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# Using the Science Writing Heuristic to Improve Critical Thinking Skills for Fifth Grade Black Girls

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*Critical thinking skills are invaluable for the process of asking reasonable questions and making rational decisions. Science classrooms are an excellent place to develop critical thinking skills for all students. Unfortunately, Black girls are often left out from opportunities to be in good science classrooms and/or exposed to effective science instruction. This marginalization diminishes their access to critical thinking skill development. Because Black girls, for a variety of reasons are not participating in science education they are missing the opportunity to develop, exercise and enhance their critical thinking skills. One approach that has shown promising effectiveness in developing critical thinking skills is the Science Writing Heuristic (SWH). The SWH approach helps students develop skills in the process of asking questions, making claims, and providing evidence through argument-based inquiry. The current study examines the impact of the SWH on critical thinking skills growth of 5th grade Black girls in a midwestern state. Results suggest practical implications for using the SWH to develop critical thinking skills for Black girls over the course of a school year. Statistical significance was found within the treatment group in two to subtest of the critical thinking measure when comparing pre- and post-test results. Practical analysis via effect size statistics is also discussed.*

*Keywords:* Black Girls, Science, Critical Thinking, Argument-Based Inquiry

## Introduction

Despite the multitude of imposed barriers past and present, Black women have made substantial advancements in educational attainment in science. According to the National Center for Education Statistics (NCES, 2015), Black women comprised 2.9% of those completing degrees in STEM. While that number may seem low that is an increase to the nearly non-existent presence of Black women in STEM in the 1970s. There has been no evidence to show disparities in Black woman's scientific aptitude or capabilities in comparison to other demographic groups. Black girls bring unique perspectives, expressions, and awareness to science (King & Pringle, 2019). Their voices are marginalized by systemic issues within the science and educational structures. The low numbers of Black women's participation in STEM lies in the discriminatory socially constructed obstacles that serve as unnecessary barriers for Black women's entry into STEM.

Historically, the marginalization of populations in science has been par for the course. Who has access to science and good science instruction has mostly been a construct of privilege and false narratives regarding predetermined ability. Gender, race, and ability status has contributed to lack of opportunities to participate in science (National Science Foundation [NSF], 2019). When considered together, these factors influence perceptions of science ability, which can negatively influence teaching behaviors, and finally results in a "cooling out" of science interest by marginalized groups (Hanson, 2008). This can be doubly problematic for Black females who are denied appropriate opportunities in science which can be linked to systematic issues that are prevalent in society.

In the United States, Black women are often the victims of consistent bouts with economic and social oppression. Systematic poverty and oppression when coupled with lack of opportunity and access have suppressed Blacks girls' strides in early STEM education. While these institutionalized practices of discrimination have had crippling results, they have not been the end of Black women's efforts to persist. In the face of obstacles Black women continue to push ahead. Despite their contributions to the field from top to bottom, Black women in science are overlooked. They are often less likely to obtain coveted research grants, NSF fellowships, gifted education placements in early grades, and out of school STEM learning opportunities (Collins et al., 2020; Ginther et al., 2011). When given equal opportunity and access, Black women are equal to and surpass their counterparts (McDaniel, 2011). These factors can affect how Black girls perform on standardized science measures and gives the impression that they have lower aptitude in science. Based on the latest 4$^{th}$ grade science scores from the National Assessment of Education Progress (NAEP), Black girls scored significantly lower than most comparison groups, including White males and females, Asian males and females, and Hispanic males and females (NCES, 2015). Due to these results, the probability of being overlooked and further marginalized is high. This marginalization in science can extend to diminished opportunities to develop critical thinking skills as well.

The National Resource Council (NRC, 2012) connects science literacy and critical thinking by stating that "critical thinking is required, whether in developing and refining an idea (an explanation or a design) or in conducting an investigation" (p. 46). In a review of the role of critical thinking and science education, Santos (2017) suggested that research supports the notion of a strong relationship between science education and critical thinking. These connections included using critical thinking for the application of science knowledge (Yacoubian, 2015), the ability to question (Demir, 2015), the skill to defend one's ideas (Osborne, 2014), and problem solving (Vieira et al., 2011). As it relates to elementary students, Vieira and Tenreiro-Vieira (2016) found that science-based learning experiences greatly influenced significant outcomes in critical thinking. The suggestions from previous researchers provide evidence that access to high quality science instruction is massively important. However, there is also supporting evidence that access to science is still at a premium for marginalized groups [e.g., Black girls] (Hanson, 2008). This lack of access may be exacerbated if marginalized students are perceived as academically struggling. Consequently, if female students of color are not given opportunities to participate in science classrooms, they are missing out on opportunities to develop much needed critical thinking skills specific to science-related content.

