Discovery Versus Inquiry: A Case for the Learning Outcomes of Student Science Process Skills

Makayla Veracka

EDG500, Nyack College

May 5, 2020

Background

Discovery learning is a research-based learning theory rooted in contruvist principles. This type of learning allows students to wrestle with important questions, problem solve, and discover relationships among concepts all while using their own past experiences and knowledge to draw conclusions. This type of learning is said to help students better remember concepts and new knowledge because they are able to discover the answers on their own (2017). But, critics argue that students are not able to discover important principles on their own without guidance and scaffolding. As discovery learning continues to enter the educational scene as being a vital aspect to learning, research on why this is ineffective is important for teachers to understand when planning their lessons, meeting objectives, and fostering a student's academic success. The problem to be identified for research is whether or not discovery learning is an effective structure for students to learn new concepts.

Literature

Kirschner and Clark (2006) are the foundation to the debate of guidance in student learning. They state that according to human cognitive architecture, students need guidance during instruction in order for them to acquire the strategies and procedures needed to learn new concepts, making discovery learning, problem-based learning and inquiry learning ineffective teaching methods that are not supported by research. Similarly, Clark et al. (2012) state that direct and explicit instruction accompanied by practice and feedback are more effective than discovery learning. They state that the research on working and long-term memory solidifies that minimal guidance is ineffective because students may latch onto misconceptions and become frustrated which can cloud future learning. They also state that students are more likely to latch onto their initial discovery rather than the teacher correction. They conclude that direct, explicit instruction is the most researched and therefore most effective compared to discovery learning methods.

Mayer (2004) clarified the definition of discovery learning as a learning environment where students are free to work with little or no guidance. In his article he states several issues with the discovery learning method. The first is that students may never come into contact with the principle they are required to learn and therefore have nothing to construct new knowledge from. The second is that students may not be able to weed out relevant information to make sense of and complete the task. Based on his reasoning, the author concluded that research proved pure discovery learning as ineffective. Rowe (2006) provided research and statistical analysis on student learning outcomes which showed and supported that teacher-directed learning is more effective for improvements in student learning and educational success. The author concluded that both constructivist and direct teaching methods have merit but problems arise when discovery learning precedes, or takes the place of, direct teaching.

Mayer (2004) states that constructivism does have merit when properly used in the classroom because it has roots in active learning such as hands-on activities, group discussions, and interactive games. The author mentioned that the constructivist view often focuses on behavior activity, meaning students engagement, rather than cognitive activity, which creates lasting educational results. Along with this, Hmelo-Silver, Duncan, and Chinn (2007) state in their response to Kirschner and Clark (2006) that both problem-based and inquiry learning are effective pedagogical practices that are actually scaffolded so that students can access the proper cognitive domains and that discovery learning is a “no guidance” strategy that is not supported by evidence. The authors mentioned that Kirschner and Clark (2006) overlooked many other analyses that favor problem-based and inquiry learning as being effective in the classroom.

Kalyuga and Singh (2016) state that the cognitive load theories have supported the acquisition of domain-specific schemas and that some discovery learning strategies may be successful in meeting different types of goals aside from these schemas. They proposed that cognitive load theory must have clearer definitions of what goals must be attained through learning because inquiry and problem based methods may be sufficient strategies. The authors conclude that research could be done on each strategy when trying to accomplish a similar, or the same, goal but to compare strategies when they are targeting different goals will result in ineffective conclusions such as the comparison between direct instruction and discovery learning. Similar to this, Lazonder and Harmsen (2016) state that inquiry-based learning has proved itself to be an effective strategy and can range in the type of guidance given. The purpose for the authors' meta-analysis is to identify the effects of guidance on student inquiry activities, performance success, and learning outcomes (p. 685). The authors' concluded that guidance provided positive outcomes in all three categories of study. Within this, the authors also concluded that adequate guidance, not specific or complete guidance, is needed in order for students to get the most out of inquiry-based learning. Within inquiry-based learning, there are a number of process skills students need in order to be successful in the acquisition of new knowledge and the completion of experiments.

