EFFECTIVELY DIFFERENTIATING SMALL GROUPS IN HIGH SCHOOL SCIENCE

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The purpose of this action research study was to determine which method of grouping differentiation had the highest effect size on student learning, how do students perceive differentiated grouping and which method of differentiated grouping has a greater impact on high performing and low performing students. This research was done at Sheridan High School in a 9th grade seminar physical science class, students were grouped together based on how they performed on a pretest. Tiered groups and flexible groups were formed throughout this research project, tiered groups are an example of homogenous grouping. This is where students with similar scores on the pretest were placed together to complete a task. Flexible or heterogenous grouping is where students were mixed for example low performing students and high performing students were intermingled to complete a task. There were several data collection instruments used such as pre-treatment Likert survey, post treatment Likert survey, pretests, posttests, and observations. The data was analyzed using a paired T-test, calculating normalized gains, box and whisker plots and stacked bar charts. The duration of the action research was eight weeks and included 42 seminar physical science freshmen. Each developed group was exposed to the two different styles of differentiated grouping at the end of eight weeks. The results included that the flexible grouping method had a significant impact on both high and low performing students. Tiered grouping method had notable impact on low performing students but hindered high performing students. Students perceived the tiered grouping method as a useful way to learn the content but it made them feel inferior or superior to their peers. Students liked the flexible grouping strategy because it allowed them to learn from other students even though students are not the best at explaining science content.

CHAPTER ONE

INTRODUCTION AND BACKGROUND

Context of the Study

It was the week before spring break, March 2020, my husband I were watching the news on a Sunday night when the Governor of Wyoming announced that the state of Wyoming was to be shut down because of the COVID-19 pandemic. At first, I was shocked and did the normal nervous texts and emails to my coworkers about our next steps; when finally, the school principal sent out an email describing what to expect Monday morning. Through a Zoom conference call, our principal told the staff that we had 48 hours to prepare a way to contact our students and engage them in content. In physical science, we were in the middle of our chemical reaction's unit, How do we effectively teach chemistry online to freshmen who have never done this before? This was the first of many challenging questions we would face in the upcoming months.

During this time the students who had access to highspeed internet, Chromebooks, and motivated parents were able to stay caught up with content in our physical science classes but the students who did not suffered. A large gap was created between the students, those who had access and those who did not. According to the Wyoming Department of Education website (2020), 32% of the students enrolled at Sheridan High School (SHS) are from low-income families and the 2019 census reports that 8.5% of the residents of Sheridan fall at or below the poverty line. Following the school closure in March 2020, there was a large impact on the D and F list at the high school. The D and F list is collected midweek every week to determine which students

are struggling in their classes and if remediation needs to be performed. In the Spring Semester of 2021 nearly a quarter of our student population at SHS had a D or F in one or more their classes, this was nearly doubled from the spring prior to the COVID-19 outbreak. Altering the methods of instruction for these students is the only foreseeable course of action for them to not fall behind in their coursework.

In the past, Sheridan High School (SHS) has boasted a ninety percent graduation rate of high school seniors, but the future looks uncertain as students hurdle through the effects of the COVID-19 pandemic and the social and emotional turmoil that had taken place. Currently SHS is ranked as the second-best high school in the state of Wyoming just behind Jackson Hole High School which has almost 300 fewer students than SHS. SHS is not a very diverse school. Of the 900 students enrolled, 89% of the students attending are Caucasian, 5% of the students are Hispanic, and 6% of the students are of other ethnicities.

Although our school ranking is high but it has been predicted that our graduation rate will fall lower than ninety percent in future years due to students dropping out in order help support their families or from emotional and social turmoil. According to an article by Elharake et al. (2022), students are stressed, and experience more anxiety in social settings due to being socially distanced from their peers in the past year. In my seminar physical science classes I have observed that students are unwilling to help each in the classroom setting and prefer to work within their social groups instead of expanding out of their comfort zone. How does the school district go about recovering from such a crisis? I believe that one-way schools can recover from this deficit is by creating classrooms that foster a community culture through heterogenous grouping

strategies that embraces differences between learners. The purpose of this study was to determine which method of grouping differentiation was more impactful on student learning, flexible grouping differentiated or tiered grouping instruction. It was my hope through this study that if the grouping was done correctly that it would help close the social distance gap between my students, they would learn to thrive once again in classroom culture while embracing differences, and learn how to communicate with other students who share different experiences than they do. I differentiated the learning process by placing students into two different groups, tiered grouping and flexible grouping instruction. These grouping methods allowed me to provide science content to my students in a variety of ways such as (1) altering the reading levels of materials, and (2) increasing the level of difficulty in a variety of concepts.

Focus Question

My focus question was, How effective is differentiated grouping instruction on students learning science?

My sub-questions include the following:

1. Which methods of differentiated grouping instruction have the highest effect size on student learning science?
2. How do students perceive these differentiated grouping strategies?
3. Which student's benefit the most from differentiated instruction, low performing science students, high performing science students, or both?

CHAPTER TWO

CONCEPTUAL FRAMEWORK

Differentiation in Science Instruction: An Overview

Differentiated instruction is a multi-tiered approach that is catered to individual groups of students who struggle with a concept in science or need enrichment in a science topic. According to Bell and Maeng (2015), differentiated instruction is an instructional strategy that provides a variety of student-centered instructional techniques that meets the goals and learning needs of individual students. This instruction is driven by data from a formative assessment and is a key component to effective differentiation based on students learning needs and interests. Bell and Maeng also mention that this instructional approach can be assessed through a post assessment that is given after the differentiation has occurred to check for student learning growth. Bell and Maeng break down instructional approaches into three different categories: (a) readiness, (b) interest, and (c) learning profile. *Readiness* refers to the student's prior knowledge of a subject and the skills they have acquired prior to the new science content. In reference to *interest*, teachers should focus on which subjects promote student's curiosity and passion as a learner. When discussing the *learning profile* teachers should consider gender, culture of the school, and learning styles of the groups of students (Bell & Maeng, 2015). Graaf et al. (2019) mentioned that pre- and post-assessments of learning are key in determining if learning has occurred and if the differentiation strategies the teacher implemented were effective. Differentiation can occur in a variety of ways but a major theme throughout the literature is that it is dependent on student interests and needs. The real question is why do teachers not differentiate more often when they notice students are struggling in an area of science content? Differentiation provides several modalities to student learning,

and it allows for an inclusive experience in the classroom that allows the student to become a master of the science content (Hue et al., 2022).

Why do Teachers Struggle to Differentiate?

Under the immense pressure of time, standardized tests and covering the science standards, teachers do not often utilize differentiated instruction to its full effect. Teachers struggle to differentiate in the classroom for a variety of reasons but a common reason is that they either do not have the time to differentiate or they have not been trained in how to differentiate for their students (Dolman et al., 2019). Embedding thoughtful differentiated units within the science classroom can be a tedious and time-consuming process and the initial planning of such units deters teachers and a one size fits all curriculum is generated. Teachers may also struggle with knowing when to differentiate curriculum and who to differentiate the curriculum for, often struggling learners are at the forefront of the scaffolding and gifted students are left bored and distracted in the classroom (Hertberg, 2009).

According to Dolman et al. (2019) differentiated instruction is a complex teaching skill that requires experience in the teaching profession. Teachers are rarely trained in how to differentiate curriculum and unless they were guided by a senior teacher, they may not know how to differentiate instruction (Hertberg, 2009). It takes years of experience, and the teachers own funding to be able know when to differentiate instruction. If a teacher is poor at differentiating it is likely because they lack the skills in one or more of the four curriculum-related elements of (a) content, (b) process, (c) product, and (d) affect. Teachers can differentiate in those four ways but if they struggle

in an area, it can make differentiating difficult. For example, if a teacher struggles in content knowledge they may not be placing the sequence of tasks in the correct order, this could become frustrating for the students because a defined goal has not been created (Dolman et al., 2018).

Educators will know when and the degree of differentiation that needs to occur by utilizing formative assessments and summative assessments. This information can provide a clear picture of what kind of teaching needs to take place the following day after instruction and assessment. Teachers who do not utilize assessments, will not know if students have grown in their learning nor will they be able to identify students who may need more differentiation, enrichment, or interventions (Almarode et al., 2018). This would cause teachers to group students without the evidence of where they should be placed, and the students could potentially be placed above or below their skill level. Teachers who lack a clear purpose on what is expected of the students struggle to differentiate because standards do not have embedded strategies for differentiation of the content (Almarode et al., 2018).

Why Should Teachers Differentiate Instruction?

Differentiated instruction provides students an opportunity to learn science content in a variety of ways based on data that was collected through pre-assessment and post-assessments. Kumar (1993) found that differentiation helped reduce the phobia or fear of science for students and these students eventually developed an appreciation for science due to personalized instruction for groups of students. Through differentiation, Bell and Maeng (2015) reported that students were more actively engaged and had a

higher conceptual understanding of major science topics because differentiation allowed for more opportunities to engage in discussions, debates and to work cooperatively with their peers.

Dolman et al. (2019) stressed that differentiated instruction is not a one-size fits all approach and that data from formative assessments is used to drive the instruction to benefit the students both socially and emotionally in the classroom. A strategy that Dolman et al. (2019) utilized was focused on goal setting in the classroom. The researchers had the students perform a pre-assessment and then set goals after it was administered. They emphasized that this approach to differentiated instruction allows for student empathy towards the science topic being taught (Dolman et al., 2019). The data is used to aid in the decisions being made for groups of students in the classroom that need different aid or instructional differences in the subject matter. Evidence is determined from pre- and post-assessments which provides strong reasoning as to why differentiated instruction is vital to students learning science content. Differentiated instruction is a teaching approach that can encompass the student as an individual instead of a statistic. It allows for students to become adverse thinkers and allows students an opportunity to deepen their knowledge of science content through a variety of ways such as altering the content, differing the process and product, and affect.

How do Teachers Differentiate Instruction?

When teachers begin to think about differentiated instruction it is important for them to have a concrete understanding of what they are expecting of students to meet the

students where they are at in their learning. Tomlinson (2017) says that by allowing students to choose their own agendas of learning, according to their interests, the students will grow in knowledge, especially when differing learning modalities are in place. Learning modalities include but are not limited to small group instruction, using technology, activities, interest centers, varied journal prompts, independent studies, jigsaws, varied texts, and supplementary materials. According to Tomlinson (2017) there are many ways to differentiate instruction and it is not a one size fits all style of teaching, but one theme is true the teacher is considered the leader who attends to the followers (students) closely and makes decisions based on the needs of those followers. These classrooms are student-centered where the students do majority of the work. The activities, space, time, and materials are the teacher's responsibility (Tomlinson, 2017). If the leader or teacher keeps the students in mind and provides multiple opportunities for student engagement and varied supplements based on student needs the teacher is differentiating.

