



## **A STUDY ON THE EFFECTIVENESS OF HANDS-ON EXPERIMENTS IN LEARNING SCIENCE AMONG YEAR 4 STUDENTS**

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### **ABSTRACT**

This study employed a mixed method, comprising of qualitative and quantitative research methods to examine the effectiveness of hands-on experiments in learning Science among twenty two Year 4 students in an international school. The study focused on two important areas which are to evaluate the students' academic development and to identify students' intrinsic motivation to learn Science when the subject is taught using hands-on experiments. The findings indicated that a number of students obtained better results as they learnt and remembered better through hands-on experiments. There was generally a higher level of participation and intrinsic motivation shown in the students when they learnt through hands-on experiments. The researchers are of the opinion that Kolb's experiential theory is very effective when doing the hands-on experiments for it ensures students grasp knowledge taught effectively. It is recommended that further studies on Bruner's theory of instruction should be carried out to further enhance the effectiveness of learning Science.

**Keywords:** hands-on experiment, intrinsic motivation and Kolb's Experiential Theory

### **INTRODUCTION**

Science is an important subject for students at all levels. The main reason is because the knowledge, understanding and skills that learners obtain in this subject encourages them to utilize and contribute their ideas in technological change to provide a better future (Jones and Wyse, 2004). Science is a natural subject for hands-on kinesthetic learning experiences that appeal to the visual and auditory senses. There are several factors that have led the researchers to look into the effectiveness of hands-on experiments in learning Science. Hands-on experiment is an active process of student-centered learning whereby it encourages children to discover and develop new concepts or ideas followed by spurring children's mind to be critical and creative (Jones and Wyse, 2004; Wilson, 2008). As children independently think critically and work through a subject matter, they develop a sense of independence and autonomy which will 'enhance their desire and ability to be self-motivated' (Blandford and Knowles, 2009: 147). Many researchers have successfully proven that this method of learning develops the students' interest in learning Science as well as other subjects (Norman, 2005).

However, in reality very few Science lessons are taught using student-centered approaches such as 'hands-on experiments'. Most lessons are conducted based on teacher-centered approach. One of the reasons is because of the teachers' beliefs and experiences in school which have influenced them in a way to practice this approach (Jones and Wyse, 2004). According to Woolnough (1994), although, it is satisfying to see the high achievements of students when the teacher-centered approach is used in schools, nevertheless, students' emotional interest in learning should also be taken into account as it is fundamental to boost their intrinsic motivation, their commitment, their enjoyment and creativity in science. As a result, the researchers were drawn to carry out this study to explore the impact of hands-on experiments in Science lessons using Kolb's experiential theory. Two questions were developed in order to fulfill the purposes of



this study. Firstly, to evaluate whether hands-on experiments increase students' motivation in learning Science and secondly to investigate whether students learn better through hands-on experiments.

## Literature Review

According to Carin and Bass, 'there are three major ways for people to learn about the world; discover things about the world from personal observations and experiences with the environment, acquire knowledge transmitted directly from other people or construct personal knowledge by transforming discovered and acquired knowledge in meaningful ways' (2001:74). Kolb agrees to the above statement mentioning that 'knowledge results from the combination of grasping and transforming experience' (1984:41). Worth (2010) affirms that learning Science is more than just gaining the facts and understanding on the particular topic. This is where learning science through hands-on experiments becomes acceptable as an effective option as it encourages students to experience and discover from observation or feelings. This will lead to the development of students' problem solving skills, creativity skills and independent learning skills (Shymansky et al., 1990). The three main ways of learning highlighted by Carin and Bass (2001) can be performed through hands-on experiments using Kolb's theory. 'The theory presents a way of structuring and sequencing the curriculum and indicates, in particular, how a session or entire course may be taught to improve student learning' (Healey and Jenkins, 2000: 185). The diagram below shows Kolb's experiential learning cycle that was developed based on Lewin's social psychology, Dewey's philosophical pragmatism and Piaget's cognitive-development genetic epistemology (Kolb, 1984).