Kuhn (2007) writes a response to Kirschner et al. (2006) stating that Kirschner (2006) never specified what the teacher is seeking to teach the students. The author attempts to redefine the goals of what students should be learning stating that students should be taught how to use their minds well both in school and beyond and the best way to do that is to teach students the skills of inquiry. Among this conclusion, the author states that if inquiry skills are necessary for students to acquire knowledge then the students should be taught these process skills directly rather than engaging in discovery to learn these skills. Similar to this, Klahr (2009) conducted a study where one group received direct instruction on process skills and the other did not. The author concluded that direct instruction on a process skill allows for students to engage in discovery learning about domain knowledge.

Rauf et al. (2013) propose a study that evaluates what types of instructional approaches provide the opportunity for students to inculcate science process skills. The authors define process skills as "learning how to learn" because it requires students to engage in critical thinking and problem solving. They state that these skills are important for students to learn because they act as a scaffold to other cognitive skills such as logical thinking, reasoning and problem solving skills (p. 54). Their conclusions found that direct guidance of process skills were necessary for students to actually acquire the skills. They state, "teachers should always give guidance throughout the experiment or lesson in order for the students to realize they are actually learning to acquire the science process skills… Children should not be left on their own and hope to be able to acquire certain skills without any intervention from the teacher."(p. 54). The authors state that students should always learn these skills based on teacher guidance rather than pure discovery in order to fulfill the goal of science education.

Problem

Among the research conducted about guidance and how it affects student learning, there are several strategies that range from highly directed to minimally directed. Some of these strategies are discovery learning, problem based learning, inquiry learning and direct teaching. Discovery learning is the least directed of all the strategies and direct teaching is the most directed of all strategies. Often, many researchers lump together discovery learning, problem-based learning, and inquiry learning as the same concept of strategies when they are inherently different. Hmelo-Silver states that inquiry-based learning is in fact highly scaffolded (Hmelo-Silver, 2006). The question proposed when deciding how much guidance students need in order to be successful, is what goals and objectives are students required to accomplish. According to Kalyuga and Singh (2016), methods such as inquiry-based learning can be effective based on what the students are supposed to learn. Therefore, in order to solve the problem of which type of guidance produces best learner outcomes, it would be beneficial to compare discovery learning to inquiry-based learning because they both have similar approaches in requiring students to use science process skills in order to make discoveries.

Purpose and Hypothesis

The purpose of this research study is to examine the different levels of guidance in discovery learning and inquiry-based learning to determine which level of guidance produces the most effective student learning outcomes through the measurement of science process skills such as observing and inferring. The focus is on the two teaching methods and the different learner outcomes that are produced. The working hypothesis of the outcomes of this research is as follows: The group who received inquiry learning method of instruction with sufficient guidance from the teacher and previous instruction on the science process skills in isolation will yield better understanding and implementation of science process skills on a science experiment as compared to the group who received discovery learning instruction. This research study serves to answer the following research questions: What role does guidance play in the acquiring and understanding of science process skills? How does the understanding of science process skills affect student learning outcomes?

Variables

In this research study, the independent variable will be represented by a classroom of students who will receive the two different types of treatment. The treatments are the discovery learning teaching method and the inquiry-based learning method of instruction. The classroom as a whole will receive both methods of instruction where discovery learning is administered first because it requires no direct instruction of the process skills, followed by inquiry-based learning. The learning outcomes of the science process skills of observing and inferring will be measured using the dependent variable of a checklist and an interview to fully assess the student's understanding and implementation of the processes.

Methods

In this section, the participants and setting of this study will be described followed by a description of the instrumentation, which maps out how scores will be obtained for the data section. The procedures will then be described discussing what methods were implemented along with how and in what order they were administered. The order of delivery is an important aspect of this study due to the amount of guidance needed in discovery learning as compared to inquiry learning. Concluding this section will be a description of how the data will be analyzed.