Differentiated instruction does not only have to be utilized for struggling learners but can also be helpful for the students who require enrichment in the content. Enrichment can take place by changing the product in which students create, the amount of rigor or depth of knowledge required of that student, or by allowing those students an opportunity to do an independent study of a branched off topic (Tomlinson, 2017). Students who are not challenged in their learning can become bored and disinterested in science, According to Hattie (2019), boredom has a reversal effect, -.49, on student learning and can lead to disengagement and deficit.

An approach to differentiating instruction that I utilized in the action research project was altering the groups that my students were placed in by comparing the flexible grouping differentiated instruction method to the tiered grouping instructional method. The flexible grouping method of instruction has another name called the jigsaw method. This approach to differentiation allows for the students to be experts in a topic to solve a larger problem. Students perform a formative assessment and are heterogeneously grouped where high performing students are mixed with low performing students. The students use their expertise, research, and communication skills to help their group answer a broad question surrounding a specific topic. This approach to differentiation has an effect size on student learning of 1.2 which is considered to greatly improve student achievement (Almarode et al., 2018). The alternative method of differentiated instruction that I utilized is the tiered grouping method also known as ability grouping. Students were placed in groups based upon their performance on a formative assessment, low performing students were placed together, and high performing students were placed together. Each group of students were given a task to perform based on the skills they showed detriments or a task that enriched what they already knew. Ability grouping of gifted students as an effect size of 0.30 which means it is likely to have a positive impact on student learning. The low performing students were required to remediate their formative assessments which is an example of intervention which has an effect size of 1.09 on student learning (Almarode et al., 2018).

The jigsaw method or flexible grouping method is an approach to learning in which students serve as experts on a topic and teach one another what they learned. For this method, I placed students into groups based upon their formative assessment results,

high performing students and low performing students were placed side by side within the same group. I placed the class into groups of four, this was dependent on the number of experts needed, each person within a group is designated a topic to become an expert in. The expert was then provided resources that only those students had access to. Individually, the experts learn as much as they can about the topic within a class period which is 52 minutes long. In the next class period, experts are asked to converse with other individuals who were the experts in the same topic and they had 15 minutes to converse. Within these expert groups, students share ideas and have small group discussions about their topics. After conversing with other experts, students are asked to teach their original groups, all individuals who focused on other topics, about their expert topic. At the end of the flexible grouping activity, students are given a post assessment to determine if the learning of the objective has been achieved (Winschel, 2015). For my study, the reason the flexible grouping method was chosen was because of (1) the effect sizes this method had on the students (Almarode et al., 2018), and (2) it requires students to synthesize information and share it with their peers. Students develop a deeper level of understanding and have a better grasp of the dialogue and vocabulary if they are speaking it to their peers (Macdonald, 2004). The flexible grouping method also enables students to be involved in the learning process because they are actively participating in the instruction. Figure 1 is a representation of what flexible grouping and tiered grouping would look like if presented side by side.

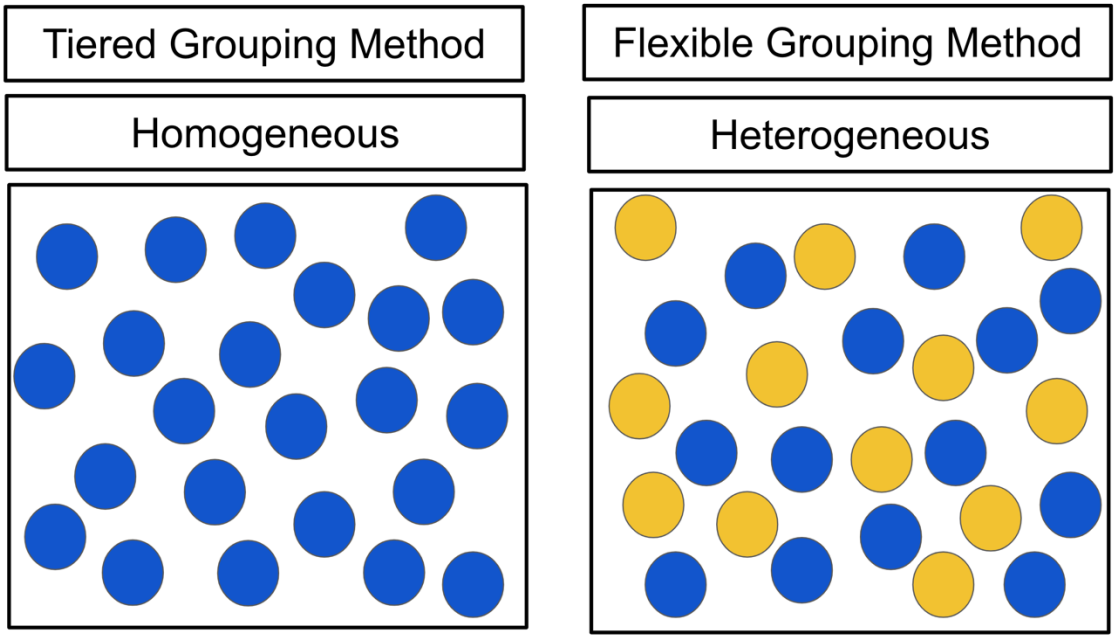


Figure 1. Representation of what the different groups might look like.

Tiered group instruction techniques place students in groups based on skills, concepts, and learners' needs (Richards, 2007). These groups were not permanent but were designed to take place in the classroom to provide a common instructional approach for each group. These tiered groupings either provided *enrichment* or *interventions* based on students' formative assessment results. Students who have achieved the targeted content were placed into *enrichment* groups where they deepened their understanding of the standards or provided a different product to show what they had learned. Students who had misconceptions or needed help learning the content or skills required for the learning goals were placed into the *intervention* groups. According to Hattie's 2017 study, intervention techniques in general have an effect size of 1.29 on students' learning (Almarode et al., 2018). The reason why the tiered grouping method was selected was because it was a stark contrast to the flexible grouping method, I wanted to compare the

differences between these instructional strategies because ability grouping has a low effect size on student learning of 0.3 (Almarode et al., 2019) and it is a common instructional strategy used amongst my colleagues.

CHAPTER THREE

METHODOLOGY

Demographics

The goal of my action research project via mixed methods research design was to determine the effectiveness of two differentiation instructional methods, tiered group instruction and the flexible grouping method, within my science classroom. I also wanted to know which students benefitted the most from differentiated instruction (a) high performing students, (b) low performing students or (c) both demographics of students. Another question the researcher focused on was how students perceive grouping strategies.

For the purpose of this action research project, I focused on my seminar physical science class at Sheridan High School in Sheridan Wyoming. The seminar physical science class was primarily made up of 9th graders who have a strong desire to go into a science field after high school. This is a group of mature students who are considered high achieving due to their placements in math and English courses. I taught three classes of seminar physical science, but for this study I focused on the 3rd and 4th period classes of students (N=42). One section had 20 students and the other section had 22 students. In these classes, 60% of my students identify as female, 2% as agender, and the remaining 38% of students identify as male. Three percent of the students enrolled in these classes represent an ethnic minority and come from several different ethnic backgrounds, including Hispanic and African American. Additionally, two students had IEP's for various reasons such as ADHD and Dyslexia and were provided accommodated

curriculum. Students are assigned Chromebooks and as a school we utilize Google Classroom as our learning platform to assign assignments, provide information, and feedback to our students quickly.

Demographically this group is considered an advanced science class but even with that there are varying degrees of being advanced. This is the third year I have taught this class and this cohort of students needed differentiated instruction more than ever. It is a fascinating time being a teacher right now, as these students were 7th graders when schools were shut down due to the COVID-19 pandemic and we were forced to teach online for an entire quarter. The amount of school students missed during quarantine and online learning had adverse effects on how they learn, do, and communicate about science. Through my action research, I hoped to determine whether differentiated instruction, either tiered groups or flexible grouping, or both, helped close the gap on how students communicate about and do science, and whether differentiated instruction supports all levels of learners in my science classroom in the same or different ways.

The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained (Appendix A).

Treatment

The seminar physical science course focused on chemistry and the units that were used for this research project were the *atom and the periodic table and bonding* units. The purpose of this study was to determine which differentiation instructional strategy had the highest effect size on science student learning, group tiered instruction or the

flexible grouping method of instruction. The treatment group performed formative assessments (Appendices B & C) associated with each unit to determine which form of differentiated instruction would take place. The method of instructional grouping depended upon if the whole class needed to remediate the information or if different levels of learning were obtained and tiered instruction should take place. Following the differentiated instructional strategy, a summative assessment was used to determine if students had learned the content. I also calculated normalized gains to determine the effect size that each instructional method had on the students science learning (Appendices I & J).

Prior to beginning the treatment session students were instructed to take a pre survey (Appendix F) to determine which students benefitted the most from differentiated instruction, high performing science students, low performing science students, or both to determine student's attitudes toward the instructional method. For the purpose of this study, high performing students are students who have a scored above average on the formative assessment and the low performing students are those who scored below average on the formative assessments. This distinguishment between students allows for easy grouping. This survey also gave me insight on the students' attitudes towards the different differentiation grouping techniques. The students took the same survey at the end of the research project to determine if their attitudes had changed and if the focus question had been answered about how students perceive differentiated grouping instructional methods.

Data Collection and Analysis Strategies

To collect data for the action research project I had to utilize a variety of ways collecting both quantitative and qualitative data. The data collected helped provide evidence towards the purpose of my action research project, which method of differentiated instruction had the greatest effect size on student learning and which students benefitted the most, high performing science students, low performing science students, or both. and how do students perceive differentiated grouping instruction. The instruments created to gather data included (a) a pre and post surveys, (b)formative assessments, (c) observations, and (d) summative assessments.

Formative assessments were a way to uncover and understand students' misconceptions and inform how instruction could be modified (Keeley, 2016). The formative assessments in this study asked students to think deeply about the science content and uncover preconditioned ideas the students had about the topics (Appendices B & C). The assessment techniques focused on improving the quality of student learning and was not utilized to evaluate the students. Instead, the assessment techniques drove instruction and determined which differentiation technique was to be utilized (Angelo & Cross, 1993). The formative assessments were generated from the teaching goal or purpose, this was created prior to instruction. The importance of this was that clear student friendly goals provided clarity and purpose for the students' as to why they were learning the material (Almarode et al., 2018). Clear teaching goals also helped guide the instructor in choosing and creating a formative assessment that helps identify the learning that had taken place and to what extent the learning had occurred.

Utilizing the results of the formative assessments, targeted instruction through differentiation strategies took place prior to the summative assessments. According to

Maeng and Bell (2015), differentiated instruction methods are used to maximize students' potential and identify if learning goals have been achieved. Two types of differentiation were utilized in this study, tiered group instruction or flexible grouping based upon the results from the formative assessment (FA). For group tiered instruction, students were placed into six different groups dependent upon their scores and provided tiered instruction based on the students' needs. In this project students who scored above average or better on the FA were placed in the high performing group. This group was provided enrichment which further explored the concept of the structure of the atom and took the students' knowledge to greater depths (Appendix F). Students were asked to work together to complete a rigorous task and turn in a completed task sheet. The cluster of students who scored below average on the FA were placed in a group together and were offered remediation based on the questions that they had answered wrong on the FA. This remediation process was led by the teacher so that reteaching could take place. The FA results from the *atom and periodic table* (Appendix B) expressed that there were large gaps in some students learning so the tiered grouping method was selected for this type of remediation.

