so, how?

Appendix D

CT Activity Prompts

1. Describe a clinical experience that represents a given principle.
2. Perform a retake analysis that sorts discarded films by error type.
3. Recognize and describe a challenging radiographic examination.
4. Interpret graphs and/or curves such as H&D curves, cell survival curves, control charts, etc.
5. Interpret the significance of non-verbal expressions presented by the patient during a radiographic examination.
6. Take an oral history from a patient and then report that history to the radiologist using your own words while retaining accuracy.
7. Select an example that would help a fellow student to understand a particular theory.
8. Describe how two patient situations differ from one another in their use of a theoretical construct.
9. Compare and contrast two different approaches to producing a given radiograph (e.g. grid versus non-grid approach to cervical spine radiography).
10. Given a complex problem for technique adaptation, break the problem down into its component parts and connections between the parts.
11. Read professionally related editorials and determine if the author is expressing a claim that is supported by reasons.
12. Read professional articles and describe the structure of the argument made by the author (main conclusion, evidence and reasons supporting the conclusion, etc.).

13. Assess the relevancy of elements of the ASRT code of ethics in a patient scenario.
14. Evaluate professional writings (textbooks, articles, etc.) to determine if the claims made are likely to be true.
15. Determine if various members of the health care team are credible sources of specific information used in determining the appropriate course of action in a patient scenario.
16. Critique a classmate's explanation of his/her approach to a particular patient scenario.
17. Determine when additional information is needed in order to more confidently proceed with a given approach to a radiographic examination.
18. Project the anticipated (desired & unavoidable) outcomes of suggested technical changes in order to determine the appropriateness of that course of action.
19. Determine what evidence would be needed to prove a given theoretical relationship (e.g. mAs effect on density) and develop a plan for obtaining this evidence.
20. Design an experiment that would provide evidence in support of the theory of mAs effect on density.
21. Given a suggested approach for dealing with a particular patient, determine what information is provided in support of that approach and how to obtain any missing information that would help to determine if the approach is the best one.
22. Suggest a variety of ways to correct a given image quality problem (e.g. density, contrast), etc.

23. Given a set of technical factor changes, hypothesize how the resulting radiographic appearance will change.
24. Predict the intended and unintended consequences of a decision not to report an instance of cheating by a classmate.
25. Consider the data gathered from a quality control test of linearity and determine whether corrective actions are needed.
26. Make a decision about whether or not to use non-ionic contrast media on a routine basis after consideration of evidence and informed opinion on both sides.
27. Write a proposal that suggests a change in an imaging protocol or purchase of a new imaging accessory device (such as a compensating filter).
28. State your reasons for choosing to perform an examination with an atypical protocol (e.g. non-grid technique for a hip examination).
29. Report on the results of an experiment that gathered density data as a result of kVp changes.
30. Critique radiographic film quality and express your judgments and reasons.
31. Explain the process by which a particular technical problem was solved in order to examine the process for adequacy.
32. Justify your choice of a non-standard approach to patient positioning.
33. Debate the value of using breast shielding on all female patients from both sides of the argument.
34. Consider the design of an experiment to determine if results were possibly due to procedural errors.

35. Reflect on the beliefs/values/assumptions underlying one's decisions about a controversial issue such as limited radiographic exams on pregnant patients.
36. Rewrite experiments or papers as a result of self-analysis of the work to correct errors in fact or reasoning.
37. Reflect on one's strong reaction to a patient situation in order to consider the beliefs, values, reasoning or assumptions that were the basis for the reaction.