Participants and Setting

This study takes place in a school district in the northeast coast of Florida. This district includes large metropolitan areas such as Daytona Beach, DeLand, Deltona, Ormond Beach and

Port Orange. The district includes 85 total schools with 7 charter schools, 45 elementary schools, 12 middle schools, 9 high schools, 9 alternative/special schools, 2 combination schools, and 1 district virtual instruction program. There are 7,623 total employees defined by 2680 support staff, 4,678 teachers, and 265 administrators with 42 percent of the instructional staff holding master's degrees, educational specialist degrees or doctoral degrees. There are a total of 62,932 total students in the district with the overall demographics of the residents being 73.6% white, 11.9% hispanic, 10.6% black, 1.7% Asaian, 1.6% mixed, and 0.6% other (Statistical Atlas, 2018).

The school in which the participants come from is ranked 444 out 2166 Florida schools and is considered a B school in academic performance. There are 809 total students in this school with a 16:1 student-teacher ratio. The demographics of the student within this school are as follows:.8% White , 8.3% Hispanic, 5.1% African American, 5.1% Two or more races, 4.6% Not Specified, and 0.2% Pacific Islander. There are 34.1% of students on free and discounted lunch (School Digger, 2019).

The classroom in which this study takes place is a 5th grade math and science class. Within the 7 hour school day, there is a total of 2 hours and 15 minutes of time allotted for math and science instruction. There are a total of 18 students in the class with 9 female students and 9 male students. The average age group of the students are between 10 and 11 years old. Among the demographics in this classroom there are no African American students, 3 Middle eastern, one Hispanic, and the remainder 14 students are White. There are 6 total students with IEPs/504s with the common classification as learning disabled and 3 English Language Learners. The socioeconomic status of the students is classified as upper middle class with common parent occupations being self-employed business owners, lawyers, and doctors. In total there are 165 students in the 5th grade.

Instrumentation

In order to assess the student's understanding of the science process skills, the students will be required to complete an experiment with the incorporation of these skills. The first part of instrumentation used to collect data will be a checklist that outlines the nature of each process skill the students are required to use in their project. The checklist will have observing and inferring as the head topics with several descriptions of these processes underneath. The checklist will have a total score of ten, five items for observing and five items for inferring. Therefore, the highest score a student can receive on the checklist is ten. The teacher will be the one who fills out this checklist according to the end performance of the students.

After the experiment is completed, the teacher will then conduct an interview with the students to assess their understanding of the two process skills. This interview will contain ten total questions, five that pertain to observing and five that pertain to inferring. Therefore, the highest score a student can receive from the interview is ten. This interview will contain questions like "what do you have to do to make an observation? What were some inferences you made in this experiment? How did you come to those conclusions?" The interview and the checklist will be guided by the teacher. Scores from both the interview and the checklist will then be combined to get a complete assessment of the student's understanding of the skills where Each science process skill will have a total score of ten, therefore the highest score a student can receive is twenty.

Procedures

This research study will begin with first administering the discovery learning teaching method to the class as a whole. This method is fairly easy to administer as compared to inquiry, because no time before the experiment is spent on direct teaching the process skills. Essentially students will be thrown into the experiment and be asked to observe and infer with only their own personal prior knowledge to draw from. The teacher will provide the prompt with minimal directions on how to solve the problem but the students know that they will need to observe and infer to complete the project. As students are working, the teacher will provide very little guidance, only questions to redirect if the student prompt. There will be no information given to students about the concepts or about how the experiment is completed. When the experiment is completed, the teacher will assess the final product using a checklist and an interview, asking students all the same questions as if they were pre taught the concepts.

After the discovery learning method has been administered, preparation for the inquiry-based learning method begins. Prior to the experiment, the teacher will spend several lessons on explaining observing and inferring in isolation. Students will be doing isolated activities on how to observe and then on how to infer. Both of these process skills are closely related because inference requires observation. Therefore, once students have learned to observe, it will make inferring easier for the students to understand, but both skills will still be taught in isolation in two seperate lessons. Once these lessons have been completed, the teacher will then have the class complete the experiment. The teacher will provide the prompt with minimal directions on how to solve the problem but the students will know that it includes observing and inferring. The students will be equipped with everything they need and they will be required to figure out how to use them. While the students are completing the experiment, the teacher will not offer up any explanation on how the experiment is to be completed but will provide guiding questions and suggestions students can use to come to their conclusions. At the completion of the experiment, the teacher will use the checklist to assess how the students used the process skills to come to their conclusion and then interview to assess student understanding of the process skills.