In the *atomic bonding* unit large amounts of remediation were not required and the research employed the flexible grouping technique. This technique has an effect size of 1.2 on student learning (Almarode et al., 2018) and in order to effectively use this strategy students are intermixed, both low performing student and high performing students are intermingled together. This is a cooperative learning approach in which small groups of students are responsible for becoming experts on specific topics and then asked to teach their classmates or apply their knowledge to a task (Winschel, 2015).

Working together, high performing students and low performing students, created a stop motion animation video describing how compounds are formed (Appendix C). The students who were lower performing were tasked with modeling the ionic and covalent bonding portion of the assignment and the high performing student was asked to model bond energies within the compound. Once again students were asked to collaborate with one another to complete the task but this time intermingled.

Observations were used to collect qualitative data, which is a means of collecting data that requires careful observation of what is said, heard and seen in a specific setting (Mertler, 2020). During this study, I made unstructured and structured observations. Unstructured observations were made using field notes (Appendix H) while students were working in their differentiated groups, allowing me to continue working with the class while looking for behaviors that were helpful for answering my research questions. I chose to use this method because Hendrick (2009) notes that it is important for the teacher to jot down things as they occur and then make more detailed notes as soon after the observation as possible to use as a narrative. Structured observations were made using recordings of the differentiated lessons and documented via field notes (Appendix G). I used this type of observations while reviewing the recordings, and reviewing the formative assessment data to determine which groups students were placed in.

Table 1. Active observer field notes

Date:	Time:	Events:

Unlike the formative assessments, the summative assessments were used to determine if the differentiation strategies were successful. Summative assessments were used to measure the amount of growth a student had made over a given topic. The summative assessment is related to the formative assessment in which it evaluates the same skills, content, and knowledge that the formative assessment evaluated (Almarode et al., 2018). The summative assessment was made with the same targeted learning goals and were utilized to determine if gains in learning had occurred. They are important to use because it allows the teacher and students closure and understanding of a topic (Mertler, 2020). The Unit 7 Summative Assessment: Atoms and the Periodic Table (Appendix I) was used to gather data to determine if the treatment was effective on student learning. The summative assessment focused on the trends of the periodic table and the structure of the atom. This was a traditional approach to test taking.

The second summative assessment, Summative Assessment Unit 8: Bonding (Appendix J) is based on how well students describe and explain how atoms bond together using models and what they have learned about how atoms interact. The reason why this assessment will be utilized is because it had students perform a variety of tasks such as select a claim, based on evidence that we had done research and a lab on and then reason through why their evidence supported their claim. In this assessment students

were asked to write a balanced chemical equation that provided evidence that atoms are neither lost nor destroyed during a chemical reaction but conserved and students are differentiate between determine bond types. This summative assessment was chosen because it determined if the chosen differentiated instruction was effective.

At the end of the project a post student survey was executed after the instructional strategies had been utilized. This student survey (Appendix F) helped the teacher determine which students benefitted the most from differentiated instruction, and it is referenced back to the question "How do students perceive these differentiated grouping strategies?" Surveys are a beneficial way to collect data when an interview or conference is unreasonable for the time allotted (Hendricks, 2009). In the survey students were asked 5 questions, three questions were a Likert survey asking them to describe how well they agreed or disagreed with an instructional grouping approach, there were also two opened ended questions associated with the survey.

Pre and Post Student Survey

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way. You do not need to put your name on this survey. Please respond to each statement as honestly as you possibly can and only circling one number for each statement, then respond to the following questions.

1 = strongly disagree 2 = disagree 3 = no opinion 4 = agree 5 = strongly agree

1. The flexible grouping differentiated instruction method was helpful

1 2 3 4 5

2. The tiered group differentiated instruction method was helpful

1 2 3 4 5

3. How can we improve upon the differentiated instruction strategies?

4. As a high achieving student do you feel these strategies helped your learning? Explain.

1 2 3 4 5

5. Is there anything else you would like to include about differentiation strategies? If so, please write your comments here.

Figure 2. Pre and post student survey.

A survey may allow students to be more honest about their answers and not pressured into saying what the teacher wants to hear. The survey contains open ended questions that allow the individual to provide their own answer and it may reveal hidden thoughts or feelings towards the content or teaching method (Mertler, 2020). Student surveys are a way to collect quantitative data that can be analyzed for trends or themes. Located in Appendix F is the student survey that treatment group completed. Overall, the pre and post student survey asked the students' which strategies were most and least effective, how can the differentiation strategies be made better and their overall feelings of the differentiated strategies.

Table 2. Data Triangulation Matrix.

	Focus Questions		
Data Collection Instruments	Which methods of differentiated instruction have the highest effect size on student learning in science?	Who benefits the most from differentiated instruction, high performing science students or low performing science students?	How do students perceive these different grouping strategies?
Formative Assessments (Pretests)	X	X	
Summative Assessments (Posttests)	X	X	
Active Observations	X	X	X
Passive Observations			X
Pre and Post Student Survey		X	X

Analysis Strategies

The pre and post student surveys were analyzed by creating a bar graph, this showed frequencies of each response reported by the students (Bowen & Bartley 2014). The pre and post student survey's included Likert type questions that asked the students to indicate on a scale of 1 to 5 if they *strongly agree, agree, no opinion, disagree* or *strongly disagree* that the different methods of differentiation were helpful. The pre and post student surveys were analyzed side by side to determine if student's attitudes had changed about differentiation instruction techniques. The data gathered from the pre and post student surveys were displayed next to one another to view trends in the pre and post student surveys (Hendricks 2009). Conclusions can be made from this analysis technique that can answer the question of "How do students perceive these different grouping strategies". There are two other questions on the pre and post student survey's that ask students "how to improve the differentiation strategies" that were presented to them. The answers to these questions were categorized based upon how the students responded, the

categories included positive comments towards tiered grouping, positive comments towards flexible grouping, negative comments towards tiered grouping and negative comments toward flexible grouping. Data collected in this fashion is considered nominal level data (Bowen & Bartley, 2014) because the data was sorted into categories and did not have an obvious order.

The paired T-test was utilized to determine if the differences between the formative and summative assessments was significant, and it would allow me to draw conclusions about my student population. Paired T-tests compare the average means between two sets of data (Bowen & Bartley, 2014), it allows teachers to determine if the averages are statistically significant. Did the variable, differentiation grouping strategy, make a significant difference or was it merely chance. If there is a significant difference between the means the p value is less than .05 and if it is insignificant the p value is greater than .05 (Salkind, 2010). The calculated value of .05 is typically used in educational settings because it allows for a 5% difference in the idea that data collected has a 5% likelihood of being by chance (Mertler, 2020). Essentially, the paired T-test allowed me to determine if the treatment influenced the student's ability to learn science content.

Normalized gains are used to measure student learning and to understand the usefulness of an instructional strategy (Nissen et al., 2018). It is a form of statistical analysis used to determine how much information the students learned compared the amount of information the students should have learned. It is a method used to measure growth or change and is often utilized in the educational setting, the normalized gain for individual students were analyzed and then averaged with the other students to observe

an overall normalized gain. If the normalized gains are less than .3 it is considered small gain, if it falls within .3-.6 it is considered medium gain and greater than .7 it is a large gain in knowledge (McKagan et al., 2018).

Box and whisker plots were generated to compare mean, median and mode between the formative and summative assessments, it provided a visual to determine the average growth in student learning between the assessments. These plots are necessary to include in the research project because it allowed the researcher to view the data, outliers are included, and the upper and lower quartiles are displayed in a graphical representation (Bowen & Bartley, 2014).

The observational data was analyzed qualitatively based on observations made during the formal and informal observations. Mertler (2020) suggests making notes about any patterns of interests and creating a coding scheme to interpret the data, the coding scheme allowed for information to be grouped and organized. The observations were analyzed by using a scatterplot from the checklist (Appendix H). These observations allowed me to view the types of behaviors that had occurred between the successful groups of students and the unsuccessful groups (Hendricks 2009). This information helped me answer the question "which method of differentiated instruction have the highest effect size on student learning in science." The reason why this helped me answer the question is because it allowed me to determine which method engaged the students in their learning.

Table 3. Field notes as a passive observer.

Behaviors and activities	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Students are engaged in the content						

Students are having appropriate conversations related to the topic						
Students are clarifying information						
Students are helping one another out						
Students are respectful of one another						
Students stay on task						
Students turned in task sheet						

Processing student comments from the pre and post student surveys was another way to determine how students perceived the differentiated instructional grouping strategies. The comments were categorized based on whether they were positive or negative towards a grouping strategy. They also provided truthful insight as to why or why not students liked an instructional strategy (Hendrick, 2009)

CHAPTER FOUR

DATA ANALYSIS

The results of placing the students into homogenous groups and heterogenous groups based on their skills are as follows. For the tiered grouping strategy, the total normalized gain was 6% (N=42) and the total normalized gain for the flexible grouping strategy was 51% (N=42) (Table 3). The average pretest scores for the tiered grouping method were 66% and increased 5% after the grouping strategy for intervention had taken affect. Average pretest scores for the flexible grouping strategy overall were higher, 82%, but after the differentiation had taken place there was greater growth in student learning by 8%. To better understand the results a paired t-test was done to determine if the results between sets of data at varying points in time were significant or not. The paired t-test indicated that the tiered grouping strategy was irrelevant with a value of 0.28, a test value less than 0.05 is deemed to be noteworthy. The paired t-test told a different story when analyzing the flexible grouping method though and a value of 8.802E-07 was calculated. There was a suggestive difference between the pre and posttest data sets.

Normalized gains were calculated to determine what the students could have learned compared to what the students did learn. When previewing the data, the tiered grouping strategy had a normalized gain of .06 which is considered low. This means the students overall did not learn very much compared to what they should have learned. In contrast the flexible grouping strategy showed a medium gain of knowledge with a value of .514.

Table 4. Grouping strategies formative and summative assessment averages and normalized gain, (*N*=42).

Grouping Strategy	Formative Assessment	Summative Assessment	Treatment Gain
Tiered Grouping	66%	71%	0.06 (low)
Flexible Grouping	82%	90%	0.514 (medium)

Tiered Grouping Strategy

An analysis of the averages between the pre and post test data showed that the average pre-test scores jumped from 66% to 71% during the summative assessment. This is a gain of 5% in the overall averages (*N*=42). A box plot was generated to represent the mean, median, and upper and lower quartiles of student data for the tiered grouping strategy. In the pretest of the tiered groups the dispersion between the numbers is nearly symmetric which means the distribution between the upper quartile and lower quartile are proportional. There is one outlier in the pre-test data where a student scored a 0% on the pretest. The post test data is skewed toward the upper quartile and the scattering of the data between upper and lower quartiles is larger meaning there was a broader range of scores between the median and the lower quartile. Neglecting to include the outlier, the range between the highest score of the posttest data and the lowest score was increased by 4%, which suggests an increased gap in student learning even though the average increased (Figure 3).

