A Study of Kinesthetic Learning Activities Effectiveness in Teaching Computer Algorithms

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Abstract

Kinesthetic learning is a teaching method that involves students' physical interaction among each other and the environment. The typical method of teaching, a classroom with an instructor talking and students listening and taking notes, has been the same for centuries. This research attempts to show that the kinesthetic learning activities (KLA) approach can be a viable alternative. In this study, the performance of students from an undergraduate level computer science course, Design and Analysis of Algorithms, is considered. In the winter 2014 quarter, selected topics were taught traditionally. The following spring quarter, these same topics were taught using KLA approach. The students' gained knowledge was measured in both quarters through pre / post tests. We hypothesized the KLA approach to be as efficient as the traditional lectures if not more efficient. The data collected proves our hypothesis to be correct. Our surveys also show that students enjoy the KLA approach.

Keywords: *kinesthetic, learning styles, teaching, algorithms.*

1. Introduction

Nowadays, technology is everywhere and in the hands of everyone. Although the benefits of technology in the learning process are immeasurable, technology itself has many drawbacks. One of these drawbacks is the increase in distraction among students. In most classroom settings, students just sit and listen to an instructor. It is easy for them to lose focus by checking social media or chatting with their friends. In addition, several studies suggest that students' attention during a lecture may last only up to fifteen minutes [8]. Therefore, it is challenging for some students to maintain concentration in a standard lecture.

Furthermore, people have different learning styles. According to Neil Fleming's model, there are four types of learners: The first group is visual learners who prefer learning through symbolic representations, using graphs and charts to obtain knowledge. Aural learners are those who perceive more knowledge when they are listening to a lecturer, and they have no problems learning in traditional lecture-based environments. There are also learners who prefer learning through text, either reading a book or writing notes. The last type is the kinesthetic learners who gain more knowledge through physical simulations for the concepts they are learning [3].

Active learning or kinesthetic learning approach is a solution for those who have trouble paying attention for a long period of time because it requires students to be physically active during the lecture. Since computer science topics are theoretical and intangible, grasping the concepts may be challenging for the students. Therefore, kinesthetic learning activities can be helpful and efficient.

1.1. Active learning characteristics:

Active learners tend to learn better through physical movement. Hence, they prefer performing arts and athletics more than studying theoretical science. They get distracted easily in a traditional lecture environment. They perfectly apply to the Chinese proverb which says "*I hear and I forget. I see and I remember. I do and I understand.*" These learners gain more knowledge when they use their hands and bodies. The KLA teaching method provides a suitable learning atmosphere because it forces learners to pay full attention in their movements. For example, a role playing KLA allows learners to imagine a situation where a problem arises, and they act like the solving agent. Another example is playing a game in the classroom like playing the tower of Hanoi puzzle. Kinesthetic learning gives an exciting learning experience for all learners, especially active learners.

1.2. Active learning techniques:

Faust and Paulson, from California State University, Los Angeles [2], have categorized active learning techniques into six types: First, exercises for individual students, which include quizzes that require the students to be in the classroom and pay attention to the lecture. Second, questions and answers, which is a method that allows the students to ask questions anonymously using the fish bowl technique, and the rest of the students answer these questions. This method empowers the students' role in their own learning process. Third, immediate feedback, which is exactly as its name suggests; it gives the professor an opportunity to measure the class's understanding as whole, and it is a helpful method that can be used in large classes. Fourth, critical thinking motivators; is a method that aims to get the students to think about the concept before they actually learn it using puzzles. The tower of Hanoi puzzle is a good example of this technique. The concept can be explained to students before they attempt to solve the puzzle. The learning process actually happens when they solve the puzzle with the algorithm that they have been provided. The fifth active

learning type is share/pair. This method forces students to work together as pairs by exchanging their thoughts and opinions and explaining unclear concepts. An example of this learning type is pair programming which always produces high quality software [9]. The last technique is the cooperative-learning strategy, which requires students to be divided into groups. Each group is responsible of solving a given problem and explaining it to the rest of the class. This method enhances students' communication and social skills.