Data Analyses

All data analyses will be conducted using the Statistical Package for the Social Sciences (SPSS). The initial data analyses include frequencies, percentages, standard deviations and means to summarize the overall nature of the data. A paired samples t-test will be used to compare the relationship between the scores of the dependent variable for both treatment methods. This will be used to find the significance of the data and to reject the Null Hypothesis that discovery learning will produce better student learning outcomes of science process skills than inquiry-based learning. The results of the paired samples t-test were evaluated at the alpha level equal to .05.

Results

In this section, the results of the data will be presented. The total scores from each student in each method will be compared to determine the significance. First, the Null hypothesis will be stated and discussed in order to establish what the data is trying to reject. Next, the means, standard deviations, frequencies, percentages and z-scores will be presented to give an overview of the nature of the data. Then, the paired samples t-test will be presented and analyzed to test the hypothesis, followed by a summary of the results.

Null Hypothesis

The alternative hypothesis of this study stated that Inquiry-based Learning would produce better student learning outcomes of the science process skills due to the nature of the guidance within this method. Therefore, the Null Hypothesis would state that Discovery Learning would produce better student learning outcomes of the science process skills. Because it is believed that more guidance produces better student learning outcomes, the goal of analyzing the data is to reject the Null Hypothesis.

Test of Hypothesis

The mean of the learning outcomes from the Discovery Learning method was 16.11 with a standard deviation of 3.05. The scores had a minimum number of eight and a maximum number twenty (*See figures 1.3, 1.5*). According to the z-scores of this method, most students scored within one standard deviation of the mean with only one student as an outlier with two standard deviations from the mean in the negatives (*See figure 1.4*). The general range, the difference between the highest and lowest number, was 12 but the interquartile range where the middle 50% between approximately 14 and 18 was 4.50 (*See figures 1.3, 1.5, 1.7*). The frequency for discovery shows that the highest percentage of 22.2% is a score of 17 with four total students receiving that score. The second highest percentage was 16.7% at 13 with 3 students receiving that score (*See figures 1.2, 1.6*).

The mean of the learning outcomes of the Inquiry-Based Learning method was 17.33 with a standard deviation of 2.44. The scores had a minimum number of 11 and a maximum number of 20 (*See figures 1.3, 1.5*). According to the z-scores of this method most students scored within one standard deviation of the mean with only one student as an outlier with two standard deviations from the mean in the negatives (*See figure 1.4*). The general range of the scores was 9 but the interquartile range where the middle 50% was between approximately 15 and 19 was 4.25 (*See figures 1.3, 1.5, 1.9*). The frequency for inquiry shows that there were two top percentages at 22.2% at scores 15 and 20, where four students received those scores at each (*See figures 1.2, 1.8)*.

The comparison between the two groups was compared at an alpha level of .05. The difference in the mean between both methods was reported as -1.22 and the difference between the standard deviation was 1.22. There was a .925 correlation between the two methods (*See figure 1.10)*. The mean of the learning outcomes increased from 16.11 (sd = 3.04) in the discovery learning method to 17.33 (sd = 2.44) in the inquiry-based learning method. The difference between the two means is statistically significant ($t(17) = -4.27$, $p < .001$). Based on the data results and the significance of the two means, the null hypothesis can be rejected.