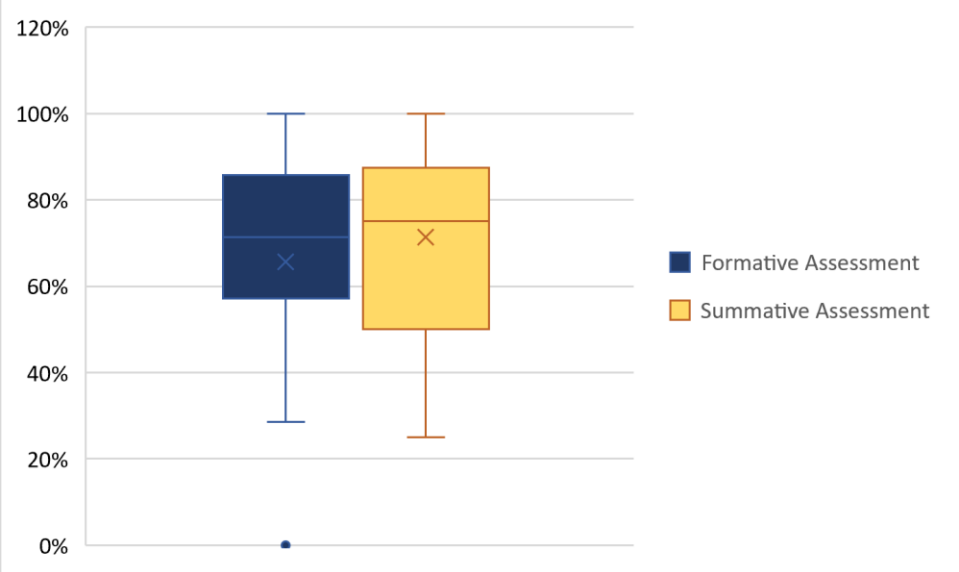


Figure 3. Score distributions of the formative and summative assessment scores for tiered grouping, (*N*=42).

Flexible Grouping Strategy

An analysis of the data between the formative and summative assessments for the flexible grouping strategy was investigated by creating a box and whisker plot. Viewing the plot, Figure 4, shows that the median score values between the formative and summative assessments increases from 83% to 92%, a growth of 9%. The bottom scores for pretest were 42% and the bottom score for the posttest was 58% and the top score in both data sets is 100% (*N*=42). The figures for the posttest were skewed towards the top end of the data set meaning that there was a greater number of students that scored above the median on the posttest. The lower quartile shifted from 76% to 85% after flexible grouping intervention had taken place and the range between the highest score and the lowest score was reduced. These results suggests that most of the students were able to show proficiency in the content area

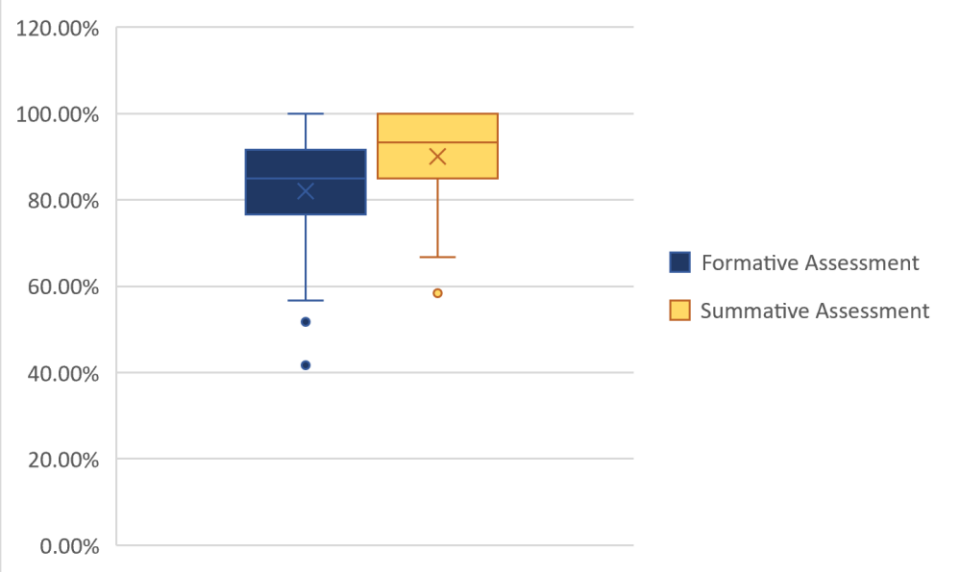


Figure 4. Score distributions of formative assessment and summative assessment for flexible grouping, (*N*=42).

Comparing Flexible and Tiered Grouping Strategies

For the study, we also needed to determine which students benefitted the most from each type of grouping strategy. I did this by sorting the students based on how well they did on a pretest, if students scored lower than the average they were placed in the lower performing group and if the students scored above the average pretest score were placed in the high performing group. A bar chart was created to represent the gains in learning between the high performing students and low performing students. This determined which students benefitted the most from each instructional strategy, high performing students, low performing students or both types of students. The flexible grouping method showed growth in both high performing (*n*=26) and low performing students (*n*=16). The high performing students increased their average scores by 7% and the low performing students increased their average score by 12% (*N*=42). Even though the students had a greater understanding of the content, it seems as though most of the

students benefitted from working with their peers in a small heterogenous grouping. The normalized gain was calculated to determine what the students may have learned. For the high performing students there was a gain of 64% and for the low performing students there was a gain of 38% (Figure 5).

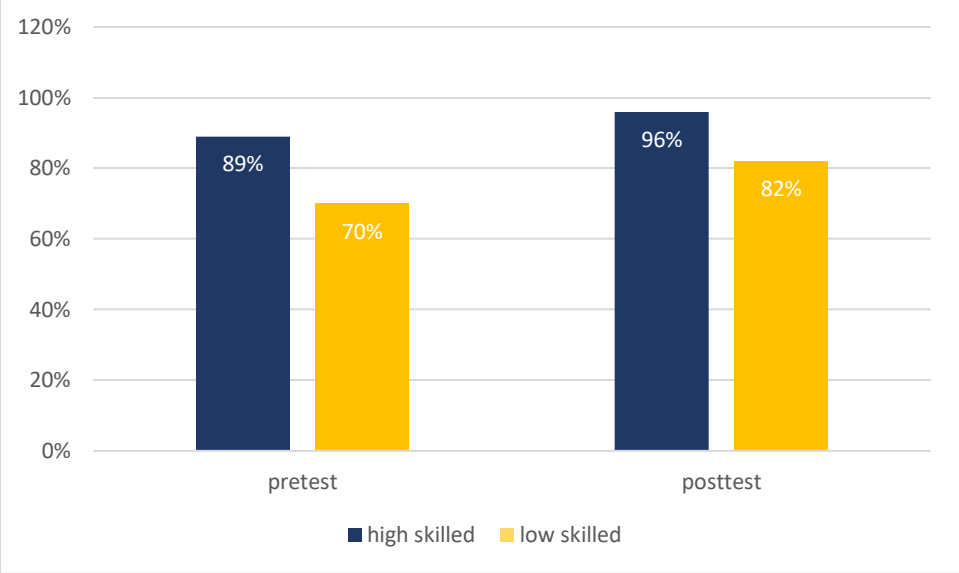


Figure 5. A comparison of high performing students and low performing students after flexible group instruction, (*n*=26) (*n*=16).

In the tiered group instruction, there was a greater difference between the high performing students and low performing students (*N*=42), the average score for the high performing students was 83% (*n*=26) and the low performing students settled at 35% (*n*=16). The tiered group instruction hindered the high performing students and they fell from 83% to 74% in their average test scores. However, the low performing students benefitted from this instructional strategy and increased their average test scores from 35% to 68%. Normalized gains were calculated to determine what the students could have learned. The low performing students in the tiered grouping instruction had a medium gain of 32% and the high performing students had a low gain of 9%.

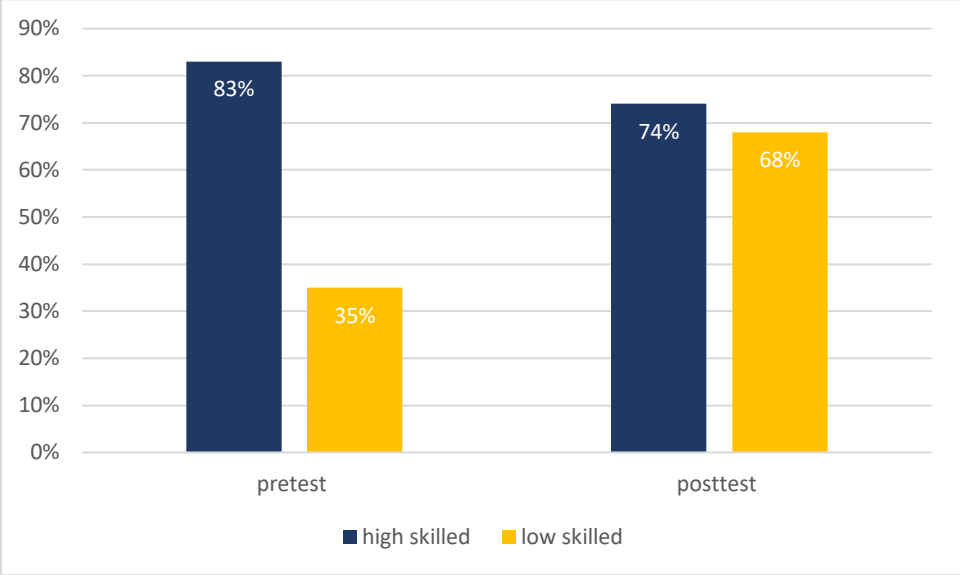


Figure 6. A comparison of high performing students and low performing students after tiered group instruction, (*n*=26) (*n*=16).

A paired t-test was done to determine if there was a significant difference between the bottom half of the students during the pretest and posttest, with a p-value of .05 the whole class (*N*=42) was 0.277, the bottom half (*n*=16) was 0.0018 and the top half (n=26) was 0.076. The tiered differentiation strategy was only significant for students who were placed in a low performing group. The paired t-test was also used to determine if there was a significant difference between the three different categories, *whole class, low performing students, and high performing students* for the flexible grouping strategy. In all three categories the data provided evidence that the grouping strategy was effective (*N*=42). The shaded groups indicate the categories and strategies that were significant.

Table 5. Paired T-test results for tiered group and flexible group instruction, (*N*=42).