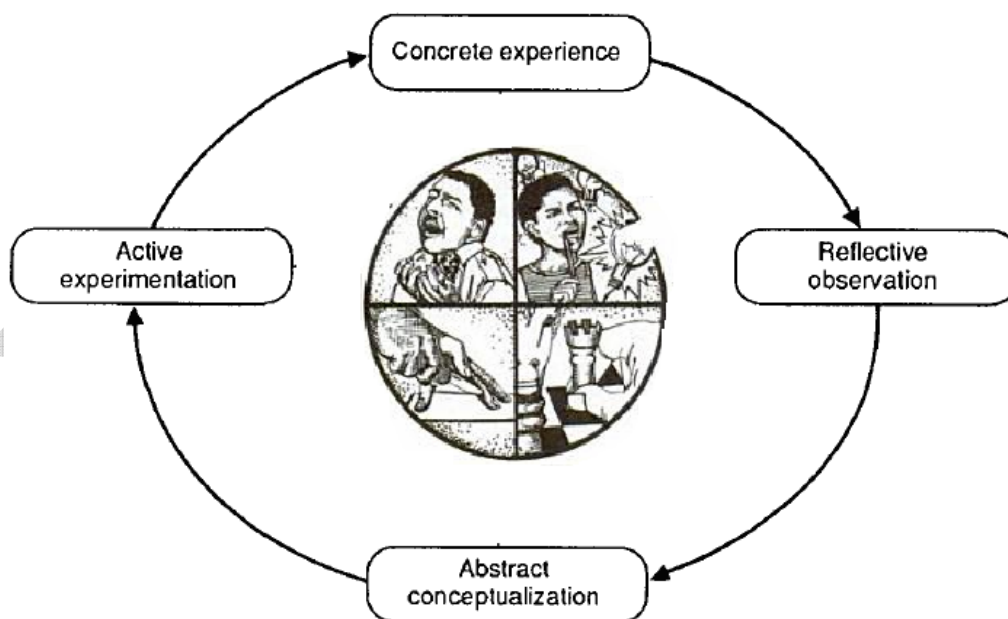


Figure 1: Kolb's Experiential Learning Cycle (Kolb, 1984)

The model portrays two dialectically related modes of grasping experience: Concrete Experience (CE) through feeling and Abstract Conceptualization (AC) through thinking (Kolb et al., 1999). It also represents two dialectically related modes of transforming experience: Reflective Observation (RO) by watching the happenings and Active Experimentation (AE) by doing research (Kolb et al., 1999). Cowan



(1998) suggests that learning is cyclic, involving four different stages that are associated with different learning styles. It caters to all learning styles consisting of kinesthetic, visual, read/write and audio learners which will allow students to learn in their best ways (FAA, 2009) and help them to be more flexible in meeting the varied demands of learning situations (Gibbs, 1988).

Many researchers have shown positive results in the development of learners when they are taught through hands-on experiments for it is ‘a process whereby concepts are derived from and continuously modified by experiences’ (Kolb, 1984: 26). Norman (2005) states that the results of a majority of researches have shown that students have more interest in Science and other subjects due to being taught using this method. Besides, hands-on experiments can create excitement among students as they develop their interest in learning Science (Andersen and Vandehey, 2012). Eventually, students’ intrinsic motivation is build which will encourage them to take their own initiative to learn more about Science. Interestingly, Allen (1973) also found that students’ discipline and behavior improved tremendously in Science classes when teachers employed hands-on experiments. On top of that, Jindrich (1998) has demonstrated that people (both children and adults) recall things better when they learn by doing.

However, very few teachers carry out hands-on experiments in their Science lessons. One of the reasons is because in the past, ‘the textbook was the curriculum for science and hence what passed as the teaching of science was nothing more than information-giving by teachers and memorization of the information by students’ (Collison and Aidoo-Taylor, 1990 cited in Ghartey-Ampiah, et. al, 2004: 2). ‘The theoretical approach to teaching science was further encouraged by the emphasis it received in public examinations’ (Ajeyalemi, 1990 cited in Ghartey-Ampiah, et. al, 2004: 2). These have led to some of the teachers’ beliefs in teacher-centered approach when delivering Science lessons based on their experiences in school (Jones and Wyse, 2004). One of the teachers interviewed by Jones and Wyse stated that ‘as a Year 6 teacher, (his) primary concern when teaching science was to ensure that the children had enough information...to be able to tackle a variety of Key Stage 2 SATs questions and he claimed that he had achieved that (2004:51). Besides that, the emphasis of practical works was minimal due to their disbelief in practical Science to convey the large amount of information that the children are required to learn (Jones and Wyse, 2004).

