Effectiveness of Two Methods for Teaching Critical Thinking to Communication Sciences and Disorders Undergraduates

Efficacité de deux méthodes d'enseignement pour développer l'esprit critique des étudiants inscrits dans un programme de premier cycle en orthophonie

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Abstract

The purpose of this study was to evaluate the effectiveness of two methods for teaching critical thinking skills to communication sciences and disorders students. It was hypothesized that a short course of critical thinking training would result in improved student scores on critical thinking assessments, and that students taught using a mixed instruction method would exhibit greater improvement in their critical thinking skills. Pre- and post-test critical thinking assessments were compared for students who completed 10 weeks of critical thinking instruction. The students were instructed using either (a) a mix of direct instruction on critical thinking concepts along with problem-based learning communication sciences and disorders examples or (b) infused problem-based learning critical thinking instruction with communication sciences and disorders based problems. The pretests and posttests consisted of a general and content specific critical thinking assessment. All of the students exhibited improved scores on both critical thinking measures. In addition, the students who received the mixed instruction method exhibited greater improvements. The greatest improvements for all students occurred for the trained critical thinking skills. These results indicate that both mixed and infused instruction can be effective in teaching students critical thinking skills; however, the mixed instruction was more effective.

Abrégé

L'objectif de cette étude était d'évaluer l'efficacité de deux méthodes d'enseignement pour développer l'esprit critique des étudiants inscrits dans un programme d'orthophonie. Les auteurs ont avancé l'hypothèse que l'ajout d'un bref cours sur des concepts d'esprit critique permettrait d'améliorer les scores obtenus par les étudiants à des évaluations de leur esprit critique. Ceux-ci ont également suggéré qu'une plus grande amélioration de l'esprit critique serait observée chez les étudiants inscrits dans un cours utilisant une méthode d'enseignement mixte. Les scores obtenus aux évaluations réalisées avant et après les 10 semaines de cours pour évaluer l'esprit critique des étudiants ont été comparés. Les cours donnés aux étudiants utilisaient soit (a) une méthode d'enseignement mixte, incluant un enseignement direct des concepts d'esprit critique et des exemples d'apprentissage par problèmes spécifiques à l'orthophonie, ou (b) une méthode où l'esprit critique était enseigné dans un contexte d'apprentissage par problèmes spécifiques à l'orthophonie. Les évaluations réalisées avant et après les 10 semaines de cours consistaient en une évaluation générale et spécifique à l'orthophonie de l'esprit critique. Les scores de tous les étudiants aux évaluations de leur esprit critique se sont améliorés. Il faut néanmoins noter que les scores des étudiants ayant reçu un enseignement mixte se sont davantage améliorés. Ajoutons également que les scores des concepts d'esprit critique ciblés dans la présente étude se sont davantage améliorés, et ce, pour tous les étudiants. Ces résultats indiquent que les deux méthodes d'enseignement investiguées dans la présente étude peuvent être efficaces pour développer l'esprit critique des étudiants. Or, la méthode d'enseignement mixte semble plus efficace.

An emphasis on evidence-based practice in the teaching and practice of communication sciences and disorders (CSD) in recent years has brought increased focus on the critical thinking (CT) skills of CSD students and professionals. For example, Finn, Brundage, and DiLollo (2016) stated that CT knowledge and skills provide a framework for quality decision making and can be considered a core competency for implementing interprofessional practice. These authors also reported that the American Speech-Language-Hearing Association recognizes that CT knowledge and skills are essential for effective clinical education. Similarly, Gunter and LeJeune (2015) explained that CSD clinicians need CT knowledge and skills in order to develop and maintain ethical practices such as the commitment to maintain and enhance professional competence, accurate representation of information, and accountability for professional standards. Essential attributes of CT, such as skepticisms and insistence on evidence to support statements, can help communication disorder professionals assess and implement the most effective treatment strategies (Finn, Bothe, & Bramlett, 2005).

To illustrate the need for CT skills in CSD clinical practice, Kamhi (2011) compared researchers in the scientific community with CSD clinicians. He contended that researchers are aware of the fallibility of scientific knowledge and the role of the scientific community in determining the reliability, validity, and importance of research findings. In contrast, he stated that most clinicians operate individually when diagnosing and treating clients and are seldom required to justify their clinical decisions to their peers. Kamhi indicated that the lack of inquiry within the clinician community lends itself to overconfidence in one's own ability and practices and a lack of recognition for the fallibility of such practices. Thus, clinicians need to be trained to question their clinical practices and to skeptically evaluate new practices. They should develop a consistent, hierarchical, data-driven approach to clinical decision making (Kamhi, 1984). Kamhi (2011) suggested that clinicians use Dollaghan's (2007) version of evidence-based practice by incorporating practice-based evidence as a means for skepticism toward their own practices and new ones. Such assessment of evidence and subsequent problem solving is a form of CT.