**Developing Critical Thinking Skills**

Critical thinking is a cognitive activity, associated with using the mind. Learning to think in critically analytical and evaluative ways means using mental processes such as attention, categorization, selection, and judgment. Ennis (1987) identified a range of dispositions and abilities associated with critical thinking. These focused on the ability to reflect skeptically and the ability to think in a reasoned way.

Although different definitions for critical thinking have been proposed, the definition most widely accepted was developed by the Delphi Committee, which identified six skills, 16 subskills, and 19 dispositions associated with critical thinking (Facione, 1990). These skills and dispositions provide a complex normative framework for understanding and assessing the qualities of human cognition. The obvious and primary appeal of the skills discourse involves its transfer between contexts. Perkins and Salomon (1988) reflect the skills approach by claiming, "Students often fail to apply knowledge and skills learned in one context to other situations. With well-designed instruction we can increase the likelihood that they will" (p. 22).

Critical thinking is a complex process of deliberation that involves a wide range of skills and attitudes (Miri et al., 2007). Critical thinking includes identifying other people's positions, arguments, and conclusions; evaluating the evidence of alternative points of view; weighing opposing arguments and evidence fairly; and being able to read between the lines. It also includes identifying false or unfair assumptions; recognizing techniques used to make certain positions more appealing than others, such as false logic and persuasive devices; reflecting on issues in a structured way. When logic and insight are brought to bear, drawing conclusions about whether arguments are valid and justifiable is an achievable goal. This allows one to synthesize and form a new position and thus presenting a point of view in a structured, clear, well-reasoned way that convinces others (Cottrell, 2017).

Critical thinking is associated with reasoning or rational thought. Our brains like to assume they are right. Research has shown that we are wired to make quick assumptions; to take the easiest route to jump to the most likely conclusion rather than to slow down and examine our reasoning (Kahneman, 2011). Skepticism in critical thinking means holding open the possibility (doubt) that what you know at any given time may be only part of the picture. Some people seem to be more naturally skeptical while others seem to be more trusting. These differences may be based on past experiences or personality traits. Critical thinking, however, is not about natural traits or personality, but rather about using structured approaches to help build trust in the probability of an outcome, and/or use doubt constructively. The skills related to critical thinking need to be developed for all students, but for Black girls who have been traditionally marginalized in science learning and thus critical thinking development, they are essential (Hanson, 2008).

**Critical Thinking and Black Girls**

Critical thinking skills are essential, at every age, for everyone, in all contexts, in every aspect of life. Applying critical thinking skills reaps all kinds of benefits, regardless of the specific situation. Success in academic study requires increasingly sophisticated levels of critical analysis. Many people who have the potential to develop more effective critical thinking can be prevented from doing so for a variety of reasons apart from a lack of ability. In the complex social dynamics of the United States, Black girls have been historically neglected, marginalized, and underserved in education settings (Muhammad & Haddix, 2016). Research continues to highlight the invisibility of Black girls in schools, classrooms, and research literature (Evans-Winters, 2005; Henry, 1998), the ways in which they are misrepresented and dehumanized in the public media (Muhammad & McArthur, 2015), and the disconnect between their lives and interests with approved curriculum (Jeffries & Jeffries, 2013). Due to the current and ongoing assaults on Black girls and the damaging instructional practices in schools across the nation, these girls have been positioned as 'less than' or have focused on pathologies rather than the intellectual promise that they carry.