1.3. Benefits:

The typical classroom setting, where students are just passively sitting and listening, leads students to enter their "relaxed zone," where it is much harder for them to maintain full attention. On the other hand, a kinesthetic activity fills the room with energy and excitement, and it makes students see things from a new angle. Moreover, a KLA also helps students to develop interpersonal skills, since it requires them to communicate with each other. It helps timid students to interact with their classmates in an observed environment. As reported by the National Training laboratories' pyramid of learning, students gain only 5% of the information given to them in the form of lectures while learn-by-doing retains 75% of the knowledge. Furthermore, students retain 90% of what they have learned when they teach each other [6].

1.4. Obstacles:

Despite the numerous advantages of active learning, some instructors are reluctant to adapt this teaching method for several reasons. For example, how an instructor decides to manage their time has a major influence of the whole learning process and its outcome. An instructor must account for the preparation and execution time, as well as students' responses to such new learning strategy. Some instructors think that they do not have enough time to cover all the topics they have assigned for a certain quarter, and active learning can reduce the amount of available time. As a result, an instructor may conclude that lecturing is more convenient for delivering the information. However, a scenario where an instructor explains and students listen does not guarantee that students will be able to absorb the knowledge. Students may leave their classroom with some bits and pieces of a lecture in their notebooks and with nothing in their heads. Also, there is a big chance that a number of students may stop the instructor to ask question, and the instructor might end up not covering every topic that needs to be covered. In addition, in a traditional lecture, the teacher has more control of the class where in an active learning session; students are more involved with how the course is run. With this in mind, an instructor may be ambivalent to use KLA as new problems with classroom management may arise.

2. Past Research:

In the past decade, kinesthetic learning activities were common in preschools and elementary schools. In 2004, Tammy Nguyen did a study named "Do kinesthetic strategies influence students' achievement?" She studied the effectiveness of teaching mathematics kinesthetically for first-graders. She taught them addition and subtraction kinesthetically using hand signals and traditionally, and she tested them. The results showed that the kinesthetic test scores were higher than the non-kinesthetic test scores. Also, she noticed that the students were excited about participating in the KLA's. Although the significant findings of the benefits of kinesthetic learning at the preschool and elementary level, this study by itself can-not prove that kinesthetic learning is more effective than traditional lecturing [5].

In 2009, Katherine Gunion taught middle school students the concept of recursion in a KLA fashion. She held a 7-weeks-after-school program for the students and used 6 different KLAs. She wanted to answer three questions:

1- Can students identify recursion?

2- Can the students understand and apply recursion?

3- What is the effect of understanding recursion on their attitudes towards computer science?

Her answers were as follows: most of the students were able to identify recursion, but few of them were able to apply it on solving different problems instead of solving them sequentially. For the last question, the different data collecting methods she used showed that the students enjoyed the activities, and half of them came back for the next offering of the program, but this still does not prove our goal [4].

Similarly, for college students, there were several publications about kinesthetic learning activities in the computer science field. "Human cons cell jeopardy" which is a KLA developed by Begel, Garcia, and Wolfman to introduce a lisp programming course [1]. Moreover, in 2007, Sivilotti and Pike developed a set of KLAs for both undergraduate and graduate students to teach them the concepts of distributed systems [7]. In general, there are only a few KLAs that have been designed for computer science education at the university level.

3. Research Goal and Methodology:

In this study, we applied kinesthetic learning strategies on students enrolled in a Design and Analysis of Algorithms course in the Computer Science department at Cal Poly Pomona University to test the efficiency of the KLAs compared to traditional lectures. Our hypothesis says that the kinesthetic learning will be as effective as traditional lecturing, if not more effective. It is important to mention that this research has been revised and approved by the Cal Poly Pomona Institutional Review Board (IRB): protocol #14-0004, and it has met the federal and state regulations and Cal Poly Pomona policies regarding the safety of the human subjects who participated in this research.

In winter 2014, the students in Dr. Young's class CS331 Design and Analysis of Algorithms participated in this study.