Finn and colleagues (Finn, 2011; Finn et al., 2016) discussed the importance of CT for the development of clinical skills in CSD students. They expressed concern that an emphasis on training CSD students to use evidence-based practices is necessary but not sufficient for these student clinicians to avoid confirmation bias and other thinking errors that can affect clinical decision making. They stated that interpretation, evaluation, and metacognition are CT skills that CSD students need in order to engage in more effective thinking about clinical practices (Finn, 2011; Finn et al., 2016). These skills are similar to the abilities reported as essential to CT in other disciplines, including analysis, evaluation, self-regulation, the ability to distinguish relevant from irrelevant information, and the ability to pose questions whose answers will help to broaden and focus understanding of an issue (Uba, 2008; Yang & Chou, 2008). This purposeful analysis requires skepticism, self-discipline, and awareness of thinking errors (Abrami et al., 2008; Finn et al., 2016; Gunter & LeJeune, 2015). Finn (2011) concluded that CT needs to be directly taught to CSD students as they are unlikely to develop the necessary thinking skills indirectly.

Critical Thinking Instruction

Student and clinician success within and beyond the classroom depends on the teaching and development of CT skills and dispositions (Semerci, 2005; Uba, 2008; Yang & Chou, 2008). However, different concepts of CT instruction result in varying curricular designs and educational approaches within and across disciplines (Thomas & Lok, 2015). Those who consider CT skills to be generic abilities that apply across different content areas state that these skills and dispositions can be taught in stand-alone courses without concern as to the content used to develop them (Royalty, 1995; Sá, West, & Stanovich, 1999). Whereas others contend that these skills are subject or content dependent and that CT skills are best learned as a component of courses centred on the students' academic interests (Halliday, 2000; Smith, 2002). A meta-analysis revealed greater effectiveness for teaching CT in a content dependent context (Abrami et al., 2015).

Abrami and colleagues (Abrami et al., 2015; Abrami et al., 2008) found that those who hold a generic skills perspective of CT tend to support explicitly teaching the underlying skills and dispositions, while those who hold a content based perspective tend to support embedding the CT skills into course content and providing implicit instruction of CT skills. From these two educational approaches come four instruction techniques: general, infused, immersed, and mixed (Abrami et al., 2015; Abrami et al., 2008; Ennis, 1989). Abrami et al. (2008) and Abrami et al. (2015) described these techniques as follows. The *general technique* involves teaching CT abilities separately from any other subject matter. When using the *infused technique*, the instructor uses familiar subject matter as the foundation for teaching CT in the context of the material and CT goals are explicitly taught. The *immersion technique* includes the same teaching structure as the infused method except that the CT goals are not explicitly taught. Finally, when using the *mixed technique*, the instructor combines the general technique with either the immersion or infused technique. Although these instruction techniques have been evaluated for other clinical fields (Choi, Lindquist, & Song, 2014; Coker, 2010; Macpherson & Owen, 2010; Oja, 2010; Prosser & Sze, 2014), assessment of the effectiveness of CT instruction techniques with CSD students is needed.

An understanding of the teaching techniques can help instructors determine how they might teach CT, but they need to appreciate some of the challenges in this instruction. For example, Thomas and Lok (2015) said that CT skills and knowledge acquisition are necessary but not sufficient for students to use evaluative reasoning and metacognition; the disposition to utilize CT knowledge and skills consistently is required. Developing these thinking skills and dispositions can appear to be a daunting task for instructors. Therefore, instructors should be aware that defining, assessing, and teaching CT skills and dispositions should be undertaken with the understanding that developing these skills and dispositions will need to be program goals over multiple courses (Wendland, Robinson, & Williams, 2015). Wendland et al. (2015) said that when students are developing and utilizing CT skills and strategies they need multiple opportunities to question the information and skills they are taught as well as encouragement to find alternative perspectives. CSD students need to recognize that a skeptical, inquisitive approach to knowledge and clinical situations will help them make better clinical decisions (Apel, 2011; Finn, 2011; Kamhi, 2011; Orlikoff, Schiavetti, & Metz, 2015).

Pedagogical Methods for Teaching Critical Thinking

Suggestions for teaching CT skills and dispositions within an embedded educational approach include pedagogical methods such as problem-based learning, team-based learning, case presentations, and a variety of mapping activities (Day & Williams, 2000; Dochy, Segers, Van den Bossche, & Gijbels, 2003; Johnstone & Otis, 2006; Leahy, Dodd, Walsh, & Murphy, 2006; Mok, Whitehill, & Dodd, 2008; Tiwari et al., 2006; West, Pomeroy, Park, Gerstenberger, & Sandoval, 2000). Meta-analyses comparing health care student outcomes from problem-based learning and traditional classrooms indicate that problem-based learning is more effective than didactic presentations in the development of psycho-motor, affective, and cognitive skills as well as better learning of clinical skills (Prosser & Sze, 2014; Shin & Kim, 2013). Although the authors of several studies have suggested the aforementioned pedagogical methods to help students develop CT, few data exist that indicate student thinking changes as a result of these methods. Thus, a need exists to empirically evaluate the effectiveness of these methods.