Category	Tiered Grouping Strategy	Flexible Grouping Strategy
Whole Class	0.28	8.802E-07

Low Performing Students	0.0018	6.846E-04
High Performing Students	0.08	1.331E-04

Student Perceptions

Pre and post surveys were used to determine the overall perception students have towards grouping differentiation; A Likert survey was given to the students before the instructional strategies took place. It was scaled from 1-5, *1 = strongly disagree, 2 = disagree, 3 = no opinion, 4 = agree, and 5 = strongly agree*. Comparing the pre and post student survey questions helped answer the question "How do students perceive these different grouping strategies?" The pre student survey data resulted in students articulating that in general they *agree* or *strongly agree* with these grouping strategies helping their learning with a combined total of 51% (N=42) (Figure 7). This average increases from 51% to 59% between the pre and post student survey. The pre and post student surveys then asked students to respond, "tiered grouping differentiated instruction method was helpful", in the pre student survey 30% of the students *agreed* and 18% of the students *strongly agreed*. The post student survey displays a different trend and the *strongly agreed* category decreases to 10% and the *agreed* category increases by 11% (Figure 8). The flexible grouping category showed the greatest growth in change of students' perceptions, in the pre student survey 43% of the students *disagreed* or *strongly disagreed* with the flexible grouping strategy and only 34% of the students either *agreed* or *strongly agreed* with this method. The remaining students had *no opinion* on the matter. After working through the differentiation strategies, the data in the post student survey showed that the perception changed about flexible grouping differentiation and the majority of the students expressed that they *agreed* or *strongly agreed* with these

categories increasing from 34% to 69%. The number of students who *disagree* or *strongly disagreed* decreased by 35% (Figure 8 & 9).

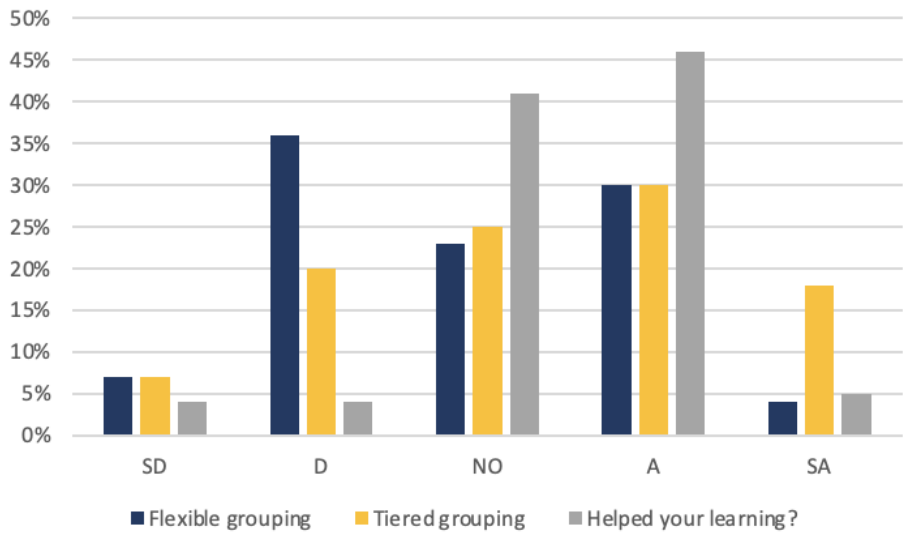


Figure 7. Pre student survey results, (*N*=42).

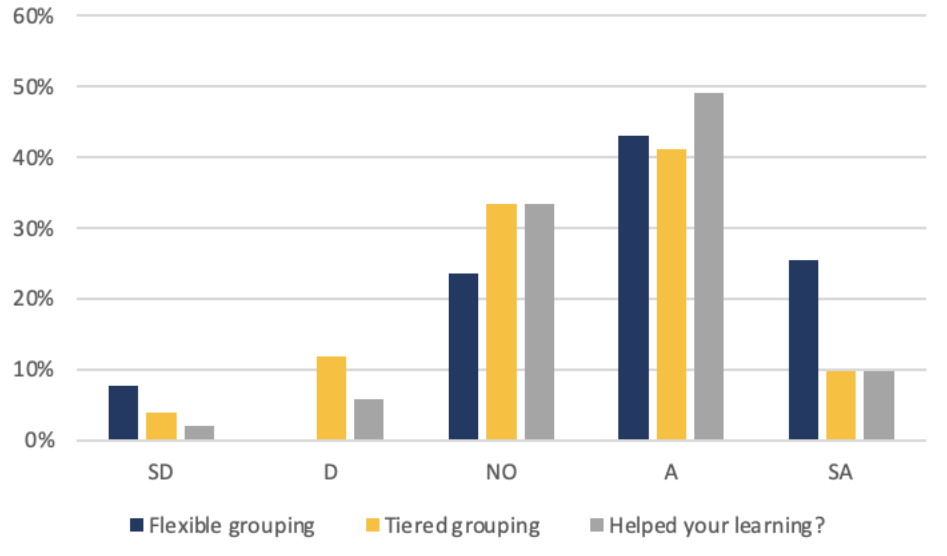


Figure 8. Post student survey results, (*N*=42).

Positive and Negative Comments

Students were asked in the surveys "As a high achieving student do you feel these strategies helped your learning?" The students' responses were then sorted based upon positive and negative comments towards each grouping method, this method of sorting provided evidence towards the student's perception of each style of differentiation. Prior to asking them this question, I explained to the students how I have been grouping them for each assigned task. I did not release the students individual scores, I kept these to myself on a separate document. A theme among the positive comments towards flexible grouping emerged about the how when the student's explained information to their peers it helped them remember material from the topic covered and they were able to get more repetition. The negative comments about flexible grouping concluded that students are bad at teaching one another and that when this happens the pace of the class slows down.

Table 6. Sample positive and negative comments for flexible group instruction, (*n*=5).

Positive Comments	Negative Comments
"this helped my learning because I got extra practice on things that I was unsure about"	"Please do not do flexible grouping because kids are bad at teaching other kids' stuff about, they know nothing about, I hate learning like this"
"I think the mixed groups helped me because I learned different ways to remember things and learned new strategies."	"If you put together everyone who understands it together, the others won't have a chance to discuss with other who understands it better"
"I think flexible is best because higher-level students explain things to lower-level students, which helps both."	"Sometimes it is better for all students to have the same research because they will all take the same test"
"Yes, because you could get the help you needed from your peers or learn more by having to explain it to your peers."	"Instructional strategies hinder our learning the way information is perceived makes it more difficult to learn harder material because of the slow pacing. Other ways of pursuing information that aren't researched taking information from Google or from others"

“Yes, I do. When placed in a flexible group, you can learn and get better which was great”	“The flexible grouping made learning less engaging, whereas tiered grouping it made me feel as though I wasn't just helping everyone else”

Several students favored the tiered grouping method, according to the positive comments it was because students were not relying on one another for answers or trying to help the weaker skilled students. They also claimed that they were able to have higher-level conversations with each other and expand their knowledge or understanding of a topic. The negative comments towards the tiered grouping method were linked however to how this strategy made students feel. Some students expressed how they felt “stuck” and judged upon when placed in tiered groups, one student even mentioned that it makes them feel “insignificant about themselves” and if teachers could reduce this “prejudice” then it would be beneficial.

Table 7. Sample positive and negative comments for the tiered grouping method, (*n*=5).

Positive Comments	Negative Comments
“I think that the tiered grouping helps me if I don't understand what is going on and it helps teach other students if they don't get it.”	“I think we shouldn't do tiered grouping because if it is people that got a let’s say 70% with everyone at that in one table, people will have a harder time learning because there is nobody to really learn from.”
“I like tiered grouping better because it is easier to learn together and everyone is more likely to help each other, whereas, in the flexible group, sometimes, nobody is willing to help you which makes it difficult.”	“I don't think tiered group instruction is very effective because it keeps low grade kids together and stuck instead of allowing them to expand and grow their knowledge and grade with peers that will influence them positively”
“I prefer the tiered group mostly because I find it a lot more annoying to have to answer other questions constantly or to be constantly asking the same person questions”	“It can be improved by each group getting a different amount of help instead the teacher working with only the ones who failed.
“When I am in the tiered group, I am much more inclined to have more intellectual conversations with my peers which I believe	“If you use tiered group method it will makes kids that don't have a good of grades as others feel insignificant about themselves and how

contrary to the date helps me progress farther in class. When I am in the flexible grouping, I feel like I am more focused on helping the others understand what is going on than I am more focused on myself which I feel keeps me flat lined.?	smart they truly feel about themselves whether it be good or not"
"I think the tiered grouping was better because people can figure stuff out together and be on the same page and in flexible grouping there is probably going to be one person that knows more that is explaining how to do something"	"When doing the strategy there becomes a ranking level and lots of judgement, when you put lower grade students in a group they are judged as being "dumb" kids compared to the "smart" kids. If that prejudice could be removed from the equation, then it will work oh so much better "

When the students were placed in the tiered groups, I had to help the students in the lower performing group grasp the content. These students were working on the basic structure of the atom and the trends of the periodic table. They had misconceptions that needed to be addressed for them to be successful on the post assessment and in later units. Once the misconception was conquered, these students were assigned a basic version of what the higher performing students were doing, they were applying the same information, but it was scaffolded. The higher skilled students were responsible for completing a task that took the concepts they had previously learned and apply them to different scenarios such as photons of light being emitted as an electron falls back to its lowest energy level (Appendix D). This was applied to a firework sparkler. These students were not assigned tasks like they would be in the flexible grouping method and in my observations, I noticed that one or two students in the groups took on the role of researching all the information, Figure 8, displays the number of groups that were on task during each grouping strategy. The students who were not researching were having side conversations about various topics, some not centered around the assignment.

Observations

Observations made during the flexible grouping method were witnessed while students were researching their specific topics. Students were selected based on their formative assessment scores which task they would be assigned; the higher performing students were appointed a task that was more tedious and difficult to do. The lower performing students were given an assignment that was easier to do investigate and I appointed them resources to use in their research. All the students took on the responsibility of doing research, but they struggled in sharing the information they learned. One student said, "here just copy this down", instead of teaching the group the information they had researched.