It must be accepted that there are several barriers to implementing hands-on experiments in classrooms. On one hand, in conducting an experiment, learners would construct their own ideas by interpreting what they hear, read and see but on the other hand, students requiring more guidance find difficulties in interpreting the experiment (Thanasoulas, 2001). In addition to the challenge faced by teachers in ensuring proper understanding among students, many research studies have also highlighted the necessity for teachers who are teaching Science to primary school students through hands-on experiments to possess specific and adequate training (Allen, 1973; Klahr et al., 1999). This is important so that teachers are aware of the safety precautions in conducting an experiment, are prepared in handling the classroom and are familiar with the correct ways to handle the materials and apparatus. The materials and resources used during the hands-on experiments too must be appropriate and taken care of in order to avoid unnecessary incidents taking place during lessons (Ghazaria, 2008). Thus it can be said that there are still gaps in this area, and further investigation should be done.

## **Methodology**

A mixed method comprising of qualitative and quantitative research methods was employed in this study to identify the effectiveness of the hands-on experiment approach in Science lessons. A mixed method was chosen due to its



...ability to provide a more thorough understanding of a research problem because of the opportunity to examine multiple forms of data...as well as...to answer complex research questions that cannot be addressed through the use of quantitative or qualitative methods alone.

(James and McMillan, 2008: 310)

For example, evidence gathered from surveys might only help the researchers to identify the effectiveness of hands-on experiments in measurement, but it may not be adequate to allow the researchers to understand the process and the challenges faced by the teacher. Thus, classroom observation enabled the researchers to understand the entire process in detail. Further, Gorard claims that the mixed methods research is acknowledged as the 'key element in the improvement of social science, including educational research' whereby the research is strengthened by the use of various methods (2004: 7).

In this study, the researchers did classroom observation besides getting teachers to fill up reflection forms. Two lessons on the topic 'Air', conducted by a Science teacher in Year 4 classroom were observed. The classroom observation was done to obtain a deeper understanding on the teaching approach used in the classroom. Recording was done of both Science lessons, with and without the implementation of hands-on experiments. In terms of quantitative research, a pre and post test was conducted to evaluate the impact of hands-on experiments. In order to obtain more reliable and valid results, a survey questionnaire was distributed to the students. A triangulation approach was used to confirm and verify data gathered in the different ways. 'Triangulation refers to the use of several different research techniques in the same study' (McMurray et al., 2004: 263). Thus, the classroom observation, the reflection forms, survey questionnaire and students' results in the pre and post tests were utilized to investigate whether students learn better with hands-on experiments approach. Further the data collected were also used to explore whether the approach had any impact on the development of students' interest, enjoyment and self-motivation.

Twenty-two students in Year 4 from an international school identified as School X participated in this study. The children's ages ranged from 7 to 10 years old. A Year 4 Science teacher identified as Ms Peach was informed about this research and she agreed to cooperate and participate. The researchers chose to conduct this study in a Year 4 class as it is an appropriate age group to provide responses in order to obtain better results. The first Science lesson on the topic of 'Air' in a Year 4 classroom was observed. The lesson focuses on the characteristics, components and different uses of air. At the beginning of the lesson, students were given the opportunity to share their ideas about air. The teacher, Ms Peach, elaborated on the students' ideas about 'Air'. Next, students were seated in groups to read about the different uses of air consisting of nitrogen, oxygen and carbon dioxide. Later, each group was given a task to write out the uses of a particular air in their own words and then, they presented their work. During the observation, the researchers looked into various aspects, for instance, the teacher's teaching methods, classroom management skills and students' responses towards the lesson. After the lesson, the teacher was asked to fill up a reflection form. Besides that, the students were given a survey questionnaire to obtain data on their views about the lesson.

In addition to further support this study, a test was given to the students to prove students' ability in answering the questions on the topic of 'Air' based on their understanding before the hands-on experiment was implemented. The test was marked by two teachers to ensure reliability of findings. As Howell et al. (2005) and Fink (1995) mentioned 'inter-rater reliability addresses the consistency of the implementation



of rating system’ (cited in VanNoord, 2007: 56). After two weeks, a lesson on carbon dioxide using the hands-on experiment approach was conducted. The same procedures for data collection were carried out.