It is possible that problem-based learning is a more effective pedagogical method for instructing advanced students. For example, nursing and CSD student learning styles appear to develop in a manner consistent with CT skills (Elliott & Hennessey, 2001; Shin & Kim, 2013). These changes result in greater development of CT skills among graduate students after completing courses using problem-based learning than in undergraduate students who completed similar courses (Shin & Kim, 2013). Thus, a foundation of both content specific knowledge and CT skills may be needed for problem-based learning activities to be most effective, and the pedagogical method used for CT instruction may need to evolve as the students mature.

Gaps in the Current Literature

Several authors have indicated the need for CSD students to develop their CT knowledge and skills in order to effectively select and implement evidence-based practices and treatment techniques (e.g., Finn, 2011; Finn et al., 2005; Finn et al., 2016; Gunter & LeJeune, 2015; Kamhi, 2011; Orlikoff et al., 2015). Other authors have proposed pedagogical methods designed to provide students the opportunity to develop their CT knowledge and skills (e.g., Day & Williams, 2000; Dochy et al., 2003; Johnstone & Otis, 2006; Leahy et al., 2006; Mok et al., 2008; Tiwari et al., 2006; West et al., 2000). However, a need exists for evidence on the effectiveness of these pedagogical methods for the development of CT skills in CSD students. Before CSD faculty members adjust their teaching style and curriculum, they need evidence that these pedagogical methods are effective.

Objectives

As previously stated, instructors across academia and in CSD have increased interest in teaching CT skills and dispositions. However, few data are available concerning the effectiveness of teaching CT skills in CSD programs. In addition, opinions differ on the best educational approach, instructional technique, and pedagogical method for teaching these skills.

Data on the effectiveness of teaching CT skills in CSD programs are needed. In addition, a comparison of classroom instruction techniques may help guide CSD instructors to effectively teach CT skills. Thus, this study had two aims. The first aim was to determine the effectiveness of a short CT course in improving the CT skills of CSD undergraduate students. It was hypothesized that

CT instruction would positively affect the thinking skills of the CSD students. The second aim was to compare mixed CT instruction with infused CT instruction in a group of undergraduate CSD students. Both of these instruction techniques use the content dependent approach reported to be more effective for teaching CT (Abrami et al., 2015). Based on the findings of evolving thinking skills among students (Elliott & Hennessey, 2001; Shin & Kim, 2013) and the reported need for foundation CT knowledge to develop applied CT skills and dispositions (Davies, 2013), it was hypothesized that the undergraduate students taught via the mixed instruction method would exhibit greater improvement in CT skills.

Method

The Florida State University Human Subjects Committee approved the study design and the consent form on August 24, 2015, with approval number HSC # 2015.15827. The study was completed using the approved design. The study was a one-shot between groups pretest-posttest comparison.

Participants

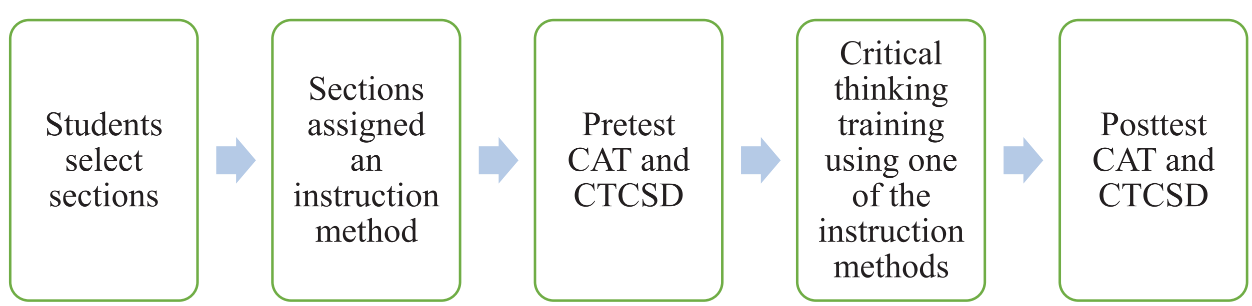
Sixty-seven undergraduate students (1 man, 66 women) aged 18–22 years who were enrolled in a mandatory CSD course served as the participants for this study. The students who participated were 67 of the 85 who had applied and been admitted to a limited access upper division CSD program that required at least a 3.3 grade point average for admission. The other 18 students opted to not participate in the study. The participating students were enrolled in four laboratory sections of a single course. The students enrolled in the sections without knowledge of the study. No attempt was made to control which students enrolled in any of the sections. Therefore, they assigned themselves to the specific sections based on their own personal criteria and the timing of when the sections reached maximum enrollment. This course is taught during the fall semester of the junior year, so the students were in their first semester of CSD undergraduate course work. Only the 85 students enrolled in the course were eligible to participate in the study. At the beginning of the semester each participant signed the approved informed consent form.

Procedures

Figure 1 shows the sequence of procedures to complete the study. As can be seen, the students selected a course section, the sections were assigned an instruction method, the pretesting was completed, the CT instruction occurred, and then the posttesting was completed.