In educational arenas, Black girls are often excluded from many high-level mathematics and science classes, the very classes that teach students the critical thinking skills necessary for success, because of achievement test scores and school tracking (Farinde & Lewis, 2012). In fact, in a qualitative study by King and Pringle (2019) reported the perceptions of six Black girls (in grades 4$^{th}$ – 6$^{th}$) perceptions of their STEM experiences with some reporting that their race greatly influenced their formal learning experiences. Further, research supports the achievement of Black girls in science when given access and opportunity (Buck et al., 2014). Oftentimes Black girls who live in low SES communities are not provided access to high-quality science courses to adequately prepare them to pursue STEM majors and careers (Moses et al.,1999). African American female students are taught the fundamentals but are not further challenged academically in science classes (Van Lagen & Dekkers, 2005). The advanced challenging skills in science classes provide practice in developing high-order critical thinking skills. These same classes typically exclude black girls. This exclusion results in missed exposure and opportunities to receive science instruction meant to develop critical thinking. For example, the Science Writing Heuristic (SWH) has been shown to be effective in developing critical thinking skills for marginalized and under-represented groups who struggle academically (Taylor et al., 2014).

**Theoretical Framework for the Science Writing Heuristic**

The NRC (2000; 2012) contend that an important part of science learning for students should include the process of inquiry with argumentation. That is, developing the skill to reason, support, and defend a positional claim with evidence from data. A critical component of inquiry-based instruction is oral and written argumentation (Choi, 2010). Argument based inquiry in science seeks to increase general science knowledge, critical thinking skills, and the ability to debate and support a position based on research and experimentation (Taufik et al., 2019). The Science Writing Heuristic (SWH) is an argument-based inquiry approach to teaching and learning science that was developed by Hand and Keys (1999) that emphasizes the use and development of science language. Foundationally, as expressed by Norton-Meier (2008), the

SWH incorporates a number of assumptions, including a) science exists through language, b) learning and meaning exist through negotiation, c) language meaning is tied to experience, d) knowledge is constructed and displayed in multiple ways, e) diversity is considered a resource, and f) learning can be a social construct (see Figure 1 for further detail regarding the foundation of the SWH). Thus, the SWH emphasizes instructional framework and practices rather than specific curricula.

The SWH incorporates theories that intersect with writing-to-learn strategies, science literacy and inquiry-based instruction (Yore et al., 2003). Another key component to the SWH as discussed by Cavagnetto (2010) is the concept of immersive learning in science; that is, students learn science processes and concepts by performing those processes. The SWH approach embeds science argumentation and negotiation while performing inquiry-based activities that resemble science processes (Next Generation Science Standards [NGSS], 2013). Further, the SWH encourages the use of multimodal representation throughout the entire learning and instructional process as supported by the NRC (2013). Hand et al. (2018) detail the SWH as having three phases a) development phase, b) argument phase, and c) summary writing phase. The development phase sets the environment, process, and parameters for argumentation, negotiation, and inquiry wrapped within the context of a "big idea" that represents a natural phenomenon for students to explore. The argument phase includes activities in generating researcher questions, making a claim regarding the research questions, and providing evidence to support the claims via determining the best methods for answering the research questions (i.e., through artifact search or hands-on experimentation). The last phase of summary writing is designed to share and disseminate information derived from the research, argumentation, and negotiation of science phenomenon explored during the science unit. Through the described phases and process, the SWH is designed to help students develop their critical thinking skills.

**Rationale for Current Study and Research Questions**

The SWH has shown to be successful in developing critical thinking in various populations of students. French et al. (2012) found that the SWH supported the rapid growth of critical thinking skills. Tseng (2014) examined the impact of the SWH versus traditional science teaching approaches as well as implementation quality. The research found that across all implementation levels (i.e., low, medium, and high) teachers who used the SWH approach had students who made higher critical thinking score gains than students in classrooms taught traditionally (Tseng, 2014). In examining the SWH's impact on critical thinking scores for low and high achieving students, Taylor et al. (2014) found that students had higher pre-/post-test gains than students in similar comparison groups. While the previous research is promising, more research is needed to determine the efficacy of the SWH on critical thinking skills of students. Hence, the current study examines the effect of the SWH on critical thinking skill growth for Black girls in science. The following research questions were examined:

1. Are there significant differences between pre- and post-test scores on the Cornell Critical Thinking Test and its subscales for 5$^{th}$ grade Black girls in treatment and control groups?
2. Are there significant differences between treatment and control groups of 5$^{th}$ grade Black girls' post-test scores on the Cornell Critical Thinking Test and its subscales?
3. What are the effect size results from pre- and post-test difference scores on the Cornell Critical Thinking Test and its subscales for 5$^{th}$ grade Black girls in treatment and control groups?