Appendix E
Sample Transcription Matrix

Definition of Critical Thinking

Site A	Site B	Site C
I want them to be able to have a clue if there is such a thing as pathology going on in the patient and if they have – if it's going to be something they're going to have to compensate for technically	delving into it by the who, the what, the where, the whys	*IS creativity part of the critical thinking or is it something separate?* I think its separate. But related.... SO I think the creativity is almost like a side effect. Or maybe it's the driving force, ... Good question. Because if you're going to think about something critically, you've got to be creative. If you're going to think about it in a new way, pull pieces from
think about what they're doing	apply, hopefully, those higher level skills that they're learning to the clinical site	looking for different answers to a solution to a problem
what to do when things aren't exactly what's in the book	this is why we did this, how we did this, this is why I apply it, this may work in this situation, or I can do it over here	reformulate what it was explained by me in the form of a question,
like when we're going over films or the students are actually doing the positioning with the patients that they're learning how to think about what they're doing and be able to apply what they learned in class to the things that they're doing in clinic	Along with those questions, I try to make sense of it all	anticipate the radiologist need.
what's wrong with this picture	explain to them the whys, which will make them more valuable as technologists. And will make them be technologists and not just someone from the street that came into a department to work and didn't know what they were talking about, didn't know what was going on.	look at a request and asking why they are requesting this.

Site A	Site B	Site C
being able to apply things like we were discussing	be able to have some kind of a method where they can, after being educated in all these factors, be able to make decisions where they can set up techniques and be able to know what the basic technique involved – what it does, and how they can correct it.	And what am I going to do next.
You have to be able to apply all these things whenever you're in the clinic.	What are the basics in x-ray – what do you do to be able to change them, to manipulate them, to be able to get a good radiograph and if you did get a bad radiograph, how to correct it.	Critical thinking, to me, is more working on the clinical aspect more than academic
about the different aspects of the patient and how that they have to be ...every patient is different and you're going to have to adjust how you deal with every patient differently	can apply that to the field when they get through	to look at the patients condition—look at why they are there—to serve the patient and from there they can see what is it is I can do to make things out of the norm to help the patient
or if that person says this to me or you know, you always have these little plans in your head. You need to have a plan. You need to know what your options are	they're having to use what they learn in the classroom, they're having to demonstrate it, they're having to perform many functions at one time	And I teach them how to use the basic positioning skill that we teach them here and do more of the variance
How did you decide to do this? How could you have done it better?	we do the film critiquing	Is it taken AP or PA and explain to us why you say PA.
can improvise when necessary	You have to know why you do what you do, when to do it, how you get creative or how you need to manipulate or adapt what you've learned that's basic positioning.	Is it taken AP or PA and explain to us why you say PA.

Site A	Site B	Site C
It's not like you have to think about it – you have a formula – you plug in the numbers – you come up with an answer. I don't feel that's critical thinking. It's problem solving, but it's not even problem solving – it's not like in the hospital where you have a problem and you solve it – you try to apply different things that you might have learned gathering information or something, problems are not critical thinking.	So hopefully I'm trying to pull on their foundational knowledge and to get them to think beyond that to go into these non-routines and how do we do these and how do we adapt these positions from the norm?	they need to substantiate their answers
There's a lot of different things that you have to think about and that you have to apply lessons that you learned at some previous patient with a new patient. It might not be exact, but it might be close enough that you can go from that point and get somewhere.	how to do your best with all the knowledge that they're giving you in patient care,	there's no right or wrong answers so they have to come up with their explanation.
whenever we start talking about density and contrast relationships where we start looking at how they that they actually work. So, I want to get them a little better idea of how that these things all relate to each other.	apply what they teaching in the classroom in your clinical site... if you encounter a situation or something, you can deal with it	So it is their job as our students to evaluate what is it that we teach that is correct and what is it that they been done that is wrong
that they all relate somehow together and all of these things have to be considered when you're putting things together	apply in the clinicals	we teach the way supposed to know when they go out there and see nobody is washing hands. So they need to know why it is they are not, or is it necessary for them to wash hands. And why is it that they need to follow what is been done or not to.
So, I really think that here we're getting more into critical thinking where they're having to actually think about a patient and what they're options are when they're taking x-rays.		Evaluate how it is done and so forth

Appendix F

Coding Schema

Category	Code				
Definition	Adapt	Evaluate/Film Critique	Relate/compare/ analyze		
	Apply	Justify	Synthesize		
	Creative	Options	Troubleshoot		
	Decision-Making	Questioning			
Activities	**Student**	**Teacher**	**Evidence**	**Cognitive**	**CT Process**
	Brainstorm	Analogy	Group	Adapt	Inference
	CE seminar	Controversy	Oral	Analyze	Analysis
	Clincal	Modeling	Performance	Apply	Interpretation
	Experiment	Negative Example	Visual	Create	Inference
	Film Critique	Questioning	Written	Decision	Evaluation
	Graph	Questioning - Guiding		Evaluate	Explanation
	Project	Questioning - Probing		Interpret	Self-Regulation
	Questions	Story		Justify	
	Reading			Options	
	Research			Predict	
	Scenario			Select	
	Story			Summarize	
				Synthesize	
				Troubleshoot	