Instruction techniques and materials. Groups were created by designating two of the sections to engage in a mixed direct and infused instruction technique and two of the sections to engage solely in an infused instruction technique. A problem-based learning pedagogical method was the infused instruction technique used for both groups. The determination of the instruction approach to use in each course section was made without any knowledge of the enrolled students. Demographic data on the students in the two instruction groups are shown in **Table 1**. In order to determine if the participants in the two instruction groups were academically equivalent, their grade point averages were compared using a *t* test. The *t* test indicated that the two groups did not differ significantly, $t(31) = 0.15$, $p > .05$. Thus, for the purpose of this study, the students in the two instruction groups were considered to be academically equivalent.

Figure 1



Flow diagram of procedures. The pre- and post-tests were the Critical-thinking Assessment Test (CAT) and Critical Thinking in Communication Sciences and Disorders (CTCSD).

Table 1

Demographic Data of Student Participants for Age, Gender, and Grade Point Average

Instruction Group	Age in Years	Gender	GPA *M* (*SD*)	GPA Range
Problem-based learning	18–21	31 women, 1 man	3.73 (0.15)	3.44–4.00
Mixed instruction	19–22	35 women	3.79 (0.18)	3.53–4.00

Note. GPA = Grade Point Average.

A designated instructor, author AB, taught the mixed instruction sections. Another instructor, author SC, taught the infused instruction sections. Both instructors were trained by the first author on the pedagogical techniques to use. The CT instruction occurred during ten 50-minute sessions—an introductory session and nine training sessions. The material and clinical cases used during the instruction were unique from those in the tests used to assess the students' CT knowledge and skills.

The topics of CT explicitly addressed during the instruction for this study included logical fallacies and thinking errors, problem solving, and evaluating causal claims. According to Facione (2015), these instructional topics fall into three of six categorical skills of critical thinking: evaluation, inferencing, and self-regulation. Examples of evaluation include analyzing the credibility of claims and the facts which support them (Facione, 2015). Examples of inferencing, according to Facione, include drawing conclusions from given information, ruling out conclusions from given information, and considering alternatives. The examples provided for self-regulation include assessing one's own methodology before committing to an answer (Facione, 2015).

The mixed instruction included presentations by the instructor and small group discussions on each of the topics during three 50-minute class sessions. Student evaluations included a set of short answer responses concerning the thinking skills and two concept maps. The concept maps depicted the student thinking on two case studies, one focused on problem solving and the other on decision making skills.

For example, the training on effective problem solving began with instruction on creating a concept map with examples and simple practice problems. Then author AB presented a clinical case issue about the Individualized Education Program of a school-aged child. The students were directed to individually write their solution to the problems in the case; then they were directed to write the thinking procedures they used to solve the problems. After that, they formed groups of two or three students and compared the strategies they used. Next, they had a full class discussion of the strengths and weaknesses of the various strategies. Then author AB presented an organization for thinking about problem solving based on the writing of Beyer (1987). The students returned to their small groups and compared their strategies to Beyer's. Then a second case was presented that involved an older person with a hearing loss. Again they wrote out how they would solve the problem followed by writing out the thinking process used in developing the solution. They discussed the second case in their small groups. Then author AB answered questions regarding the problem-solving strategies and how to develop a concept map of their problem solving for this case. Then a third case study about a post-cardiac surgery patient with a swallowing problem was presented and the students wrote out solutions to the presented problem. Each student then created a concept map of her problem-solving strategy that was submitted for a grade.

The infused instruction included three clinical cases created by the first author. The first clinical case included thinking errors by a parent and clinician for the students to explore. The students were encouraged to develop a problem-solving strategy for structuring an evaluation of the communication problem in the second clinical case. Finally, the third clinical case included a variety of professionals discussing the cause of a communication problem. The discussions of the cases were structured with times for dyad, small group, and large group discussion. The instructor was trained to reflectively respond to the students and to minimize her input to the students' developing CT skills and dispositions. At the end of each section, the groups of students submitted concept maps to represent how they conceptualized the situation. In addition, the students were encouraged to ask questions and to complete independent research to understand each clinical case.

For example, the second clinical case involved a young woman who was having difficulties singing. The case background included information about vocal demands in her work environment, her singing, and her personal life. During the first session the students read the clinical case and wrote a list of questions/issues. They were then directed to discuss their questions/issues with two or three other students in the section. The groups of students then provided questions for author SC to answer for all of the students in the section. As noted above, author SC would respond in a manner to help them focus on the problem-solving strategies they used, such as, "What was the focus of your thinking when you developed that question? Might there be another way to think about the material that could lead you to a different question?" or "Since that point might not be relevant to solving the issue, how might you approach the case to develop more relevant ideas?" In the next session, the focus tended to be on the research students had done on the topic to help them determine appropriate and relevant problem-solving strategies. In the third session the students brought their individual concept maps of how they structured the known information, what they still needed to know, and what evaluation tools and methods they would use. They shared their concept maps in small groups and discussed their similarities and differences. After author SC answered the students' questions and discussed problem solving with them, the students recreated individual concept maps and submitted them.