4. What are the effect size results between treatment and control groups of 5th grade Black girls' post-test difference scores on the Cornell Critical Thinking Test and its subscales?

## Method

### Participants and Settings

A randomized control trial (RCT) experimental design was structured using 48 elementary school buildings in a Midwest state. The schools were randomly assigned to teach their fifth-grade science classes using either the SWH approach (treatment group) or traditional approaches (control group). Traditional science approaches included lecture style instruction or kit-based science instruction. Randomization to treatment or control groups was performed within clustered blocks. Either the clustered blocks were districts with multiple buildings or a collection of districts that were similar in enrollment and size. For the purposes of the current study, after the clustered randomization, participants were further determined through identified race/ethnicity (i.e., Black), gender (i.e., female), and science achievement scores (i.e., less than the 40th percentile on the Iowa Test of Basic Skills [ITBS] science subtest). A total of 28 black females (treatment n= 17; control n= 11) were included in the current study as permitted by their parents via consent.

The schools that were included in the study from which the 28 participants were culled were from urban, rural, and suburban school districts. The overwhelming major of the students in populations identify as White (86%) with 5% of students identifying as Black. Black girls make up only 2% from the overall number of students culled from the overall participation. Across treatment and control schools 37.5% (treatment= 38.1%; control=36.8%) receive free or reduced lunch with a combined 12.7% as English language learners.

### Independent Variable

#### *Treatment Group*

The SWH is an argument-based inquiry approach to teaching science using a number of embedded strategies. It is a particular instructional methodology beyond just inquiry and argumentation. Figure 2 provides context for the procedure and questions that teachers and students go through in the SWH. The treatment group had teachers trained in using and used the SWH. Hand and Keys (1999) developed the SWH to involve students in inquiry, argumentation, and experimentation as a means of learning science and improving critical thinking skills using what they describe as 'questions, claims, and evidence'. The SWH approach uses multiple research-based methods to provide support within inquiry-based instruction and structure for students and teachers. Teachers develop instructional units around 'big ideas' which can provide opportunities for science instruction across science foci (e.g., earth science, plant science, life science). Students and teachers can refer to the SWH template (see Figure 2) that provides a scaffold for teaching and learning. While not necessarily linear, the template provides structure for points of interesting in the teaching and learning cycle. Further, the SWH also provides opportunity for whole group and small group interactions, multimodal representation for teaching, learning, hands-on experimentation, data collection, and argumentation.

Teachers are tasked with guiding students through questioning. The teacher provides a "big idea" (an encompassing idea such as, water is needed for life on Earth) which allows for students to participate in describing all things that are connected to idea.

***Control Group***

The control group teachers used teaching techniques approved by their respective school districts. These techniques included textbook-based instruction, lecture-based instruction, and kit-based instruction. Textbook-based indicates that teachers primarily derived science lessons, content, and activities from a designated district approached science textbook appropriate for the grade. Lecture-based instruction indicates that teachers used supplemental materials from a text or web-based sources to deliver instruction directly to students with some interaction throughout class and the classroom. Kit-based instruction generally involved the use of grade-appropriate commercially purchased science kits with pre-developed lessons and activities for students delivered using step-by-step instructions.

**Dependent Variable**

The Cornell Critical Thinking Test (CCTT [Level X]) (Ennis et al., 2005) is a 76-question multiple choice test that means to measures critical thinking ability of students in grades 4-14. Along with an overall critical thinking score, the CCTT has five subscales assessed using the instrument: Induction, Deductions, Credibility, Observations, and Assumptions. The questions on the test focus on a scenario regarding the exploration of a new planet and provide students with choices based on presented contexts. The CCTT reports to explore the critical thinking ability disconnected to any content knowledge. Reliability and validity information reported in the technical manual reports internal consistency reliability estimates ranging from 0.67 to 0.90 for the Level X booklet.