**Findings**

Teachers including well-known authors on learning styles have demonstrated that people perceive and process information in qualitatively different ways (Witkin et al., 1977; Hudson, 1966; Pask, 1976; Entwistle, 1981, 1991; Entwistle and Ramsden, 1983 cited in Fielding, 2006). Thus, it is vital for the teachers and the students to identify their own learning styles as a foundation towards effective teaching and learning (Fielding, 1994). Therefore, the students’ preferences in learning Science before and after the implementation of hands-on experiments were identified through the survey questionnaires which are tabulated in Table 1.

Table 1: Year 4 students’ preferred learning method in Science

The implementation of hands-on experiments	Silent reading	PowerPoint presentation	Note taking	Experiments
Before	0	2	1	19
After	1	1	2	18

Table 1 shows that after the implementation of hands-on experiments in the class, one of the students, Student Q claimed that he or she prefers silent reading. However, Student Q still enjoys hands-on experiment and believes that hands-on experiment made Science lessons enjoyable (refer to Table 2). Similarly, Student I who prefers note taking and Student V who prefers PowerPoint presentation as listed in Table2, stated that they favor experiment after they did the hands-on experiments in class.

Table 2: Change in students’ perspectives on learning styles in learning Science

Student	Which type of activity would be the best in learning Science?				What did you enjoy most in today's lesson?			
	Without experiments	hands-on	With experiment	hands-on	Without experiments	hands-on	With experiment	hands-on
I	Note taking because it's easier		Experiments		Doing poster of what we did		When we did experiments I enjoy very much	
N	Experiments		Note taking		When we did poster		Note taking	
Q	Experiments because it is creative		Silent reading		Science presentation		Experiments	
U	PowerPoint presentation		PowerPoint presentation		No comment		Nothing	
V	PowerPoint presentation		Experiments		Nothing		Experiments	

Even during the first lesson, the students enjoyed other activities that did not involve hands-on experiment such as making posters in groups and presenting their work on different uses of air as seen in Table 3.



Table 3: Students’ perspectives on different activities in Science lesson

Student	What did you enjoy most in today's lesson?	
	Without hands-on experiment	With hands-on experiment
A	Group work	Experiments
B	We get to write and decorate	The way teacher teaches me.
D	Presenting our poster	Experiments
T	The presentation	Experiments

In addition, twelve students in fact recommended Science experiments to be conducted in class at the beginning of the study when hands-on experiment was not involved. The survey questionnaire requested students to give their suggestions on how Science lessons can be further improved so that lessons can be enjoyable. It was proven that the majority of the students stated that they enjoyed doing the experiments both before and after hands-on experiments were implemented. Based on a research done by Flowerday and Schraw (2000 cited in Brophy, 2010), teachers believed that a choice of learning strategies especially experience-based learning will increase the interest, engagement and learning in students. They also mentioned that students who did not show much motivation towards school activities at first experienced a stronger impact from the implementation of various learning strategies. In line with this, the researchers found quite a number of positive responses from the students in this research involving hands-on experiments which incorporated Kolb’s experiential theory in the lesson.

#### 4.1 The Impact of Hands-on Experiments on Students’ Motivation in Learning Science

As mentioned, a survey questionnaire was given to twenty-two Year 4 students after the lessons with or without hands-on experiment. All the data obtained from the students before and after the implementation of hands-on experiments were tabulated to compare the students’ responses before and after the implementation of hands-on experiment.