Critical thinking assessments. Baseline measurements of the students' CT skills were taken during the first week of class. These same assessments were repeated at the beginning of the following semester to collect post-treatment data. A 60-minute period was allotted for completing each of the CT assessments. The students finished the assessments in 45–60 minutes.

Measurements were taken using a general CT assessment, the Critical-thinking Assessment Test (CAT; Center for Assessment and Improvement of Learning, n.d.), and a content specific CT assessment, Critical Thinking in Communication Sciences and Disorders (CTCSD; Morris, Gorham-Rowan, Coston, & Scholz, 2014). The CAT contains 15 items, 14 of the items are prompts for short essay responses and one is a prompt for mathematical calculation. The 15 items assess four CT skills: evaluating and interpreting information (8 items), problem solving (8 items), creative thinking (6 items), and effective communication (9 items). Four of the items assess evaluating and interpreting information only, one item assesses problem solving only, five of the items assess two of the CT skills, and the remaining six assess three of the CT skills. Stein and Haynes (2011) reported that performance on the CAT was significantly correlated with performance on other tests of critical thinking, $r = .65$ with the California Critical Thinking Skills Test (Facione, 1990) and $r = .69$ with the Critical Think Module of the Collegiate Assessment of Academic Proficiency (ACT Inc., 2000). These findings demonstrate the content validity of the CAT. Higher education faculty members from a broad range of disciplines who score the CAT have agreed that the items on the CAT assess CT skills with a range of 80% to 100% agreement for each of the items, indicating face validity of the assessment (Stein & Haynes, 2011). These trained faculty members have a high inter-judge reliability of $r = .92$ (Stein, Haynes, & Redding, 2007). The items on the CAT exhibited high internal consistency with a Cronbach alpha of $\alpha = 0.82$ (Stein et al., 2007).

The CTCSD consists of 14 prompts for short answer responses and two prompts for mathematical calculations. **Table 2** displays the target CT skills for the items in the CAT and CTCSD. Student performance on the CTCSD has been highly correlated with performance on the CAT with $r = .793$ ($p < .01$) and on the Ennis-Weir Critical Thinking Essay Test (Ennis & Weir, 1985) with $r = .629$ ($p < .01$) indicating the content validity of the CTCSD (Morris et al., 2014). The scorers of the CTCSD had a high inter-judge reliability of $r = .95$.

The two tests have similar prompt styles and scoring systems. An example of a prompt from the CTCSD reads:

> In the late 1990s a new modality of treatment for oropharyngeal dysphagia was approved by the FDA. This treatment involves electrical stimulation of the neck muscles via surface electrodes (NMES). Speech language pathologists (SLPs) working in acute care hospitals and rehabilitation facilities have observed that 85% of their patients who received NMES as part of their post-stroke treatment exhibited improved swallow. These SLPs say that NMES is an effective tool for improving swallow function among post-stroke people with dysphagia.
>
> *Provide two alternative explanations that might explain the improvements in swallow behavior among these patients.*

These prompts were scored on the quality of the explanations and reason underlying the explanations. The scoring on the individual prompts ranged from a two-point 0–1 range for yes/no questions and mathematical

Table 2

Skills Targeted by Each Critical-Thinking Assessment Test and Critical Thinking in Communication Sciences and Disorders Assessment Item

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

Note. CAT = Critical-thinking Assessment Test; CTCSD = Critical Thinking in Communication Sciences and Disorders.

calculations to three- and four-point 0–2 and 0–3 ranges for questions like the one above that had a range of 0–3.

Analysis

Once the CT pre- and post-tests were completed, participants' responses were scored for both assessment tools. The people scoring the two assessments underwent training to develop inter- and intra-judge reliability. For a score to be counted, two scorers had to agree on the points awarded for the written response. If agreement was not reached between the first two scorers, the third scorer read and scored the test item, with the students' scores always requiring that two scorers agree on the score for every item. The faculty members who scored the CAT were trained by instructors from the Center for Assessment and Improvement of Learning, who also rescored the test for reliability. The faculty members completing the scoring only knew that the assessments were completed by CSD students and were not aware of this study. For the CTCSD, the first author trained the other two authors until they could consistently score items and report their criteria for the scoring of the responses. When necessary, the first author also served as the third scorer.

The numbering system of the student responses provided by the Center for Assessment and Improvement of Learning for the university scoring of the CAT did not provide for separating the sections of the course. Thus, the CAT scores provided information on the CT skills exhibited pre- and post-training, but separate scores were not available for the students who participated in the mixed or infused instruction sections. The CTCSD responses were identified by a participant number only so that the scorers would not know whose responses they were reading. After scores were assigned to all of the completed CTCSDs, the scores were separated between the mixed and infused instruction sections based on a digit in the participant numbers.