**Procedures**

The CCTT was given to the participating students in both control and treatment groups prior to any science instruction at the beginning of the school year. Post-tests were administered within a month of the end of the school year. Neither treatment nor control teachers had access to the CCTT prior to the testing periods and thus were unaware of what the CCTT included as test items or metrics. There was no specific emphasis on critical thinking as part of the control and treatment teachers' instructions or training.

***Control Group***

Teachers in the control group were encouraged to use 'business as usual' science instruction as encouraged by their home school districts. The instructional approaches included lecture style presentations, science textbooks with accompanying worksheets, kit-based science instruction.

***Treatment Group***

**Pre-Instructional Training.** Elementary and special education teachers in treatment schools were trained in the SWH approach during the summer in a three-day professional development. Workshops were led by university faculty and doctoral students in science education and special education from a large university located in the state the current study takes place. Workshops focused on providing teachers with experiences in a) immersive teaching using argument-based inquiry, b) using science language and multimodal representation in whole group and small group discussions, and c) building pedagogical and content knowledge to negotiations and learning via the SWH. Prior to the start of the school year, two additional days of school-based professional development were held that centered on developing unit plans, 'big ideas,' and activities and science learning demonstration tasks for potential pathways of student discussions.

**School Year Supports.** Three days of professional development were conducted throughout the academic year and focused on bringing the teachers together as a clustered group to compare experiences and discuss positives, negatives, and receive support with implementing the SWH approach. Teachers were encouraged to use the SWH template (see Figure 2) in implementing the approach. Additionally, individual cluster coordinators worked with teachers to address issues related to implementation.

### Data Analysis

Significant testing was conducted using a group design and SPSS data analysis software. Dependent samples t-test were conducted for pre- and post-test data analysis of results on the CCTT and its subscales for both treatment and control groups. An independent samples t-test was conducted on the post-test data of results on the CCTT between treatment and control groups. Effect size analysis (Hedge's *g*) was conducted using the data from the current study. Hedges' *g* is a measure of effect size that analyzes how much one group differs from another. Hedges and Olkin (1985) suggest that the Hedges' *g* statistic is best for evaluating effect size for small sample sizes. Hedges' g was calculated for treatment and control group results on pre- and post-test results of the CCTT and its subscales. Hedges' *g* was also calculated for CCTT post-test results between treatment and control groups. Cohen (1977) suggests that interpretations of effect sizes results should be as follows: less than 0.2 (small effect), between 0.2 and 0.8 (medium effect), and 0.8 and above (large effect).

## Results

The current study results include paired t-test analyses of a) mean pre- and post-intervention CCTT and subscale scores for treatment and control groups, b) mean post-intervention CCTT and subscale scores between treatment and control groups, c) effect size results on pre- and post-test CCTT and subscale scores for treatment and control groups, and d) effect size results on post-test CCTT and subscale scores between treatment and control groups. The study consisted of 28 Black $5^{th}$ grade girls (treatment n= 17; control n= 11). Treatment students were taught in SWH classrooms and control students were in elementary science classes that conducted "business as usual" instruction.

### t-Test Analyses

Both treatment and control group data were analyzed using dependent paired t-test analysis of pre- and post-test results from the CCTT and its subscales. Significance was established at the 0.05 level. For the treatment group, only two of the CCTT subscales yielded significant results based on pre- and post-test results. CCTT subscale Deduction had a result of $t(16) = -2.36$, $p < 0.03$, 95% CI [-4.92, -0.26]. CCTT subscale Assumptions had a result of $t(16) = -2.57$, $p < 0.02$, 95% CI [-2.26, -0.21]. See Table 1 for full dependent t-test results for treatment group. None of the CCTT subscales or overall measure were significant for the control group. See Table 2 for full dependent t-test results for control group. When comparing CCTT and subscale post-test scores between groups there were no significant differences between treatment and control groups (see Table 3).