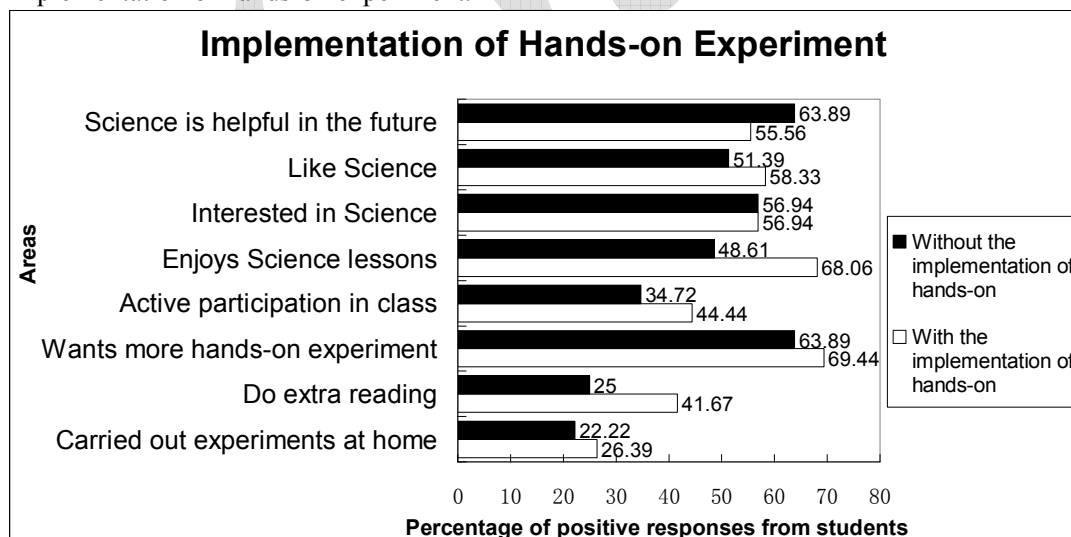


Figure 4: A comparison of students’ responses towards Science lessons with and without the implementation of hands-on experiments.



The differences of percentage in students' responses towards Science lessons with and without the implementation of hands-on experiments were calculated and recorded. After the implementation of hands-on experiment, students showed more anticipation in the implementation of hands-on experiments. There was an increase from 63.89% to 69.44% as seen in Figure 4. Besides, from Figure 4, it is shown that students enjoyed Science lessons more with hands-on experiments. The percentage of students' positive responses before and after the application of hands-on experiments increased from 48.61% to 68.06%.

As students enjoyed the lesson, it developed students' liking towards Science as a subject. Among twenty two Year 4 students, 51.39% of students like Science as a subject even before the hands-on experiments were implemented. After the application of the experiment in class, 58.33% of students liked Science as a subject. There was an increase of 6.94% of students who had developed their liking towards Science subject after they had gained the experience from experiments.

However, based on the results obtained from the survey questionnaire, it was found that there was no change in students' interest in learning Science. Nevertheless, from the researchers' opinion, students showed slightly more interest in learning Science when hands-on experiment was implemented. The researchers identified the development of students' interest through the students' expressions, responses and participation in class based on the classroom observation. For example, most of the students cheered together at the beginning of the Science lesson with hands-on experiment.

According to Brophy (2010), as students enjoy learning and build their interest in learning, it will lead them to be active participants in class. Although students' interest in learning Science remained 56.94% with and without hands-on experiment, the classroom observation revealed that there was more active participation when hands-on experiment was involved. From the students' perspective, there was an increase of 9.72% of students' participation which increased from 34.72% to 44.44%. Furthermore, the Science teacher, Ms Peach commented briefly that students were very engaging and participative in both of the Science lessons with and without hands-on experiments. The researchers, on the other hand, observed both of the lessons and found a slight difference in students' participation. During the observation, the researchers noticed that students showed more participation when hands-on experiment was conducted especially during the experiment as well as questioning and answering sessions.

Surprisingly, there was decrease of percentage from 63.89% to 55.56% on students' perspective in applying their knowledge and understanding on Science subject in their future. From the view of the researchers, most of the students who had been relying on memorizing the information in their textbooks to achieve academically failed to relate the concepts learnt through experiments with the real world. Although they had conducted the hands-on experiments, they only gained the knowledge and understanding of the content. They had not learned to connect their new knowledge gained to their prior knowledge, interpret what they learn from various ways, and apply their knowledge to novel situations as well as to explain and predict phenomena and events happening in the surroundings.