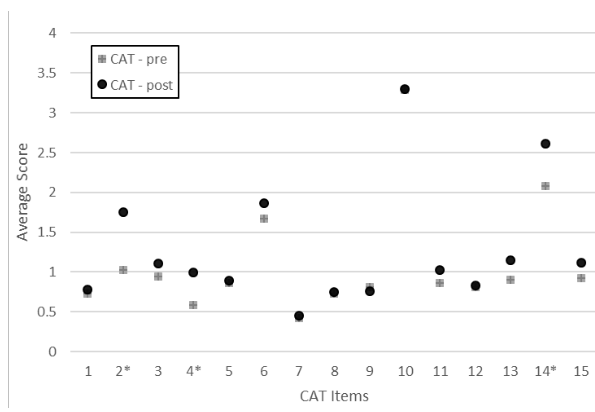
To determine any changes in the students' scores Pillai's Trace MANOVA was used. Pillai's Trace was selected because it is regarded as the most powerful and robust of the four MANOVA test statistics (Pillai, 2004). This statistic was completed as part of the SPSS repeated measure ANOVA routine (IBM Corp, 2015). The between-subjects effect of the repeated measures ANOVA was used to determine any instruction group effect.

Results

The results of the student performance on the CAT provided by the Center for Assessment and Improvement of Learning indicated that the students in both instruction groups exhibited significant overall CT skill improvement on the posttest (see **Figure 2**). The mean total score improved from 16.55 to 19.28, $p < .001$, with an effect size of .62. In addition, the Center for Assessment and Improvement of Learning reported improvement on three of the 15 assessment items (i.e., 2, 4, and 14), two of which relate to problem solving and one to evaluating and interpreting information. The average of the student scores improved from 0.59 to 0.99, $p < .01$, with an effect size of .38 for item 4, and improved from 2.08 to 2.61, $p < .05$, with an effect size of .29 for item 14. For item 2, the average of the students' scores improved from 1.03 to 1.75, $p < .001$, with an effect size of .72. The average student scores for 11 of the other 12 CAT items improved, but not significantly (see **Figure 2**).

Similarly, the students in both instruction groups exhibited an overall improvement on the posttest of the CTCSD in comparison to the pretest. As shown in **Figure 3**, the average posttest scores for all but one of the CTCSD prompts (i.e., prompt 8) was higher than the matched pretest score. In addition, the average score of the students in the infused instruction group did not change between the pretest and posttest for one prompt

Figure 2

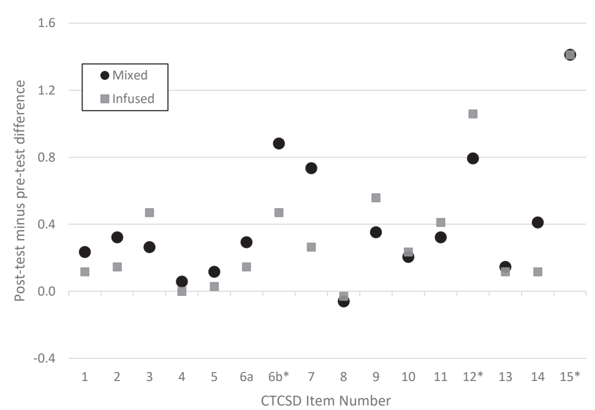


Average Critical-thinking Assessment Test scores from assessments of participants before and after the training sessions. Item with * significantly improved ($p < .05$). CAT = Critical-thinking Assessment Test.

(i.e., prompt 4). The average posttest scores on the CTCSD were significantly higher than the average pretest scores as indicated by the Pillai's Trace MANOVA, $F(1, 63) = 199.73$, $p < .01$, $\eta_p^2 = .760$. **Figure 3** shows similar results for the CAT, the student scores varied among the CTCSD questions, as shown by the Pillai's Trace MANOVA comparison across the assessment items, $F(15, 49) = 86.02$, $p < .01$, $\eta_p^2 = .963$. The students exhibited the greatest improvements on the CTCSD prompts that were associated with the content of the instruction. This finding indicates an association between participant responses to certain prompts on the CTCSD and the average score differences between the pre- and post-tests, $F(15, 49) = 11.96$, $p < .01$, $\eta_p^2 = .785$. CTCSD item 6b evaluated the students' mathematical skills. The mean on this item improved from 0.83 to 1.71 among the students in the mixed instruction group and from 0.87 to 1.39 among the students in the infused instruction group with an overall $p < .001$. Item 12 evaluated their ability to provide alternative explanations for a pattern of results. The mean on this item improved from 1.59 to 2.38 among the students in the mixed instruction group and from 0.84 to 1.97 among the students in the infused instruction group with an overall $p = .002$. Finally, item 15 evaluated their ability to explain how changes in a problem might affect the solution. The mean on this item improved from 1.11 to 2.53 among the students in the mixed instruction group and from 0.35 to 1.81 among the students in the infused instruction group with an overall $p < .001$.

Although the specific focus of the items with significant improvement on the CAT and CTCSD differed, the items assessed the students' ability to evaluate and interpret information. The exception was the improvement in mathematical skill on the CTCSD. In general, the greatest student improvements occurred for similar CT skills on both assessments.

