# Inquiry/Hands-on Based Learning and Its Effect on Adolescents Mastery Motivation in Chemistry Classrooms

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**Abstract:** Many researchers have investigated ways to spark high school chemistry students' interests. Inquiry-based learning was studied to determine its effect on adolescents reaching mastery motivation stage where they are not focusing on winning, but on the achievement outcome. The studies have also showed great impact of these activities on adolescents' self-efficacy. Despite the effectiveness of inquiry-based learning, there are some drawbacks that were highlighted by the authors, it can be unaffordable, time consuming, and unappealing for some experienced teachers. These drawbacks can be resolved by using simple and affordable materials, modifying the activities to fit within the class period and offering more time for teachers to explore the topic and to get training before implementing inquiry-based activities. To validate the effectiveness of these activities on adolescents' reaching mastery motivation and self-efficacy, more research is needed to include multiple schools locations with diverse populations among students and teachers. Furthermore, researchers from different ethnicity and background are needed in these types of research to avoid biases.
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## Introduction

It is known among high school students that science is all about facts and memorization." Education has traditionally emphasized science as factual information to be learned, largely through memorization. Consequently, students typically view science as difficult, boring and irrelevant to everyday life" (Patrick and Yoon, 2004,). Adolescents in high school years are working on choices and career paths. They can lose interests if they find education useless and inapplicable to their everyday life experience. A lot of our high school students in science classrooms and especially in chemistry feel lost and unengaged and as a result they don't try to understand the material, which can lead to a complete loss of interests in the science fields. Researchers in the science education have found that inquiry-based learning can initiate adolescents' interests in the science fields and if delivered appropriately it can enhance students' mastery motivation level and self-efficacy. It was found that students who feel that school is a way to reach goals tend to be intrinsically motivated. When school is a place where adolescents feel that they are engaged in their own learning, they get excited and motivated (Kover and Worrell, 2010). Inquiry-based activities can spark adolescents intrinsic motivation and hence their mastery motivation and self-efficacy.

Adolescents can either display mastery orientation where students are focused on learning and engaging in the process and not on their ability, or helpless orientations where adolescents feel overwhelmed and refer their difficulties to their lack of ability. Adolescents in this stage believe that they can't perform or understand any material, which can lead them to unpleasant consequences. On the other hand, the mastery-oriented adolescents are more motivated, and driven to succeed.

Moreover, it was found that students who reached mastery motivation stage and consequently self-efficacy tend to care about understanding the concept and not winning or getting higher grades. It is important to note that teachers play an effective role in helping adolescents achieve that goal if they set high expectations for their students. Effective teachers always engage their students into activities that will allow them to become self-regulated, and driven achievers. There are many other ways to unleash adolescents' motivation, such as good mentors, productive teachers, good parenting, etc (Santrock, 2014).

In this paper, the use of hands-on/inquiry-based activities and its effect in general on students' mastery motivation and self-efficacy/achievement and especially in chemistry classrooms is discussed. Chemistry is one of the science subjects that can cause anxiety to students, simply because they can't find the connections to the real world experience. Researchers emphasized the importance of encouraging students to be better thinkers. They highlighted the importance of being creative while teaching to keep students

engaged and interested. Many teaching methods were suggested to bring students into an active learning environment rather than passive. For instance, peer instruction, this method, is a way for students to brainstorm, and to share their ideas and thoughts. "Think-pair-share-create" (DeHaan, 2011) is a way of instruction that fosters peer instruction. During a lecture, teachers can embed an open ended question, students can then think of how to approach the question, share their thoughts with the a peer or get involve in a whole class discussion. The last step of this method is the creation of the final answer that will be generated from multiple groups (DeHaan, 2011).

It is important to note that students in this context are engaged, interested, and motivated. They are working towards a purpose of finding an answer, which can enhance their self-efficacy. Adolescents need to be encouraged by their teachers to gain confident in their ability. "Inquiry has been defined as a pedagogical method that combines hands-on activities with students- centered discussion and discovery of concepts" (Bruck 2009). When adolescents are engaged and involved in the subject matter they own their learning. It was found that prolonged engagement in chemistry classroom activities leads to creating a constructivist environment, where students link prior knowledge with newly constructed knowledge as they work in small groups. In this process students are planning, monitoring and evaluating their success, which is the true meaning of metacognition (Pulmones, 2011). Students need to be given the opportunity to reflect on their thinking which would allow them to modify, to adjust and to recreate their thinking strategy. During metacognition reflection, students think about the science concept that they have learned and its relation to the inquiry question given by the teacher.