Furthermore, this study has shown that hands-on experiments motivated students to take further actions such as doing extra reading and conducting experiments at home. According to Ormrod (1999), motivation refers to the inner states that arouse us to take action, push us in particular directions and keep us engage in certain activities. Burner 'points out that most children are intrinsically motivated to learn about the natural world, particularly when learning involves...hands-on experiences and is perceived as relevant and can be made meaningful' (1965 cited in Carin and Bass, 2001: 130). As shown in Figure 4, an increase of 16.67%, from 25% to 41.67% of students took the initiative to do extra reading at home about Science. Subsequently, students widened their knowledge and understanding about Science.



Wigfield et al. (1998) also mentioned that when students are intrinsically motivated, they willingly engage and actively participate for their own sake and out of interest in an activity. This statement was also proven in this study. There was an increase of percentage of active participants in class as shown in Figure 4. Besides that, students also improved in their communication skills in questioning and answering as they involved themselves in the activities conducted. Stronge et al. (2004) stated that each student's learning style are met as they undergo the cycle of experiential learning in hands-on experiment, resulting in the development of students' confidence, enthusiasm, motivation and achievements.

In contrast, the findings on the students' initiative in carrying out experiments at home obtained from the survey questionnaire showed a decrease of 4.17% from 26.39% to 22.22%. The researchers believed that since the students had just conducted an experiment in school, they would be interested to gain additional knowledge regarding the topic. Thus, this would encourage them to do extra reading to expand their understanding or develop new ideas about the subject before carrying out an experiment.

#### **4.2 Impact of Hands-on Experiment on Students' Academic Achievements**

This study supports the statement made by Jindrich (1998) mentioning that researches demonstrate that people recall things better though hands-on experiment. The results of the pre-test before the implementation of hands-on experiments and post-test after the implementation of hands-on experiments given to the students prove this. Figure 5 shows the record of students' pre and post test results which identifies the students' academic development.

Overall, the twenty-two students in Year 4 have shown a slight improvement of 4.32% based on the pre-test before the implementation of hands-on experiment and post-test after the implementation of hands-on experiments. Interestingly, there were equally ten students who had improved and declined in their academic achievement after the implementation of hands-on experiment whereas the other two students, Student M and Student V remained constant.

Based on Figure 5, there were some of the students' results which had increased significantly and some had dropped drastically. For example, Student R and Student Q had showed a significant improvement in their results. The researchers believe that both of the students' learning styles were met through hands-on experiments, resulting in the great improvement in their results. On the other hand, Student N's result had dropped from 85% to 20%. As Fielding (2006) and Thanasoulas (2001) mention, certain situations or tasks may require a way of working that a learner discovers hard to handle. Therefore, the researchers concluded that Student N was unable to adapt and be flexible with the diverse learning styles. Fielding also mentions that 'such situations can either tap into a learning style we seldom use and begin to stretch it or encourage us to develop learning strategies which enables us to cope effectively' (2006: 7). Another reason that may cause Student N's results to drop is because students will construct their own ideas by interpreting what they hear, read and see in conducting hands-on experiments (NSTA, 2001). Students who were not exposed to this method of learning will not be able to hear or see what is before them.