Appendix: Data Results and Charts

	Discovery	Inquiry	var
1	13.00	15.00	
2	13.00	15.00	
3	17.00	18.00	
4	19.00	20.00	
5	18.00	19.00	
6	19.00	20.00	
7	20.00	19.00	
8	13.00	15.00	
9	8.00	11.00	
10	15.00	15.00	
11	17.00	16.00	
12	14.00	17.00	
13	17.00	18.00	
14	20.00	20.00	
15	16.00	18.00	
16	17.00	20.00	
17	16.00	17.00	
18	18.00	19.00	

Figure 1.1. *Data set of the learning outcomes of Discovery learning and Inquiry-based Learning.*

Frequency Table

Discovery Learning Method

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	8.00	1	5.6	5.6	5.6
	13.00	3	16.7	16.7	22.2
	14.00	1	5.6	5.6	27.8
	15.00	1	5.6	5.6	33.3
	16.00	2	11.1	11.1	44.4
	17.00	4	22.2	22.2	66.7
	18.00	2	11.1	11.1	77.8
	19.00	2	11.1	11.1	88.9
	20.00	2	11.1	11.1	100.0
	Total	18	100.0	100.0	

Inquiry-Based Learning Method

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	11.00	1	5.6	5.6	5.6
	15.00	4	22.2	22.2	27.8
	16.00	1	5.6	5.6	33.3
	17.00	2	11.1	11.1	44.4
	18.00	3	16.7	16.7	61.1
	19.00	3	16.7	16.7	77.8
	20.00	4	22.2	22.2	100.0
	Total	18	100.0	100.0	

Figure 1.2. *Frequencies of the scores from the learning outcome dependent variable between Discovery learning and Inquiry-based learning.*

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation
Discovery Learning Method	18	12.00	8.00	20.00	16.1111	3.04648
Inquiry-Based Learning Method	18	9.00	11.00	20.00	17.3333	2.44949
Valid N (listwise)	18					

Figure 1.3. *Descriptive statistics including the range, min, max, mean, and standard deviations of the learning outcome scores of Discovery Learning and Inquiry-based Learning.*

	Discovery	Inquiry	ZDiscovery	ZInquiry
1	13.00	15.00	-1.02121	-.95258
2	13.00	15.00	-1.02121	-.95258
3	17.00	18.00	.29178	.27217
4	19.00	20.00	.94827	1.08866
5	18.00	19.00	.62002	.68041
6	19.00	20.00	.94827	1.08866
7	20.00	19.00	1.27652	.68041
8	13.00	15.00	-1.02121	-.95258
9	8.00	11.00	-2.66245	-2.58557
10	15.00	15.00	-.36472	-.95258
11	17.00	16.00	.29178	-.54433
12	14.00	17.00	-.69297	-.13608
13	17.00	18.00	.29178	.27217
14	20.00	20.00	1.27652	1.08866
15	16.00	18.00	-.03647	.27217
16	17.00	20.00	.29178	1.08866
17	16.00	17.00	-.03647	-.13608
18	18.00	19.00	.62002	.68041

Figure 1.4. *Z-scores of Discovery Learning and Inquiry-Based Learning.*

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Discovery Learning Method	18	100.0%	0	0.0%	18	100.0%
Inquiry-Based Learning Method	18	100.0%	0	0.0%	18	100.0%

Descriptives

			Statistic	Std. Error
Discovery Learning Method	Mean		16.1111	.71806
	95% Confidence Interval for Mean	Lower Bound	14.5961	
		Upper Bound	17.6261	
	5% Trimmed Mean		16.3457	
	Median		17.0000	
	Variance		9.281	
	Std. Deviation		3.04648	
	Minimum		8.00	
	Maximum		20.00	
	Range		12.00	
	Interquartile Range		4.50	
	Skewness		-1.059	.536
	Kurtosis		1.502	1.038
Inquiry-Based Learning Method	Mean		17.3333	.57735
	95% Confidence Interval for Mean	Lower Bound	16.1152	
		Upper Bound	18.5514	
	5% Trimmed Mean		17.5370	
	Median		18.0000	
	Variance		6.000	
	Std. Deviation		2.44949	
	Minimum		11.00	
	Maximum		20.00	
	Range		9.00	
	Interquartile Range		4.25	
	Skewness		-.976	.536
	Kurtosis		.943	1.038