**Table 1**

*Treatment Group Dependent t-Test Comparisons of Cornell Critical Thinking Tests*

| | N | Mean | SD | *t*-score | 95% CI | | *p*-value |
|---|---|---|---|---|---|---|---|
| | | | | | *Lower* | *Upper* | |
| **Induction** | | | | | | | |
| pre-test | 17 | 10.65 | 2.52 | | | | |
| post-test | | 11.29 | 2.69 | | | | |
| comparison | | | | -.623 | -2.85 | 1.56 | 0.54 |
| **Deduction** | | | | | | | |
| pre-test | 17 | 5.88 | 3.20 | | | | |
| post-test | | 8.47 | 2.32 | | | | |
| comparison | | | | -2.36 | -4.92 | -0.26 | 0.03* |
| **Observation** | | | | | | | |
| pre-test | 17 | 8.41 | 3.00 | | | | |
| post-test | | 8.29 | 2.57 | | | | |
| comparison | | | | 0.16 | -1.44 | 1.68 | 0.88 |
| **Assumption** | | | | | | | |
| pre-test | 17 | 1.59 | 1.00 | | | | |
| post-test | | 2.82 | 1.42 | | | | |
| comparison | | | | -2.57 | -2.26 | -0.21 | 0.02* |
| **Total** | | | | | | | |
| pre-test | 17 | 28.00 | 6.47 | | | | |
| post-test | | 31.35 | 2.37 | | | | |
| comparison | | | | -1.90 | -7.10 | 0.39 | 0.08 |

*Note.* N = number; SD = standard deviation; CI = confidence interval. *$p < .05$.

**Table 2**

*Control Group Dependent t-Test Comparisons of Cornell Critical Thinking Tests*

| | N | Mean | SD | *t*-score | 95% CI | | *p*-value |
|---|---|---|---|---|---|---|---|
| | | | | | *Lower* | *Upper* | |
| **Induction** | | | | | | | |
| pre-test | 11 | 11.09 | 3.23 | | | | |
| post-test | | 10.00 | 2.75 | | | | |
| comparison | | | | 0.86 | -1.71 | 3.90 | 0.40 |
| **Deduction** | | | | | | | |
| pre-test | 11 | 7.27 | 4.36 | | | | |
| post-test | | 7.27 | 2.76 | | | | |

| | N | Mean | SD | *t*-score | 95% CI Lower | 95% CI Upper | *p*-value |
|---|---|---|---|---|---|---|---|
| comparison | | | | -0.34 | -3.43 | 2.52 | 0.74 |
| **Observation** | | | | | | | |
| pre-test | 11 | 8.27 | 3.63 | | | | |
| post-test | | 8.90 | 3.41 | | | | |
| comparison | | | | -0.53 | -3.29 | 2.02 | 0.60 |
| **Assumption** | | | | | | | |
| pre-test | 11 | 2.63 | 2.06 | | | | |
| post-test | | 2.72 | 1.48 | | | | |
| comparison | | | | -0.10 | -1.97 | 1.79 | 0.91 |
| **Total** | | | | | | | |
| pre-test | 11 | 29.00 | 10.00 | | | | |
| post-test | | 29.45 | 6.26 | | | | |
| comparison | | | | -0.16 | -6.51 | 5.60 | 0.87 |

*Note.* N = number; SD = standard deviation; CI = confidence interval.

**Table 3**

*Independent t-Test Comparisons of Cornell Critical Thinking Tests Post-Test Between Groups*

| | N | Mean | SD | *t*-score | 95% CI | | *p*-value |
|---|---|---|---|---|---|---|---|
| | | | | | *Lower* | *Upper* | |
| **Induction** | | | | | | | |
| treatment | 17 | 11.29 | 2.69 | | | | |
| control | 11 | 10.00 | 2.76 | | | | |
| comparison | | | | 1.23 | -0.86 | 3.45 | 0.23 |
| **Deduction** | | | | | | | |
| treatment | 17 | 8.47 | 2.32 | | | | |
| control | 11 | 7.72 | 2.76 | | | | |
| comparison | | | | 0.77 | -1.24 | 2.73 | 0.45 |
| **Observation** | | | | | | | |
| treatment | 17 | 8.29 | 2.57 | | | | |
| control | 11 | 8.91 | 3.42 | | | | |
| comparison | | | | -0.54 | -2.94 | 1.71 | 0.59 |
| **Assumption** | | | | | | | |
| treatment | 17 | 2.82 | 1.42 | | | | |
| control | 11 | 2.73 | 1.49 | | | | |
| comparison | | | | 0.17 | -1.06 | 1.25 | 0.87 |
| **Total** | | | | | | | |
| treatment | 17 | 31.35 | 2.37 | | | | |
| control | 11 | 29.45 | 6.27 | | | | |
| comparison | | | | 1.14 | -1.53 | 5.33 | 0.27 |

*Note.* N = number; SD = standard deviation; CI = confidence interval.