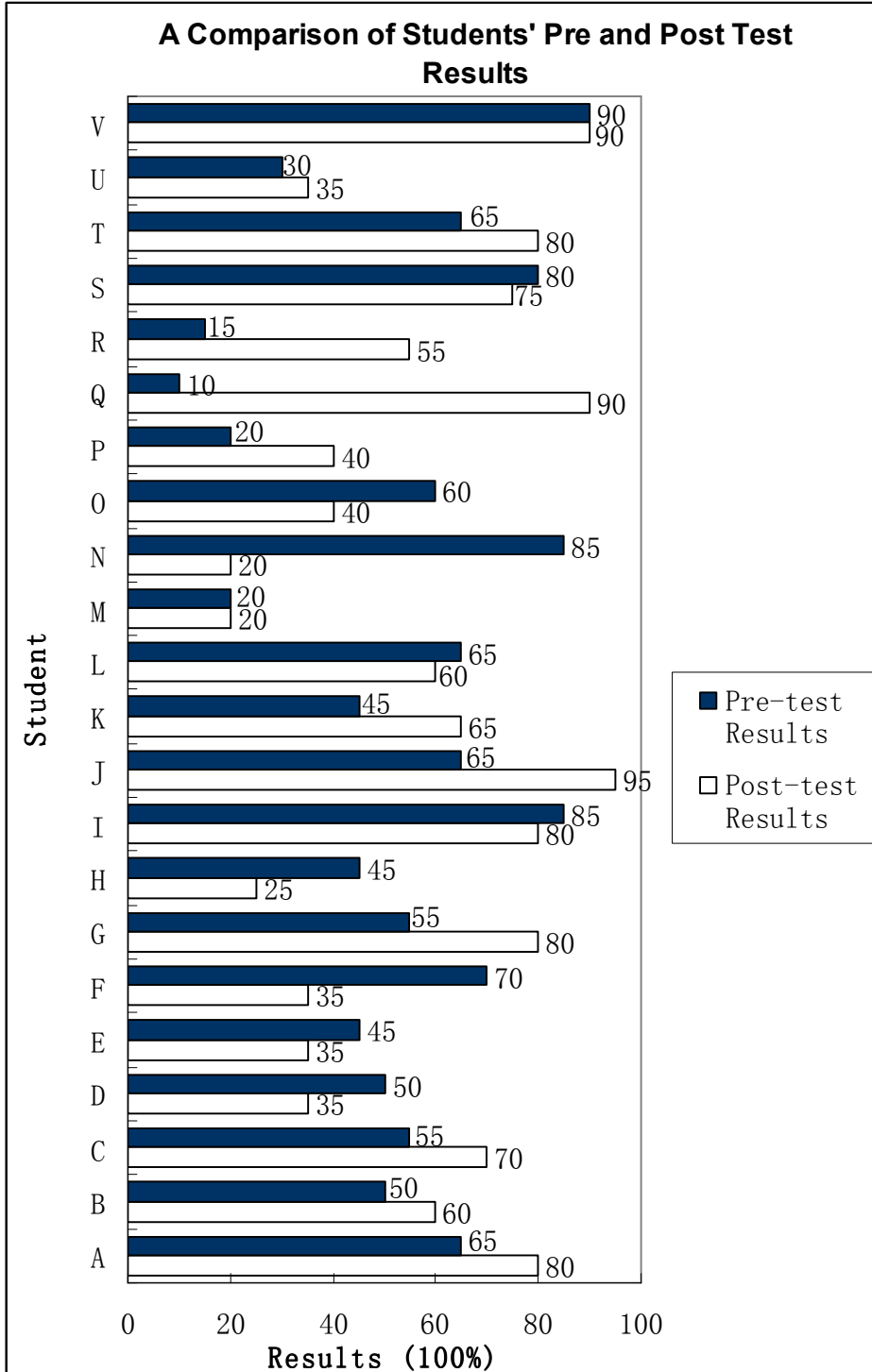


Figure 5: A Comparison of Students' Pre and Post Test Results



Thus, sufficient guidance must be given by the teacher to enable students to adapt to different learning styles as well as to facilitate them in understanding the concepts and connections in learning Science (Allen, 1973; Klahr et al., 1999). This matter led to another significant matter which is the importance and requirements for teachers to undergo adequate training in order to teach Science through hands-on experiments appropriately (Thanasoulas, 2001). Generally, Ms Peach agreed to the implementation of hands-on experiments. She also stated that the class was manageable and she did not face any barriers in implementing the experiment except for the level of noise. However, based on observation and findings gathered, the researchers suggested that more guidance should be provided for not only a particular group of students but for all of the students. The teacher should be alert and aware of students' responses in order to identify if any child is facing an issue.

## Conclusion

From this study, the researchers recommend that further research can be carried out on Bruner's theory of instruction in learning Science with the implementation of hands-on experiments. According to Bruner (1960), a theory of instruction should address four major aspects which are predisposition to learn, structure of knowledge, modes of representation and effective sequencing. It is vital for teachers to utilize the theory as guidance as it supports and acts as a foundation to guide the students to be independent learners whereby they are able to discover new things, construct new knowledge, interpret what they have learned and carry out experiments to test their findings.

In conclusion, there are several areas that can be examined and further research be conducted as there are still gaps in this study. To sum up this research report, the effectiveness of hands-on experiments towards students' learning process and academic development were shown in various data collected. The majority of the data collected had shown positive results in most of the areas. As a result, this study has proven that hands-on experiments promote students' learning and builds on their intrinsic motivation.

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