Figure 1.5. *Case processing summary and descriptives for both Discovery Learning and Inquiry-based Learning.*

Discovery Learning Method

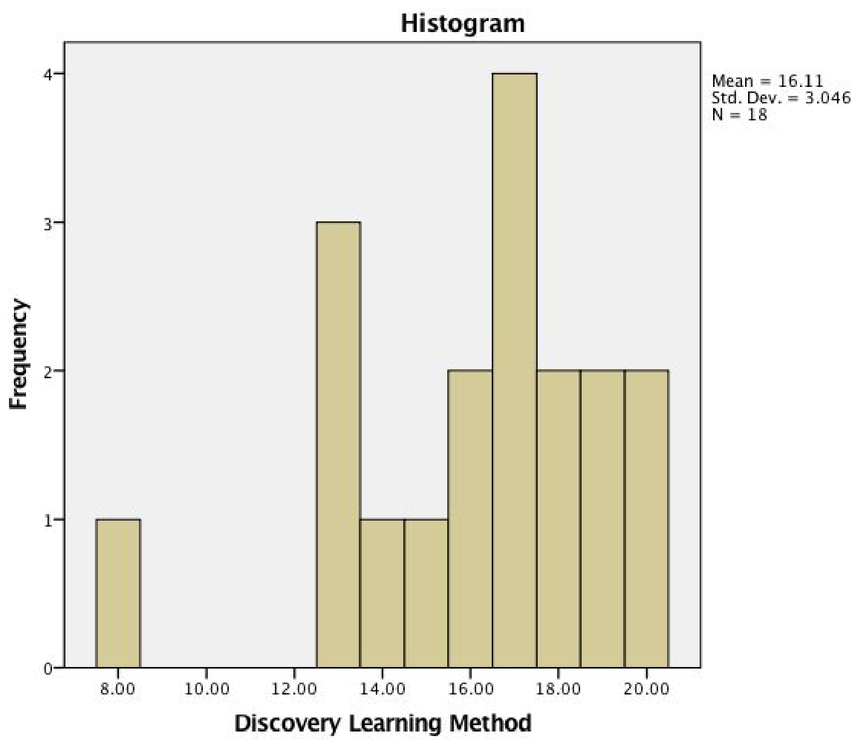

Figure 1.6. *Histogram for frequency of scores in Discovery Learning method.*

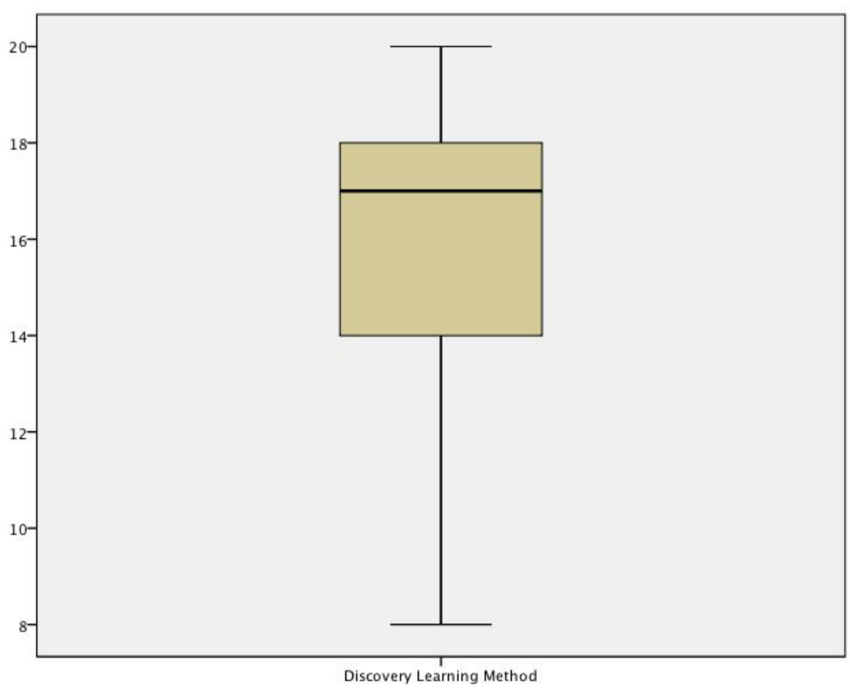

Figure 1.7. *Box plot showing interquartile range of scores for Discovery Learning method.*