Figure 3



Differences in average Critical Thinking in Communication Sciences and Disorders scores between the assessments of the participants before and after the training sessions for the students who had the mixed instruction and those who had the problem-based learning instruction. Item with * significantly improved ($p < .05$). CTCSD = Critical Thinking in Communication Sciences and Disorders.

Although the mean scores for both instruction groups improved on the CTCSD posttest, a between-group ANOVA comparison of the two instruction groups revealed that the average of the students' scores in the mixed instruction group exhibited more improvements than those of the students in the infused instruction group, $F(1, 63) = 13.13$, $p < .01$, $\eta_p^2 = .172$. The average pretest to posttest change for the two teaching styles can be seen in **Figure 3.** The students in the mixed instruction group exhibited greater average pretest to posttest improvement for nine of the CTCSD prompts (i.e., 1, 2, 4, 5, 6a, 6b, 7, 13, and 14). The change was the same for one prompt (i.e., prompt 15), and the students in the infused instruction group exhibited greater average improvements for six of the prompts (i.e., 3, 8, 9, 10, 11, and 12). In addition to exhibiting greater improvement for more of the prompts, the students' average scores in the mixed instruction group also showed greater improvement for their individual CTCSD prompt scores ($M = 0.41$) than the students in the infused instruction group ($M = 0.35$).

The effect sizes for both the main effects as well as the interaction effect were in the high range (Cohen, 1988). This finding indicates that all of the statistical effects explain a high proportion of the observed variability in the data.

Discussion

Effectiveness of Critical Thinking Training

The findings from this study indicate that a 10-week course utilizing either a mixed or infused instruction technique can be effective in improving CT skills in CSD students. These results are consistent with the findings from other higher education disciplines of statistically significant CT improvements after instruction using a problem-based learning pedagogical method (Butchart et al., 2009; Casotti, Rieser-Danner, & Knabb, 2008; Lombard, 2008; Reynolds & Hancock, 2010).

The responses by the students in both instruction groups indicated a modest improvement in selected CT skills from the instruction, which corresponds with previous reports (e.g., Abrami et al., 2015). These results were found in the outcomes of both the general knowledge CAT and the content specific CTCSD. The students exhibited improvements for the assessment items that evaluated the CT skills that were trained during the semester. In contrast, their posttest scores for the other items on both tests improved slightly, but were similar to the pretest scores. Since the training in both groups targeted similar CT skills, the other items could be regarded as control items. Improvements in the targeted skill items may indicate the effectiveness of the training methods in teaching CT skills to these students. In addition, the contrast between the trained and untrained assessment items reveals that the higher scores were more content specific than general learning or experience would explain. However, the possibility exists that the improvements reflected the acquisition of skills for responding to specific prompts. Thus, the improvements may not indicate a change in generic thinking skills, but specific content knowledge.

As noted previously, the topics of CT explicitly addressed during the instruction for this study included logical fallacies and thinking errors, problem solving, and evaluating causal claims. These topics are included in three of the six categorical CT skills that Facione (2015) listed: evaluation, inferencing, and self-regulation.

These CT skills align with the target skills associated with the CTCSD prompts with the greatest posttest improvement—6b: use basic mathematical skills to help solve a real-world problem (self-regulation), 7: provide relevant alternative interpretations for a specific set of results (inferencing), 12: provide alternative explanations for a pattern of results that has many possible causes (inferencing, evaluation), and 15: explain how changes in a real-world problem situation might affect the solution (inferencing). These findings suggest that the CT instruction was associated with improvements in these students' CT assessment scores. This finding concurs with previous research on the effectiveness of teaching CT skills (Abrami et al., 2015; Abrami et al., 2008; Glaser, 1941).

The exception to this pattern was the improvement in mathematical skills exhibited by the students on the CTCSD posttest. This difference may have been a result of increased student comfort with the assessment and reduced test related anxiety.

Effectiveness of Instruction Technique

The results of the instruction technique comparison in this study agree with the previous reports (Abrami et al., 2015; Abrami et al., 2008) that the mixed method of instruction is an effective method for initial teaching of CT skills. These findings are similar to those of Stoiber (1991) who found that direct instruction in the use of reflective thinking for solving discipline specific problems resulted in improved evaluation of information and problem-solving skills. These results also indicate that the explicit CT instruction in this study appears to be more effective in teaching these undergraduate CSD students CT skills than the implicit instruction method used with CSD students (Grillo, Koenig, Gunter, & Kim, 2015). These authors reported limited improvements in CT skills after problem-based learning instruction. In contrast to Grillo et al.'s (2015) findings, results from other clinical fields also indicate that short-term problem-based learning instruction is associated with improved CT skills (Choi et al., 2014; Coker, 2010; Macpherson & Owen, 2010; Oja, 2010). More research is needed on the effectiveness of all CT pedagogical methods when teaching CSD students. Future studies can use the examples of undergraduate and graduate CSD courses provided by Finn et al. (2016). These authors also reported a variety of pedagogical methods designed for CSD students to improve CT skills (Finn et al., 2016).