## Effect Size Analyses

Effect size analyses were conducted on treatment and control group data using Hedges' g analysis of the CCTT and its subscales. Pre- and post-test analysis indicate that treatment groups mainly demonstrated the greatest gains and resulted in higher effect sizes except for the Observation subscale (treatment g= -0.04; control g= 0.17). Based on the interpretations suggested by Cohen (1977), the treatment group had moderate to large effects in three of the four CCTT subscales and on the CCTT overall (g range= -0.04 – 0.98). The control group effect sizes for the CCTT and its subscales resulted in little to negative effects (g range= -0.35 – 0.17). Comparing post-test scores between treatment and control groups resulted in wide range of effect sizes and interpretations. The largest effect was in the Induction subscale (g= 0.46) that indicates a moderate effect. The Observation subscale resulted in a negative effect size (-0.12) indicating that the control group outperformed the treatment group on post-test measure. See Table 4 for the complete list of effect size results.

**Table 4**

*Within Group Pre/Post-Test Differences and Between Group Differences Hedges' g Effect Sizes*

| | **Hedges' *g*** | **95% CI (High – Low)** |
|---|---|---|
| **Induction** | | |
| treatment group (pre/post) | 0.24 | -0.43 - 0.91 |
| control group (pre/post) | -0.35 | -1.19 - 0.49 |
| ***comparison (post between groups)*** | ***0.46*** | ***-0.31 - 1.23*** |
| **Deduction** | | |
| treatment group (pre/post) | 0.90 | 0.20 - 1.61 |
| control group (pre/post) | 0.00 | -0.84 - 0.84 |
| ***comparison (post between groups)*** | ***0.29*** | ***-0.47 - 1.05*** |
| **Observation** | | |
| treatment group (pre/post) | -0.04 | -0.71 - 0.63 |
| control group (pre/post) | 0.17 | -0.67 - 1.01 |
| ***comparison (post between groups)*** | ***-0.21*** | ***-0.97 - 0.55*** |
| **Assumption** | | |
| treatment group (pre/post) | 0.98 | 0.27 - 1.69 |
| control group (pre/post) | 0.04 | -0.79 - 0.88 |
| ***comparison (post between groups)*** | ***0.06*** | ***-0.70 - 0.82*** |
| **Total** | | |
| treatment group (pre/post) | 0.67 | -0.02 - 1.36 |
| control group (pre/post) | 0.05 | -0.78 - 0.89 |
| ***comparison (post between groups)*** | ***0.43*** | ***-0.34 - 1.19*** |

*Note.* CI = confidence interval.

## Discussion

This study examined the effects of the SWH on critical thinking skills for 5th grade Black girls who struggle in science. All participants in the current study (treatment and control groups) had standardized science achievement scores (Iowa Test of Basic Skills) of 40% or lower. Participants were all in a state considered to be in the rural Midwest. The SWH is an argument-based inquiry approach to teaching science. Critical thinking was measured using the Cornell Critical Thinking Test (Ennis et al., 2005). Treatment and control group data were compared as well as within group comparisons of pre- and post-test scores on the CCTT and its subscales (i.e., Induction, Deduction, Observation, and Assumption). The current study found some similarities with the findings of Taylor et al. (2014).