Inquiry-Based Learning Method

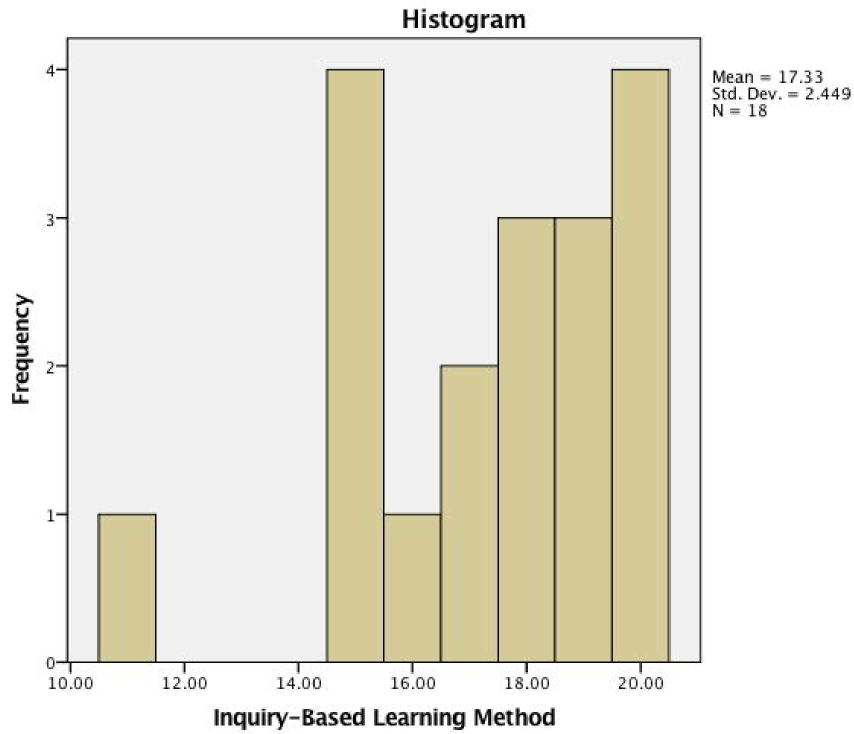

Figure 1.8. *Histogram showing frequencies for scores of Inquiry-based learning method.*