Inquiry –based activities allow students to think on a deeper level, where they are actually trying to comprehend the material, which can lead them to the mastery stage. Teachers should assess students' understanding of the concepts formally or informally before introducing the inquiry activity (Bruck, 2009). Researchers recommend that teachers need to explain the concept before conducting the inquiry lab activity. Students should be the center of the experience, but in order to achieve higher analytical thinking ability, mastery level and hence self-efficacy; they need to understand the main concept behind the experiment.

In addition, "There are two main contemporary approaches to student learning: constructivist and direct instruction"(Santrock, 2014). The constructivist approach is students centered, where they are encouraged in investigating the world. In this approach students are actively constructing their knowledge and understanding, with directions from the teacher. It's an environment where students are highly expected to find a solution for a problem, to brainstorm ideas, and to design or to create a product. Inquiry-based activities create that environment. On the other hand, the direct instruction approach is a teacher centered. This approach alone can lead to creating passive learners; students are only familiar with the content, but not the application of the concept. This approach can create helpless adolescents with no interests in achieving or reaching any goals. Students in this environment are not given the opportunity to keep trying until reaching a desirable goal. The constructivist approach helps adolescents to unleash their creativity. In other words, offering inquiry-based learning approach will allow high school chemistry students to explore without the "constraint environment that the direct instruction approach creates" (Adams, et al., 2015). Adolescents will gradually reach mastery motivation stage that they need to become more confident in their abilities.

One major drawback of the inquiry-based approach is the cost of the materials. Researchers in science education have found that in some schools teachers had to teach chemistry with no laboratory experiments due to financial constraints that can lead to declining the enthusiasm of both the educators and students. The methods that were suggested by researchers to overcome the lack of supplies in the chemistry classrooms were simple and applicable. For example, the use of small-scale chemistry activities, designing and implementing of microchemistry kits. These alternatives are great as they reduce the cost of performing any standard chemistry lab activity and provide great outcomes (Bradley, et al., 1998). Educators should keep adolescents engaged into their learning experience to avoid reaching the helpless stage among adolescents. Schools with limited budget can use cheap household materials to conduct simple hands-on activities that will keep students involved and interested.

Many learning strategies were suggested by researchers to help students succeed during their learning journey. For instance collaborative learning, quick writes, weekly summaries, graphic organizer/concept maps and hands-on activities. Students especially enjoy hands-on activities and small group activities. They gain more when they feel that they have a second chance. Educators should tell students that failure is ok, as long as it leads to success (Dirksen, 2011). Students in chemistry classrooms can get anxious about the complexity of the material. This anxiety can lead students to lose interests and to reach helpless stage. Inquiry-based activities can ease students' anxiety because it takes them to a different level of learning. Students will always have a chance to try again.

Researchers had found that hands-on activities and small groups interaction could enhance students' mastery motivation, "Cognitive engagement and self-motivation"(Santrock, 2014). When adolescents find purpose of learning they become motivated and driven to succeed. For example, when the classroom environment is including everyone and is encouraging every student to participate, adolescents will feel comfortable and excited about learning, which can lead to reaching mastery motivation stage, and as a result self-efficacy will be developed. Adolescents will be able to understand the material being taught in a deeper level and they will achieve the desirable outcomes. When students work together to brainstorm ideas, they help each other understand the material, and with the help of the teacher they can master concepts, (Zone of proximal development by Vygotsky).

**Research question**

Does Hands-on/Inquiry-based learning help adolescents reach mastery motivation and competency in chemistry classrooms?

**Participants**

Participants in this study were students enrolled in an honors chemistry course taught at a suburban Catholic high school in Rhode Island. The total number of students was seventy-one students five of which are African Americans. The majority of students were females. I started this research for the required teacher research project during the Masters of Arts in Teaching graduate program at Brown University.

**Methodology and procedures**

In this study, multiple hands-on/inquiry activities were used with chemistry students. As mentioned, students need to connect their learning experience with real life applications to spark their interests and to get them engaged in the subject matter. Typically, I would introduce the activities by first explaining the concept then engaging all students in active discussion followed by hands-on activity. For instance, when my students learned percent composition concept, they understood it theoretically, part over whole times a hundred. They were not excited about a theoretical concept that may not be useful in real life. When I added hands-on activity to measure the percent of sugar in Oreo Cookies, students were interested and the concept became exciting to dive in more enthusiastically. Not only students were able to connect theoretical concepts to a useful life experience, but also they were driven and motivated to test other types of Oreo cookies to determine the ones with lower sugar content. This simple activity made students truly understand the concept and as a result they became more confident in their ability, and more motivated.

Another example of a hands-on activity that I used with the participants was examining Boyle's' law of gases. Students were given mini marshmallows and a syringe. This activity, made them connect the pressure applied with their finger to the volume change of the mini marshmallow trapped inside the syringe. They realized the inverse relationship that the law is explaining, but this activity made the law come to life and become visible. Similar activities were used throughout the year with my students to determine the effectiveness of these activities on participants' motivation and self-efficacy.