Strategy	Group
	Instructor Delivery
	Activity Design
	Instructor Characteristics
	Classroom Environment
	Motivation
Disposition	Truthseeking
	Openmindedness
	Analyticity
	Systematicity
	CT Self-Confidence
	Inquisitiveness
	Maturity

Appendix G
Skills and Dispositions Correlations

	Truth	Open	Anal	Syste m	Conf	Inq	Mat	Disp Total	Skill Total	Anal	Inf	Eval	Ind	Ded
Truth	1.00	.036	-.036	.194	.131	-.085	.614**	.492*	.301	.310	.200	.230	.279	.245
Open		1.00	.240	.158	.125	.658**	.088	.591**	,184	,069	.085	.272	.254	.091
Anal			1.00	.502*	.622**	.137	.074	.634**	.299	.470*	.202	.080	.373	.173
Syst				1.00	.201	.349	-.080	.611**	.237	.283	.159	.132	.271	.151
Conf					1.00	.160	.161	.590**	.424*	.366	.505*	.034	.263	.409*
Inq						1.00	-.173	.531**	.339	.129	.320	.271	.113	.387
Mat							1.00	.442*	.035	.187	.004	-.064	-.020	.060
Disp Total								1.00	.464*	.462*	.370	.248	.388	.385
Skill Total									1.00	.691**	.859**	.679**	.718**	.903**
Anal										1.00	.460*	.257	.608**	.555**
Inf											1.00	.317	.429*	.892**
Eval												1.00	.667**	.502*
Ind													1.00	.350
Ded														1.00

* $p<.05$ ** $p<.01$

Appendix H

Analysis of Variance for CT Skills and Dispositions

Category	Source	Sum of Squares	Df	Mean Square	F	Sig
Truthseeking Disposition	Between	32.16	2	16.08	0.34	0.71
	Within	1020.00	22	46.82		
	Total	1062.16	24			
Openmindedness Disposition	Between	38.49	2	19.24	0.46	0.64
	Within	923.68	22	41.99		
	Total	962.10	24			
Analyticity Disposition	Between	31.39	2	16.70	0.39	0.68
	Within	879.17	22	39.96		
	Total	910.56	24			
Systematicity Disposition	Between	192.32	2	96.16	2.05	0.15
	Within	1034.33	22	47.02		
	Total	1226.64	24			
CT Confidence Disposition	Between	154.54	2	77.27	2.57	0.10
	Within	661.30	22	30.06		
	Total	815.84	24			
Inquisitiveness Disposition	Between	80.41	2	40.21	0.85	0.44
	Within	1035.75	22	47.08		
	Total	1116.16	24			
Maturity Disposition	Between	49.49	2	24.75	0.49	0.62
	Within	1108.67	22	50.39		
	Total	1158.16	24			
Total Disposition	Between	1551.27	2	775.64	1.22	0.31
	Within	13946.17	22	633.92		
	Total	15497.44	24			
Total Skill	Between	4.42	2	2.21	0.14	0.87
	Within	339.74	22	15.44		
	Total	344.16	24			
Analysis Skill	Between	0.893	2	0.45	0.29	0.75
	Within	33.67	22	1.53		
	Total	34.56	24			
Inference Skill	Between	8.46	2	4.23	0.86	0.44
	Within	108.5	22	4.93		
	Total	116.96	24			
Evaluation Skill	Between	1.49	2	0.74	0.29	0.75
	Within	57.08	22	2.59		
	Total	58.56	24			
Induction Skill	Between	1.21	2	0.61	0.19	0.83
	Within	70.95	22	3.23		
	Total	72.16	24			
Deduction Skill	Between	5.41	2	2.70	0.32	0.73
	Within	184.59	22	8.39		
	Total	190.00	24			