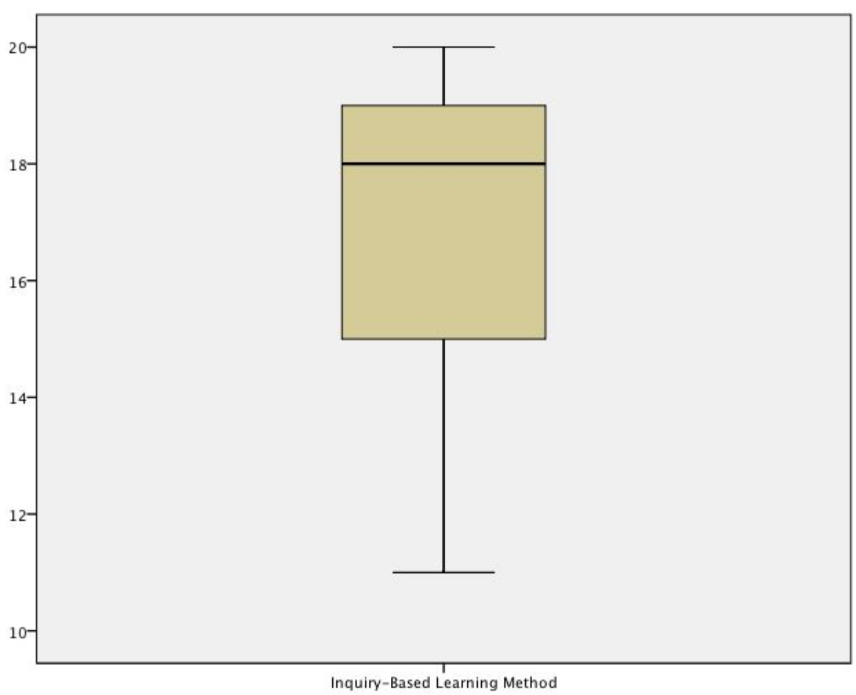

Figure 1.9. *Box plot showing interquartile range for scores of Inquiry-based Learning method.*

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Discovery Learning Method	16.1111	18	3.04648	.71806
	Inquiry-Based Learning Method	17.3333	18	2.44949	.57735

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Discovery Learning Method & Inquiry-Based Learning Method	18	.925	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Discovery Learning Method - Inquiry-Based Learning Method	-1.22222	1.21537	.28647	-1.82661	-.61783	-4.267	17	.001

Figure 1.10. *Paired samples t-test showing comparison and differences between Discovery Learning and Inquiry-based learning.*

References

Clark, R. E., Kirschner, P. A., & Sweller, J. (2012). How much and what type of guidance is optimal for learning from instruction? *American Educator*, 6-11. Retrieved from Researchgate database.

Cypress creek elementary school. (2019, June 28). Retrieved March 19, 2020, from School Digger website: https://www.schooldigger.com/go/FL/schools/0192005404/school.aspx

David, L. (Ed.). (2017, February 2). Discovery learning (Bruner). Retrieved January 27, 2020, from Learning Theories website: https://www.learning-theories.com/discovery-learning-bruner.html

Demographics & statistics. (n.d.). Retrieved March 19, 2020, from Volusia County Schools website: https://www.vcsedu.org/community-information-services/demographics-statistics

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark. *Educational Psychologist,* 42(2), 99-107. https://doi.org/10.1080/00461520701263368

Kalyuga, S., & Singh, A.-M. (2016). Rethinking the boundaries of cognitive load theory in complex learning. *Educational Psychology Review,* 28(1), 831-852. https://doi.org/10.1007/s10648-015-9352-0

Kirschner, P., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry based teaching. *Educational Psychologist*, 41(2), 75-86.

https/doi.org/10.1207/s15326985ep4102_1

Klahr, D. (2009). "To every thing there is a season, and a time to every purpose under the heavens": What about direct instruction? In S. Tobias & T. M. Duffy (Eds.), *Constructivist instruction: Success or failure?* (p. 291–310). Routledge/Taylor & Francis Group.

Kuhn, D. (2007). Is direct instruction an answer to the right question. *Educational Psychologist*, 42(2), 109-113. Retrieved from ebook collection (EBSCO) database.

Lazonder, A. W., & Harmsen, R. (2016). Meta-analysis of inquiry-based learning: Effects of guidance. *Review of Educational Research,* 86(3), 681-718. https://doi.org/10.3102/0034654315627366

Mayer, R. E. (2004). Should there be a three-strikes rule against pure discovery learning? American Psychologist, 59(1), 14-19. https://doi.org/10.1037/0003-066X.59.1.14

Race and ethnicity in volusia county school district, florida. (2018, September 14). Retrieved March 19, 2020, from Statistical Atlas website: https://statisticalatlas.com/school-district/Florida/ Volusia-County-School-District/Race-and-Ethnicity

Rauf, R. A. A., Rasul, M. S., Mansor, A. N., Othman, Z., & Lyndon, N. (2013). Inculcation of science process skills in a science classroom. *Asian Social Science*, 9(8), 47-57. Retrieved from ebook collection (EBSCO) database.

Rowe, K. (2006). Effective teaching practices for students with and without learning difficulties: Constructivism as a legitimate theory of learning and teaching. *Student Learning Processes*, 1-24. https://doi.org/10.1080/19404150609546813