To measure students' performance in terms of grades, I usually use multiple-choice tests with my students after every unit. I do not use the same test questions every year, but to validate the results for this research, I used the same test questions from the previous year with students from the following year and I compared the results. Students from previous year who were not exposed to hands-on activities scored lower on the same multiple choice test compared to students from the following year who were exposed to these activities prior to taking the test. Moreover, I also noticed that students' lab reports were written in a deeper level of understanding if compared to students from previous years who had no exposure to hands-on/inquiry activities. Students wrote research papers that showed a magnificent level of analytical thinking as well as more confidence in their ability. Below are sample results of students' assessments after the involvement in hands-on activities.

**Results**

Based on multiple data, it was found that inquiry-based learning/hands-on activities help adolescents' to reach mastery motivation stage and self-efficacy in chemistry classrooms. These activities were shown to improve students' performance on chemistry tests, lab reports, and as a result it helped students to reach mastery motivation, content competency, and self-efficacy. During the hands-on activities students were engaged and enthusiastically interested in learning chemistry concepts. Adolescents may lose interest easily and educators need to continue finding ways to keep students driven and excited about their learning. In this paper only some sample results were presented, but enough to reinforce the importance of engaging adolescents in inquiry/hands-on activities to motivate and to encourage them to become driven, confident and better analytical thinkers.

Figure 1 shows three data sets that represent students' performance on tests and lab reports with and without the use of hands-on activities. Students from 2014/2015 school year were not exposed to these activities if compared to students from 2015/2016 school who exposed to many hands-on activities throughout the year. In Fig 1, data set #1 represents a comparison between students' average on lab reports in 2014/2015 and 2015/2016 school year. Students from 2015/2016 school year were engaged in hands-on activity to test Boyle's law using marshmallow, while students from the previous year used the traditional Boyle's law lab known in all chemistry lab manuals. One can notice that students with an exposure to hands-on activities showed a great depth of knowledge in writing the lab reports content and as a result they scored higher average on their lab reports if compared to students' average from 2014/2015. Data set #2, represents the student's' average for the Boyle's' law assessment test. These data shows that students with more exposure to hands-on activities become more confident in taking tests and score higher than students' who were not exposed to these types of activities. Data set #3 represents the assessment results for the percent composition unit test. Students with an exposure to hands-on activities for this unit such as calculating the percent composition of sugar in the Oreo cookies were able to understand the concept thoroughly and to score higher average on the test than students without prior exposure to hands-on activities.

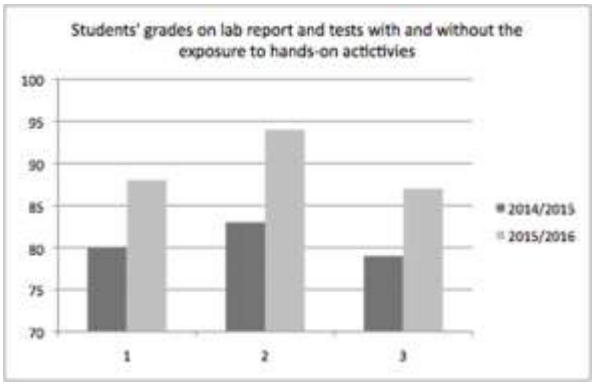


Figure 1

**Discussion and Future work**

Longitudinal studies are needed to test the absolute effectiveness of the hands-on/inquiry-based learning on adolescents' mastery motivation and self-efficacy. Furthermore, with more time, experienced teacher can go through training to create new and creative teaching methods that will allow them to cover the curriculum within the school year time limit. In addition, other effects of the inquiry-based learning on adolescents' psychology should be considered. For instance, its effect on adolescents' cognitive and social development is an important aspect that needs to be considered closely as it affects adolescents' lives. Moreover, the effect of inquiry-based learning on adolescents' motivation and self-efficacy in other classes, science, math, or humanities needs to be investigated. Based on these findings policy maker can start shifting the wheel of education to be more students centered where they can create, innovate and become more confident and achieve their goals. In addition, more diverse schools will be included in the future research to cover the effectiveness of hands-on activities on a broader perspective.

**Conclusion**

Adolescents' reach the mastery orientation stage in the chemistry classrooms when they are actively engaged in inquiry activities. They get intrinsically motivated when they get exposed to inquiry-based/hands-on activities in the chemistry classrooms. In this context, students are given the second chance, allowed to make mistakes, and encouraged to succeed. As the result, they will care about understanding the material and mastering it rather than getting the A+ on the report card. Chemistry concepts can be complex to understand, and as a chemistry teacher who actually tried inquiry-based learning, I experienced the effectiveness of these activities on adolescents' achievements and self-efficacy.

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