As previously noted, an infused or immersed technique of problem-based learning instruction without direct CT instruction may not be the best method when teaching new content (Butchart et al., 2009; Casotti et al., 2008; Lombard, 2008; Reynolds & Hancock, 2010). Participants in this study, like those in other studies that successfully used problem-based learning (e.g., Butchart et al., 2009), expressed concern about their difficulties in determining what was expected of them and the lack of confidence they felt when completing the concept maps.

Limitations

The participants in this study may have been influenced by outside factors, such as the CSD content in other courses. At the beginning of the study they had no formal CSD training and may have only known of CSD treatments through family members or generally available internet/media information. This particular effect may be seen in the improvement of CTCSD item 15 whose target skill was to explain how changes in a real-world problem might affect the solution. Item 15 centred on hearing loss and amplification, and at the time of posttest administration the participants were completing the second week of an Introduction to Audiology course. The content that the students learned in the other course may have informed their answers more than the CT instruction. A time-series type of study with a sequence of CT skills taught over a series of semesters could be a way to more thoroughly evaluate the effectiveness of teaching CT skills.

Another possible issue with this study could be the competence of the instructors. The improvements on the prompts that addressed inferencing skills with little change for the prompts that addressed interpretation and analysis could imply that the instruction was varied in quality as a result of the instructor's own CT strengths or weaknesses. Although the instructors were trained on the methodology used for this study, no assessment was given to gauge their skills. Previous work indicates that instructor quality affects CT instruction effectiveness (Abrami et al., 2008).

A third limitation was that two of the study's authors (i.e., AB and SC) were both instructors and scorers of the CTCSD. Although the CTCSD responses were identified only by a participant number, AB and SC knew the numbering scheme and could identify the participant's section. However, as reported above, AB and SC exhibited high inter-judge reliability. Thus, they did not exhibit a tendency to score the participants from their sections higher than they scored the other participants. In the future, it will be better to have scorers who have no other involvement with the study and do not know the participants' training group.

Finally, since the CAT and CTCSD have a similar structure they may assess the same aspects of CT skills. Pairing these two assessments with an assessment that has a different structure, such as the California Critical Thinking Skills Test, might improve the validity of the findings. In addition, the lack of CAT data that could separate the CT instruction methods limits the information on differences in student outcomes. Future studies should provide a method for separating the data. Another suggestion is that future studies involving CT assessment of CSD students should include a qualitative analysis of student opinions concerning the CT training and assessment.

Critical Thinking and Communication Sciences and Disorders Training

Further research is required to demonstrate the effectiveness of CT instruction in CSD programs and to more clearly define the relationship between specific methods of CT instruction and improved CT skills among CSD students. Such studies could include a longer course of training and use of other pedagogical techniques.

Critical thinking skills are vital to speech-language pathologists and audiologists as they provide a quality thinking structure to assist in the decision making and problem solving involved in the evaluation and treatment of clients (Finn et al., 2005; Gunter & LeJeune, 2015). As Orlikoff et al. (2015) stated, CT is a fundamental aspect of clinical practice in communication disorders. By working to improve these thinking skills and dispositions through targeted classroom activities, students can hone their ability to reevaluate their thought processes and relevant information in order to solve a clinical problem. By doing so, they can be better prepared to make accurate diagnoses and create appropriate treatment plans. The improvement of these skills should help these students become clinicians who will recognize the need to be current in their understanding of communication disorders as well as the evaluation and treatment of the disorders. With these thinking skills and attributes they should be willing and able to work and re-work complex clinical problems until they find the most functional solutions for their clients.

The pedagogical implications from the current and previous studies indicate a sequence of instruction to help students develop their CT skills and dispositions (Bailin & Battersby, 2015; Byrnes & Dunbar, 2014; Shin & Kim, 2013; Wendland et al., 2015). These results indicate that a mixed instruction method may be the better method for an initial course in which students directly learn CT skills. Future research may reveal that the problem-based learning pedagogical approach may be more effective in a subsequent course to help the students develop their CT skills into CT dispositions. In addition to the sequencing of CT courses for better student learning, instructors should be aware that students often have difficulty grasping the purpose of problem-based learning activities. Therefore, the instructor needs to invest time explaining how problem-based learning works in order to increase the effectiveness of the course (Prosser & Sze, 2014). In addition, student response to the pedagogical techniques needs to be known. Future studies should ask the students for their opinions of the techniques and determine (a) what they felt they learned, (b) if they found benefit to the material, and (c) if they found benefit to the pedagogical techniques.

In conclusion, the pursuit to advance CT instruction for CSD students has achieved significant notice but needs wider implementation. The present and past studies indicate teaching strategies and techniques associated with improved CT assessment scores. As the need for these skills have been established, routine implementation of CT instruction in CSD programs is the logical next step (Finn, 2011). The current study provides evaluation of two teaching strategies for implementing Finn's suggestion. Further studies of CT teaching strategies in CSD courses should provide improved understanding of the best methods to improve thinking strategies among CSD students. Improvements in thinking strategies can be a tool for the increased scientific and skeptical thinking that Kamhi (2011) suggested for improved clinical effectiveness.

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