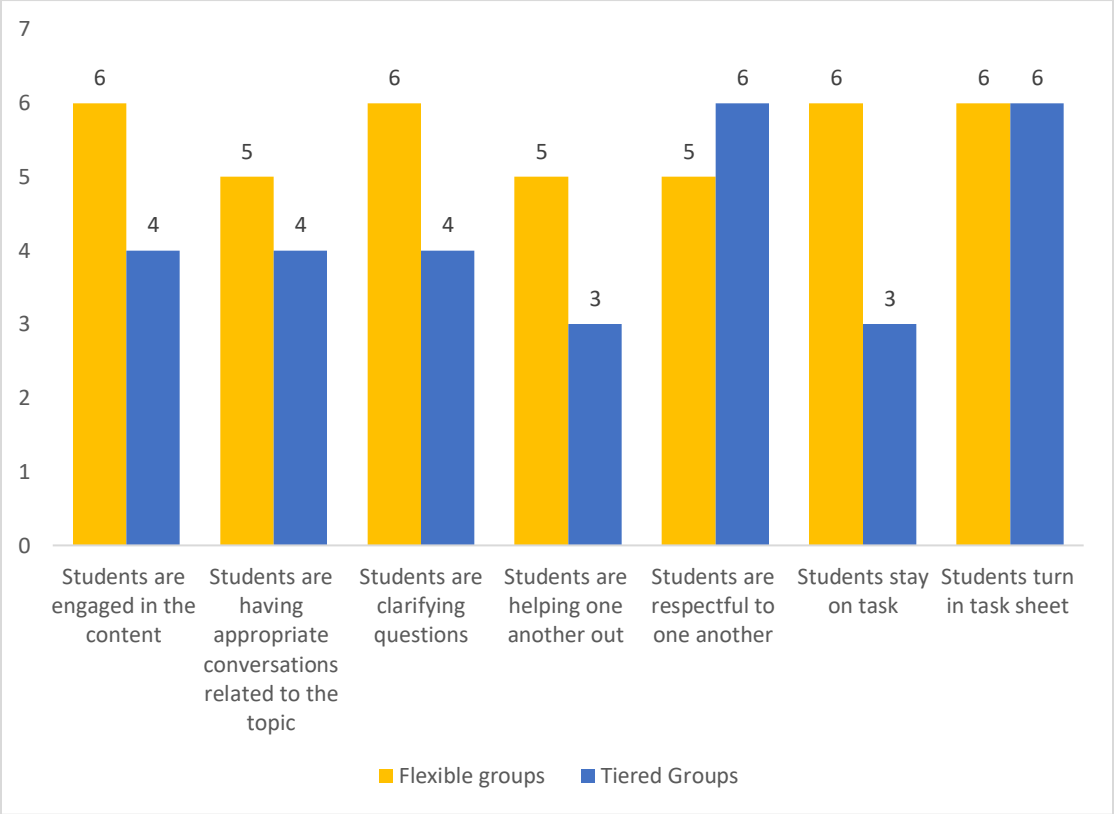


Figure 9. Observations as a passive observer, the number of groups that were on task, (*n*=6).

After making this observation I gave students 12 minutes to be a teacher and present their information, as they presented the other students were responsible for taking notes on the topic. I graded the student's note sheet to hold them accountable for the information and in the end these students completed a task that required them to come together with the different pieces of information that they explored. During the flexible grouping differentiation, I noticed that nearly all the students were on task and were able to share information about their topic.

CHAPTER 5

CLAIMS EVIDENCE AND REASONING

Claims from the Study

Flexible Grouping is Superior

The data collected in this study shows that flexible grouping differentiation plays a significant impact on both high performing and low performing students and improves the overall understanding of the class. When comparing the formative and summative assessment test scores, there was a considerable gain in knowledge of .514 (N=42) using the flexible grouping method, the tiered group instruction did not have the same effect on students and there was only an increase of .06 (N=42) which is considered low. During the flexible grouping method students had the opportunity to use the language of the content and were held responsible for not only learning specific information but then were asked to teach it to their classmates. According to *Why use jigsaws* (2021) there are multiple benefits to using this strategy such as

1. students must speak the language of the content
2. each student has an opportunity to contribute
3. cooperative learning must take place in order for the students to be successful.

This is starting to sound a lot like the successful work environments we encounter every day.

Another term for flexible learning is cooperative learning and it's described as being active learning where the students are held accountable to help develop a solution to a problem (Oakes, 2018). This method promotes group processing, critical thinking, problem solving, and social interactions, I found this to be a very important method when developing students for the real world. Through utilizing the method of flexible grouping, I hope to foster a culture of learning in my classroom. This led me to think about a comment that a student made about flexible learning and tiered learning:

> When doing the strategy there becomes a ranking level and lots of judgement, when you put lower grade students in a group they are judged as being "dumb" kids compared to the "smart" kids. If that prejudice could be removed from the equation, then it will work oh so much better.

I can completely agree with this statement, and I feel that tiered grouping instruction gives the students this perception that there are "smart" and "dumb" kids because students are grouped based on their proficiency of a skill. If we could help alleviate the "dumb" kid "smart" kid ranking system that kids subject themselves to then maybe we can help our students become better citizen scientists. Meaning that they are more open to sharing their ideas, working collaboratively, and nurturing each other's ability to do science! According to Alamarode et al. (2018), the flexible grouping method (cooperative learning) has an effect size on student learning of 1.2 and tiered grouping (ability grouping) has an effect size of student learning of 0.30 effect size on student learning. My research project demonstrated evidence of the effect size values that Hattie had calculated.

Flexible Grouping Method Benefits All Students

In doing this research project, I found that both high and low performing students benefitted from this instructional strategy. The data concluded that after the flexible grouping treatment the high performing students had increased their scores from the formative assessment to summative assessment by 7% and the low performing students increase their assessment scores by 12%. The paired T-test values also suggested that the flexible grouping method is the better option because both high performing students and low performing students had a significant gain in knowledge between the formative and summative assessments. The paired T-test also identified that the treatment during the tiered group instructional method was significant to my low performing students. This is because they had direct instruction from myself, and they had a large gap to fill.

Observations also support this idea that the flexible grouping method benefits all students. Mosg of the students were on task and were engaged in the content during the flexible grouping method. When viewing Figure 9, most of the students during the flexible grouping method showed positive engagement in the content such as *asking clarifying questions* and *staying on task*.

Students Prefer Tiered Grouping

Unfortunately, students perceive the different methods of differentiated instruction as a hinderance to their own learning. One student mentioned that “I prefer the tiered group mostly because I find it a lot more annoying to have to answer other questions constantly or to be constantly asking the same person questions.” This student did not want to take on the role of helping their classmate understand the material that they were engaging with. Another student mentioned “please do not do flexible grouping

because kids are bad at teaching other kids' stuff about, they know nothing about, I hate learning like this." The flexible grouping method was frustrating to many of my students, but the data speaks for itself. Even though it was more difficult for the students to perform it had an overall higher impact on the students with a calculated t-test value of 8.802E-07 (N=42) for the flexible grouping method and a t-test value of 0.28 for the tiered group instructional strategy. These values were calculated to determine if the data showed a significant difference between the formative and summative assessment data and a p-value less than .05 was determined to be significant.

Value of the Study and Consideration for Further Research

My action research project was a small-scale result of what happens when students are placed in homogenous and heterogenous groups. At Sheridan High School, we have been creating homogenous groups amongst our 9th and 10th grade students according to the classes that students have been enrolled in. For example, the freshman class that I taught was a seminar physical science class. This class was designed for students who scored advanced in Wyoming state assessments. This class teaches the exact same standards, but it is geared to our high performing population of students. What we have done inadvertently at the high school is taken the "cream of the crop" and placed them in a single group. The other students who are not considered high performing are placed in the general physical science class. I believe this hinders the general physical science population because those students have no high performing students to set the bar higher and so expectations are set low. These classes also tend to have more behavioral issues that could be absorbed when there are more well behaved

and higher performing students in the class. A ranking system has been created between the “smart” kids and the “dumb” kids and it widens the gap between these students socially.

Moving forward in my classroom, I will continue the idea of fostering a community for learning. I plan on using alternative methods of instruction in my classroom that will allow all my students to feel that they can contribute to a group, feel a sense of purpose, and obtain the skills required to associate with their classmates and be successful. As we found within the seminar physical science class, there were gaps between my high performing students and low performing students and the gaps needed to be shortened in a way where both students benefit.

Impact of Action Research on the Author

In the beginning of this action research project, I really thought that I was “jumping through the hoops” to obtain a master’s degree in science education. I did not feel the true value of the project until later in my process when I was describing my research to the assistant principal of my building. She said, “oh wow, you get to be your own researcher and act as a scientist.” For some reason I had never framed this in my mind that way and I felt a spark of joy and excitement as I was finally able to do what I preach to my students about: (a) Develop a claim from observations that I had in my classroom, (b) create focus questions to help guide my research, (c) craft tools to help gather and (d) analyze data and, finally, (e) reason through my evidence to support or refute my claim. I am my own scientist!

This action research taught me that I am capable of conducting credible research to inform my instructional practices and the decisions of others. Through action research, I can conduct my own research to best support my students in science class. As a science educator, the data collection process is a valuable tool that I can apply to my own teaching practices and potentially to other professionals. Using collected data, I could put together a purposeful presentation and present my findings to my colleagues and network. Maybe I can help guide and inform instructional practices to best fit our student's needs in the future.

One next step I'm interested in exploring connected to this research project is long term effects of utilizing homogenous groups during 9th and 10th grade years. The reason why I care about this topic is because my project implied that homogenously grouping students had adverse effects on their learning. As a result, I would like to explore the effects that this grouping has on student populations. Current ACT data is out for the 2021 school year, and it would be interesting to analyze the data to view downward or upward trends through this homogenous grouping of students.

By participating in this research project, I plan on continuing to implement the various grouping strategies that I researched. Even though through my research the flexible grouping method was superior to the other, I plan on using a healthy dose of both. I have learned that when students collaborate with their peers that they learn best, and I should nurture this community of learners. I never would have made these connections without this process. The process was frustrating at times. I had to make many decisions such as which methods to use to analyze data and digging through research to better understand my own. It was worth it though. I am happy that I pushed through the frustrating

moments for the end goal. I have grown both professionally and personally as now I know that I have the tools to make noticeable and recordable changes within my teaching career. I will continue through the process of doing action research to best support or refute my actions as a teacher.

REFERENCES CITED

Almarode, J., Fisher, D., Frey, N., & Hattie, J. (2018). *Visible learning for science, grades K-12: What works best to optimize student learning*. Corwin.

Alt, D. (2018). Teachers' practices in science learning environments and their use of formative and summative assessment tasks. *Learning Environments Research*, *21*(3), 387–406. http://dx.doi.org.proxybz.lib.montana.edu/10.1007/s10984-018-9259-z

Angelo, T. A., & Cross, K. P. (1993). *Classroom assessment techniques*. Jossey-Bass.

Barron, B., Cook-Harvey, C., Darling-Hammond, L., Flook, L., & Osher, D. (2020). Implications for educational practices of the science of learning and development. *Applied Developmental Science, 24*(2), 97-140. https://doi.org/10.1080/10888691.2018.1537791

Bell, R.L., & Maeng, B.L. (2015). Differentiating science instruction: Secondary science teachers' practice. *International Journal of Science Education, 37*(13), 2065-2090. https://doi.org/10.1080/09500693.2015.1064553

Bowen, M., & Bartley, A. (2014). *The basics of data literacy: Helping your students (and you!) make sense of data.* NSTA Press.