**t-Tests**

Results from the current study suggest that the SWH is a viable instructional approach for science teaching that positively affects Black female students' critical thinking skills. This is consistent with previous research that examined the connection between the SWH and critical thinking. Taylor et al. (2014) found that the SWH statistical significance with improved critical thinking skills for students who struggle and excel academically when juxtaposed with a comparison group. The current study found no statistical significance between treatment and control groups on critical thinking improvement. Yet, when comparing within group means, the treatment group only had two of the four subscale measures (Deduction and Assumption) result in statically significant findings. Two things should be noted when examining statistically significant results from the current study: a) the analysis from the overall CCTT scale was close to statistical significance at the 0.05 level and b) none of the CCTT measures for the control group were close to statistical significance. Specifically, the current study suggests that the SWH may support 5$^{th}$ grade Black girls' independent personal growth in the critical thinking skill areas of deduction (i.e., the ability to reason from a premise to reach a logical conclusion) and assumption (i.e., the ability to identify if a statement is supported by factual evidence or opinion). In contrast, the science instruction received by the 5$^{th}$ grade Black girls in the control group did not support any significant independent growth in these skills. However, beyond statistical significance, practical significance should be considered when interpreting these results.

**Effect Sizes**

Effect sizes may provide more practical knowledge regarding intervention effectiveness (Coe, 2002). Similarly, with the Taylor et al. (2014) study, the current study examined and found more that subtle practical (i.e., effect size) differences within and between treatment and control groups. All but one subscale (i.e., Observation) indicates that the treatment group practically outperformed the control group. Results support the interpretation of moderate to large effects in four of the five measures for the treatment group suggesting that the SWH does influence critical thinking to some effect. The control group results suggest that "business as usual" instruction, methods reported by the school district including lecture style presentations, science textbooks with accompanying worksheets, kit-based science instruction, has a small to no effect on critical thinking improvement. However, between group comparisons suggest that at most, moderate differences exist in improving critical thinking skills using the SWH for Black 5$^{th}$ grade girls. These findings are consistent with effect size results from Taylor et al. (2014). One difference between the current study and Taylor et al. (2014) is that the latter found both statistical and practical significance in critical thinking improvement. Ultimately, the results from the current study support the notion of the SWH being used to moderately to largely improving most critical thinking skills of 5th grade black girls. This is especially striking when compared to traditional science instructional methods (e.g., textbook based, kit-based) which either did not improve 5th grade Black girls critical thinking skills or indicated negative effects.

**Limitations**

There are a number of limitations associated with the results of this study including participants, treatment fidelity, and dependent variable. Two limitations related to study participants involve the number of participants and the homogenous nature of the study participants. A larger sample size in treatment and control groups would allow for a more robust and complex analyses including analysis of variance and power analysis. Further since the study used a homogeneous group of students, extrapolation of the results would be difficult. The quality of SWH implementation could not be determined. The authors did not have access to implementation quality on the following: a) SWH implementation; b) feedback, or c) professional development. The authors recognize that teaching fidelity data would allow for deeper analysis. Lastly, using the Cornell Critical Thinking Test and its subscales as dependent variables for critical thinking skills limits the interpretations that can be made. While a viable measure, the CCTT requires reading ability at a 4th grade level and is designed to examine transferability of critical thinking skills to a standardized measure. Both of which can be barriers for students.

**Implications and Conclusion**

Black girls have expressed experiences and perceptions of their identities and their relationship to STEM instruction (King & Pringle, 2019; McCoy, 2020). Further, Black girls are often excluded from science learning opportunities in many settings. It has been suggested that science learning contributes and develops critical thinking skills in students (NRC, 2012). If science learning supports critical thinking development and Black girls are routinely excluded from science; and students in general who struggle in science are left behind, it can be extrapolated that Black girls who struggle in science will miss significant opportunities to grow critical thinking skills in school settings as they are currently designed. Additionally, advanced science learning opportunities will be limited to this marginalized group. The SWH approach is a promising way to support critical thinking growth for Black girls through a science learning approach.

Supported inquiry and argumentation influencing knowledge construction is the base of the SWH approach. The data and results from the current study support the notion that the SWH can positively influence the critical thinking growth of young Black girls in science classrooms, even if they struggle with performance on standardized science measures. The emphasis on debate, investigation, and negotiating understanding may contribute to how critical thinking skills are developed outside of science classrooms and contexts. The authors suggest more research is needed to examine the connection between science learning and critical thinking as well as how these constructs relate to Black girls and access to science learning. Additionally, further study that specifically focuses on the effect of the SWH on Black girls' science and critical thinking outcomes is needed. Ultimately, access to science instruction that challenges and supports Black girls to be science literate critical thinkers should be the goal of all science educators. Thus, continuing the true notions of "science for all."

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