Corrigan, R., Gunstone, D., Jones, R., Gunstone, Richard, Corrigan, Deborah, & Jones, Alister., (2013). *Valuing assessment in science education: Pedagogy, curriculum, policy.*

Dolman, D., Frerejean, J., Geel, M., Keuning, T., Merrienboer, J., & Visscher A., (2019) Capturing the complexity of differentiated instruction. *School Effectiveness and School Improvement, 30*(1), 51-67. https://doi.org/10.1080/09243453.2018.1539013

Elharake, J. A., Akbar, F., Malik, A. A., Gilliam, W., & Omer, S. B., (2022). Mental health impact of COVID-19 among children and college Students: A systematic review. *Child psychiatry and human development*, 1–13. https://doi.org/10.1007/s10578-021-01297-1

Graaf, A., Janssen, F., & Westbroek, H., (2019). A practical approach to differentiated instruction: How biology teachers redesigned their genetics and ecology lessons. *Journal of Science Teacher Education, 30*(1), 6-23. https://doi.org/10.1080/1046560X.2018.1523646

Harackiwicz, J.M., & Priniski, S.J. (2018). Improving student outcomes in higher education: The science of targeted intervention. *Annual Review of Psychology, 69*(1), 409-435. https://doi.org/10.1146/annurev-psych-122216-011725

Harris, K., & Meltzer, L. (2015). *The power of peers in the classroom: Enhancing learning and social skills.*

Hendricks, C. (2009). *Improving schools through action research: A comprehensive guide for educators* (3rd ed.). Pearson.

Hertberg-Davis, H. (2009). Myth 7: Differentiation in the regular classroom is equivalent to gifted programs and is sufficient. *The Gifted Child Quarterly*, *53*(4), 251-253.

Hue, R., Greenhalgh-Spencer, H., & Childers, G. (2022). Differentiation in the life science classroom using station rotations. *Science Scope*, *45*(5), 52+. https://link.gale.com/apps/doc/A703332486/AONE?u=mtlib_1_1123&sid=bookmark-AONE&xid=df1d75b1

Keeley, P. (2016). *Science formative assessment, second edition*. Corwin.

Kumar, D. D. (1993). Effective instructional strategies in science revisited. *American Secondary Education, 21*(3), 9-14. https://www.jstor.org/stable/41064032

Macdonald, H. (2004) Geologic puzzles: Morrison formation, *Starting Point*. http://serc.carleton.edu/introgeo/interactive/examples/morrisonpuzzle.html

McKagan , S., Sayre, E., & Madsen , A. (2016, March 18). *Normalized gain: What is it and when and how should I use it?* PhysPort. https://www.physport.org/recommendations/Entry.cfm?ID=93334

Mertler, C.A. (2020). *Action research*. SAGE Publications, Inc.

Mills, G. E. (2018). *Action research: A guide for the teacher researcher* (5th ed.). Pearson.

Minner, D. (2009). Inquiry-based science instruction-what is it and does it matter? Results from a research synthesis year 1984 to 2002. *Journal of Research in Science Teaching, 47*(4), 474-496. https://doi.org/10.1002/tea.20347

Nissen, J., Talbot, R., Nasim Thompson, A., & Van Dusen, B. (2018). Comparison of normalized gain and Cohen's d for analyzing gains on concept inventories. Physical Review. Physics Education Research, *14*(1), 010115.

Oakes, D. J., Hegedus, E. M., Ollerenshaw, S. L., Drury, H., & Ritchie, H. E. (2018). Using the jigsaw method to teach abdominal anatomy. *Anatomical Sciences Education, 12*(3), 272–283. https://doi.org/10.1002/ase.1802

Reiser, B. J. (2004). Scaffolding complex learning: The mechanisms of structuring and problematizing student work. *The Journal of Learning Sciences, 13*(3), 273–304. https://www.sesp.northwestern.edu/docs/publications/78857602544049eb20ee68.pdf.

Richards, M., & Omdal, S. (2007). Effects of tiered instruction on academic performance in a secondary science course. *Journal of Advanced Academics, 18*(3), 424-453. https://doi.org/10.4219/jaa-2007-499

Salkind, N. J. (2010). Encyclopedia of research design (Vols. 1-0). SAGE Publications, Inc. https://10.4135/9781412961288

Snap assessments. SNAP Assessments | Stanford NGSS curriculum & assessment. (n.d.). https://scienceeducation.stanford.edu/snap/assessments-ngss.

Waack, S. (2022). *Influences overview - visible learning*. Visible-Learning.org. https://visible-learning.org/wp-content/uploads/2022/01/Influences-overview-Visible-Learning.pdf

Winschel, G., Everett, R., Coppola, B., Shultz, G., & Lonn, S. (2015). Using jigsaw-style spectroscopy problem-solving to elucidate molecular structure through online cooperative learning. *Journal of Chemical Education, 92*(7), 1188-1193. https://doi.org. 10.1021/acs.jchemed.5b00114

Why use jigsaws. (2021, October 23). Jigsaws. https://serc.carleton.edu/nagtworkshops/teaching_methods/jigsaws/why.html.

APPENDICES

APPENDIX A

MONTANA STATE UNIVERSITY'S INSTITUTION REVIEW BOARD

COMPLIANCE

APPENDIX B

FORMATIVE ASSESSMENT 7.4: IDENITFYING AN ELEMENT

Identifying an Element

You are excited to learn that you have been chosen to be your chemistry teacher's lab assistant! She asked you to put away the element samples she used earlier today. You are doing fine until you reach sample #4. This solid sample is not labeled! Using the process of elimination you know the unknown element must be aluminum, calcium, sodium, or sulfur. What element is it?

To help determine the identity of the element, the following data were obtained for unknown sample #4, called X and your copy of the Periodic Table.

Sample mass	Appearance	Conductivity	Reaction with water
27.5 g	Silver gray-colored solid, shiny surface when scratched Cut with a butter knife, malleable	yes	A vigorous reaction occurred with the water, it fizzed, smoked and danced around the test tube. Flammable gas was also produced.

1. (2, c) Based on patterns within the Periodic Table of Elements classify element X as either a metal, metalloid or nonmetal element. Support your answer using two pieces of evidence from the data table.

2. (2, c) Identify the unknown element as either aluminum, calcium, sodium, or sulfur. Explain your reasoning based on the properties of the sample and your knowledge of chemistry.

3. (3, c) Use valence electrons and the Octet Rule to explain the reactivity of this element.

APPENDIX C

FORMATIVE ASSESSMENT 8.1 IONIC AND COVALENT BONDING

Seminar Physical Science Name_____

Formative Assessment 8.1: Ionic and Covalent Bonding

1. Draw the Lewis Dot Diagrams for calcium and oxygen.

2. How many bonds can calcium form? How many bonds can oxygen form?

3. What type of bond will form between them? How do you know? Use two pieces of evidence.

4. Create a diagram of how this bond will form.

APPENDIX D

INDEPENDENT STUDY: WIZARDRY AND CHEMISTRY

Seminar Physical Science Names_____
Independent Study: Wizardry and Chemistry
Synthesis Questions

In your lab, you created a sparkler using certain materials. The Gryffindor sparkler employed aluminum powder to influence its color, while the Slytherin sparkler used iron powder.

1. Write the electron configuration for Al and for Fe.
    a. Aluminum:

    b. Iron:

2. As the electrons for these different metals reach their excited state, which majority compound (that in the Gryffindor sparkler or that in the Slytherin sparkler) has a greater difference from ground state to excited state? Draw a model to illustrate this concept.

3. Give a brief but complete explanation of how the wavelengths of colors shown in the sparklers are related to the difference described in the question above.

4. What was the role of the dextrin in fireworks?

APPENDIX E

STOP MOTION ANIMATION VIDEO REQUIREMENTS

Video Requirements

1. Your video must have a Purpose slide.
2. Your video must show a bond forming and a bond breaking (it can be the same bond).
3. Your video must contain an explanation (written or demonstrated) of how energy is moving during the formation of a bond and the breaking of a bond.
4. Include the connection of valence electrons (or Lewis Dot Diagrams) to the number of bonds an atoms can form.
5. During the process of bond formation and bond breaking, show how energy and mass are conserved throughout.
6. Your video must not be longer than one minute.
7. Your video must be shared with your teacher no later than Friday at the end of class.

APPENDIX F

Pre and Post Student Survey

Pre and Post Student Survey

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in anyway. You do not need to put your name on this survey. Please respond to each statement has honestly as you possibly can and only circling one number for each statement, then respond to the following questions.

1 = strongly disagree 2 = disagree 3 = no opinion 4 = agree 5 = strongly agree

1. The flexible grouping differentiation instruction method was helpful

   1 2 3 4 5

2. The tiered group differentiation instruction method was helpful

   1 2 3 4 5

3. How can we improve upon the differentiation instruction strategies?

4. As a high achieving student do you feel these strategies helped your learning? Explain.

   1 2 3 4 5

5. Is there anything else you would like to include about differentiation strategies? If so, please write your comments here.

APPENDIX G

ACTIVE OBSERVER FIELD NOTES

Active Observer Field Notes

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in anyway.

Active Observer Field Notes		
Date:	Time:	Events:

APPENDIX H

FIELD NOTES AS A PASSIVE OBSERVER

Field notes as a passive observer

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in anyway.

Field notes as a passive observer							
Behaviors and activities	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
Students are engaged in the content							
Students are having appropriate conversations related to the topic							
Students are clarifying information							
Students are helping one another out							
Students are respectful to one another							
Students stay on task							
Students turn in task sheets.							

APPENDIX I

UNIT 7 SUMMATIVE ASSESSMENT ATOMS AND THE PERIODIC TABLE

Edulastic

SPS Unit 7 Summative Assessment: Atoms- 2022

Created By Kelsey Ferguson

1 Complete the following table:

Element Symbol	Element Name	Atomic Number	Atomic Mass (Mass Number)	Number of Protons	Number of Neutrons
1	2	2	3	4	5
C	7	8	9	10	11
13	14	15	16	11	17

2 Elements in the same _____ share physical and chemical properties.

- (A) Box
- (B) Group
- (C) Period
- (D) Table

3 All elements in **period 5** have

- (A) 5 protons
- (B) 5 electron energy levels
- (C) 5 valence electrons
- (D) 5 neutrons

4 Based on the Lewis Dot structures below, select which **GROUP** each of the elements belongs to.

·Be· a

·Ċ· b

:Ne: c

a
- Group 1A
- Group 2A
- Group 3A
- Group 4A
- Group 5A
- Group 6A
- Group 7A
- Group 8A

b
- Group 1A
- Group 2A
- Group 3A
- Group 4A
- Group 5A
- Group 6A
- Group 7A
- Group 8A

c
- Group1A
- Group 2A
- Group 3A
- Group 4A
- Group 5A
- Group 6A
- Group 7A
- Group 8A

5 Fluorine, Chlorine, Bromine, Iodine, and Astatine all belong to what elemental classification

a
- Alkali Metal
- Alkaline Earth Metals
- Halogens
- Noble Gasses

6 Describe the distribution of electrons. State how many valence electrons oxygen has. How is this number of valence electrons related to oxygen's location on the periodic table?

7 Match the number of valence electrons to the element.

Beryllium (Be)	
Nitrogen (N)	
Aluminum (Al)	
Argon (Ar)	

DRAG & DROP THE ANSWER

3 | 8 | 5 | 2

8 Select the correct electron configuration for Na (Sodium).

(A) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$

(B) $1s^2\ 2s^2\ 2p^6\ 3s^2$

(C) $1s^2\ 2s^2\ 2p^6\ 3s^1$

(D) $1s^2\ 2s^2\ 2p^6\ 3s^1\ 3p^6\ 4s^2$

9 Select the correct electron configuration for Cs (Cesium).

(A) [Xe] $6s^1$

(B) [Og] $6s^1$

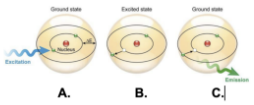
(C) [Og] $6s^2$

(D) [Xe] $6s^2$

10 Explain why the Noble Gases of group 8A are chemically inactive or inert.

11 Create a model to compare two elements in the same group that are at least 2 periods apart. Which has a larger atomic radius and why? You may draw only the valence electrons. Be sure to label all 3 atomic particles' locations.

12 Write a short caption explaining what is happening in parts A, B, and C below.



13 A water pipe next door to the storage room containing our supply of pure elements bursts. The room is filling quickly with water. The lab technician grabs you from the hallway and asks you to help remove the elements and put them in a safe location.

(a)

1. List patterns you know between the position of elements in the periodic table and their corresponding arrangement of electrons in their atomic structure.

(b)

2. To help your lab technician, you will remove the elements from the storage room in three groups by order of priority. The ones that need to be removed first are high priority, followed by medium priority, and finally the ones with the lowest priority. Justify your grouping by explaining the connection between atomic structure and the relative properties of the elements.

14 As the [a] and [b] of the star **increases**, [c] elements are formed.

a	b	c
mass	temperature	heavier
thermal conductivity	specific heat	lighter
specific heat	thermal conductivity	more metallic
		less metallic

15 Determine which phase of the star cycle each element is formed in.

DRAG & DROP THE ANSWER

Helium | Phosphorus | Hydrogen | Oxygen | Carbon | Zinc | Silver (Ag)

Big Bang	
Main Sequence / Red Giant	
Supernova	

16 Select all of the conditions needed for element formation via nuclear fusion in stars.

[A] high temperature

[B] high pressure

[C] high amount of protons

[D] high density

APPENDIX J

UNIT 8 SUMMATIVE ASSESSMENT BONDING

Edulastic

SPS UNIT 8 Summative Assessment: Atomic Bonding (2022)

Created By Kelsey Ferguson

1 The air living organisms breathe on Earth consists of oxygen gas (O_2), nitrogen gas (N_2), gaseous carbon dioxide (CO_2), and various other gases. When animals breathe in oxygen, they are able to metabolize glucose sugar, $C_6H_{12}O_6$. This sugar is obtained through the foods the animals eat, like a chocolate chip granola bar and Kool-Aid. Identify an element, compound, heterogeneous mixture, and homogenous mixture from the scenario above. Then describe your reasoning for each one.

	Example	Reasoning
Element	1	2
Compound	3	4
Heterogeneous Mixture	5	6
Homogeneous Mixture	7	8

Read both articles and then answer the questions that follow. HIGHLIGHT in the text to show where you found your answer for each question.

Passage 1

Physical and Chemical Changes

There are several differences between a physical and a chemical change.

A physical change in a substance doesn't change what the substance is. In a chemical change a new substance is formed.

For example, if a piece of paper is cut up into small pieces it still is paper. This would be a physical change in the shape and size of the paper. If the same piece of paper is burned, it is broken up into different substances that are not paper.

Physical changes can be reversed, or changed back. For example, a cup of water can be frozen when cooled and then can be returned to a liquid form when heated. If you dissolve sugar in water to make sugar water, this would be a physical change. You could leave the water out to evaporate and the sugar crystals would remain.

Chemical changes cannot be reversed easily, if at all. For example, if you made a recipe for a cake with flour, water, sugar and other ingredients and baked them together, it would be incredibly difficult to separate the various ingredients out to their original form.

3 Identify the following as a Chemical Change or Physical Change.

	Chemical Change	Physical Change
Ice melting	☐	☐
Eggs cooking	☐	☐
Salt dissolving	☐	☐
Wood burning	☐	☐
Fireworks exploding	☐	☐

4 Select all of the following events in which a chemical change occurs.

- [A] Chocolate syrup dissolves into warm milk.
- [B] Toast is lightly charred in a toaster.
- [C] A piece of paper is cut up into 12 pieces.
- [D] Two unknown liquids are mixed together and a gas is produced.
- [E] Sugar is heated until it turns into a brown caramel sauce.
- [F] A sugar cube dissolves in coffee.

5 A science teacher demonstrated physical and chemical changes by using a fork to hold a marshmallow over a lit candle.

Which observation is the best evidence of a chemical change?

- (A) Some candle wax melted.
- (B) Metal in the fork became warmer.
- (C) The marshmallow became sticky on the inside
- (D) The marshmallow developed a brown crust on the outside.

Read both articles and then answer the questions that follow. HIGHLIGHT in the text to show where you found your answer for each question.

Passage 2

How Matter Changes

Changes in matter happen around you every day. Some changes make matter look different. Other changes make one kind of matter become another kind of matter.

Physical changes are changes in the way matter looks. Changes in size and shape, like the changes that happen when you cut a piece of paper, are physical changes. Physical changes are changes in the size, shape, state, or appearance of matter.

Another kind of physical change happens when matter changes from one state to another state. When water freezes and makes ice, it is still water. It has only changed its state of matter from a liquid to a solid. It has changed its appearance and shape, but it is still water. You can change the ice back into water by letting it melt. Matter looks different when it changes states, but it stays the same kind of matter.

Another way matter can change is a chemical change. A **chemical change** takes place when matter changes into a different kind of matter. An example of a chemical change is burning wood. The wood changes into smoke and ash. This chemical change produces heat and light.

Have you ever seen a nail or other piece of metal that was rusted? Rusting is a chemical change, too. The metal in the nails mixes with the air to form a different kind of matter, rust.

Have you ever seen an old piece of silverware that has turned black? This is another kind of chemical change. A gas in the air causes a black covering called tarnish to form on silver. The tarnish is a different kind of matter from the air or the silver.

Signs of a chemical change are a change in color or temperature or the production of heat or light. Bubbling, fizzing, or making a noise or smell are some more signs. Not all of these things happen during a chemical change. But usually at least one of them does happen.

Changes in the way matter looks are physical changes. A physical change happens when matter changes from one state into another. A chemical change takes place when matter changes to a different kind of matter.

2 Water is boiled and steam is produced. This is a physical change because the water particles....

- (A) have turned into something new.
- (B) are still water particles.
- (C) have reacted with each other.
- (D) have been destroyed.

6 Four changes are shown below.

Which of these represents a chemical change?

- (A) A match is lit, creating a yellow-orange fl ame.
- (B) A small piece of ice melts, changing from a solid to a liquid.
- (C) A ball of clay sinks in water, and fl oats when reshaped.
- (D) A pot of water is heated to boiling, and evaporation occurs.

7 What is the main difference between a physical and chemical change? What would be a clue that a chemical change is taking place?

8 Which of these is an example of a physical change?

- (A) Melting ice
- (B) Rusting metal
- (C) Baking a cake
- (D) Burning leaves

9 Read each statement. Decide if the idea is found in passage 1, passage 2, or both passages.

	Passage 1	Both	Passage 2
A physical change is a change in the size, shape, or state of matter. The molecules stay the same so it is still the same type of matter.	○	○	○
A chemical change is a change in which the matter is changed into something different. The molecules change so it becomes a different type of matter.	○	○	○
Signs of a chemical change include a change in color or temperature, the formation of gas, and light or a scent being given off.	○	○	○
Baking a cake is an example of a chemical change because it would be incredibly difficult to separate the various ingredients back to their original form.	○	○	○

10 An atom which has gained or lost an electron is known as a(n)

(A) Ion
(B) Isotope
(C) Compound
(D) Neutron

11 If an atom loses an electron, what charge does it become?

(A) Positive
(B) Negative
(C) Neutral

12 Almost all atoms form bonds to

(A) Have a stable nucleus
(B) Have a full outermost electron energy level
(C) Have 10 valence electrons
(D) Add more energy levels or orbitals

13 The transfer or sharing of _____ results in chemical bonds.

(A) Protons
(B) Neutrons
(C) Electrons
(D) Valence electrons

14 In a compound (like H_2O), the sum of all oxidation numbers must be _____.

(A) 0
(B) +1
(C) -1

15 All elements in Group 1A have an oxidation number of

(A) -1
(B) +1
(C) +7
(D) -7

16 If an atom tends to gain 2 electrons when it forms a bond, then its oxidation number is:

(A) -1
(B) -2
(C) -3
(D) +2

17 Metals generally form ____ ions.

(A) positive
(B) negative
(C) neutral

18 The majority of nonmetals generally form _____ ions.

(A) positive
(B) negative
(C) neutral

19 A metal and a nonmetal would form a(n) _____ bond.

(A) ionic
(B) covalent
(C) metallic
(D) hydrogen

20 Two nonmetals would form a(n) _____ bond.

(A) ionic
(B) covalent
(C) metallic
(D) hydrogen

21 Ionic bonds are formed from the _____ of valence electrons.

(A) Sharing
(B) Transfer

22 Draw an electron dot model for water. Make sure to show your bonds, and paired electrons.

23 Use the lewis dot structure to show what happens when sodium (Na) bonds with chlorine (Cl). Make sure to show what happens to the valence electrons, and include the bond type.

24 Two or more atoms that together act as one charged particle is a

(A) Cation
(B) Anion
(C) Polyatomic Ion
(D) Negatron

25 What is the oxidation number of iron (III)?

(A) +3
(B) -3
(C) +5
(D) -5

26 What is the correct name of a compound made of lithium and chlorine?

(A) Chloride lithium
(B) Lithium chlorine
(C) Lithium chloride
(D) Lithium chlorate

27 What is the correct formula for magnesium oxide?

(A) Mg_2O
(B) MgO_2
(C) Mg_2O_2
(D) MgO

28 What is the correct formula for magnesium nitrate?

(A) $MgNO_3$
(B) $Mg(NO_3)_2$
(C) Mg_3N_2
(D) MgN

29 What is the charge (oxidation number) of phosphate in K_3PO_4?

(A) -3
(B) +1
(C) +5
(D) -7

30 How many oxygen atoms are there in the molecule K_3PO_4?

(A) 1
(B) 2
(C) 3
(D) 4

31 What is the correct name for K_2SO_4?

(A) Potassium Sulfide
(B) Potassium (II) Sulfide
(C) Potassium Sulfate
(D) Dipotassium Sulfate

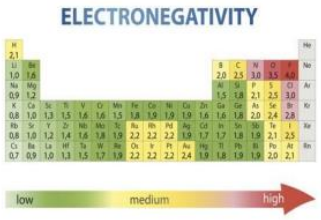
32 What is the correct formula for iron (III) chloride?

(A) FeCl
(B) Fe_3Cl
(C) $FeCl_3$
(D) Fe_3Cl_3

33 Diatomic molecules, like O_2, H_2, and N_2, are held together by

(A) Ionic Bonds
(B) Covalent bonds
(C) Metallic Bonds
(D) Stocks & Bonds

34



Calculate the electronegativity difference between Mg and Cl.

(A) 3
(B) 1.2
(C) 1.8
(D) 4.2