The chosen topics for this study were Human Sorting, Median of the Medians Divide-and-Conquer approach, and 0/1 knapsack problem Dynamic Programming solution. The students were lectured traditionally, and their background knowledge about the topics was measured using a pretest. Also, they were given a posttest after the lecture to see how much information they gained. During the following quarter spring 2014, students enrolled in the same class were taught the same topics through KLA. They were given pretests and posttests as well. After completing the posttests, the students surveyed their thoughts and opinions about the teaching method. The pretest results along with the posttest results were analyzed and compared to determine the performance of both traditional lecturing and KLA.

3.1. Human Sorting:

There are four distinguished types of sorting algorithms: bubble sort, selection sort, merge sort, and quick sort. Twenty-five students participated in this activity. The students were divided into four groups (six to seven students per group). Each group was responsible for learning the assigned algorithm using the textbook or the Internet. They were given approximately 20 minutes. After that, they were asked to sort themselves kinesthetically according to their heights in an ascending order using the assigned algorithm's strategy in front of the class. After each demonstration, an explanation was presented by the instructor to make sure the rest of students understood the strategy and the complexity of the algorithm.

3.2. Median of the Medians – Divide and Conquer Approach:

This exercise solves the following problem: Given a list of n elements, find the k^{th} smallest element with worst case time complexity *O(n)*. Twenty one students were involved in this KLA. Six students acted as judges for the students' height. The rest of the students formed a table of three rows and five columns. Each column represented a group. Each group was asked to sort themselves in an ascending order with the help of the judges with the tallest student at the back seat. After that, each student in the middle row was announced as the group leader. Next, the leaders were asked to sort themselves in front of the class beginning with the tallest student on the left (facing the rest of the class). Once the leaders were sorted, they were asked to sit in the new column they belonged to. The rest of the seated students were asked to follow their leaders with the original order of the column. The student who was sitting in the middle column and the middle row was declared as the median of the medians. When facing the students, the bottom right quarter of the students was shorter than the median of the medians or at most as tall as him /her, and the top left quarter was at least as tall as the median of the medians as illustrated in figure 3.2.

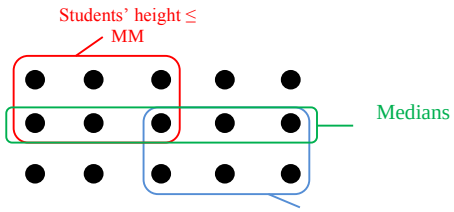

Figure 3.2.

3.3. 0/1 knapsack problem – Dynamic Programming Solution:

This particular activity solves the following problem with dynamic programming approach: "Giving a set of *n* items each with weight *w* and profit *v*, determine the items with most possible total profit to include in a set without exceeding the set's weight limit *W*." The data for this exercise is as follows: $n = 3$, $W = 5$. According to the problem's data, we needed to create a four by six table, where each student represents a cell in the table. For this activity, the more students are involved, the larger the table will be needed. Nineteen students participated in this exercise. Fifteen students were asked to form a human table, and each one of them was given a cup labeled with its capacity. Because the first row represents having zero items, the students were asked to leave the first row empty, and the same was asked for the first column because it illustrates having a knapsack with zero capacity, so no item will fit in this capacity. Three other students were asked to act like the objects, and the last remaining student was asked to flag the cells that chose to keep the object. After forming the table and explaining what the rows and columns represent, each student representing an object was asked to go to each column in his/her row and ask them if the object fits in their cell's capacity and whether they chose to keep it or not. If the object fit and they chose to keep it, the student representing the object placed the object into the cup. The object holders students needed to go check with their columns one after another. This means that object two had to wait until object one finished checking with each column in his row before start checking his/her row cells. Once a cell chose to keep the object, the flag student marked the cell as chosen. This step was important to trace back the optimal solution. Besides explaining to the students what each row and column represent, the students were given a scenario sheet to help them decide whether to keep the object or not. After filling the table, the students traced back the flagged cells by checking the leftover capacity to choose the optimal solution.

4. Research Findings:

With the contributions of about 60 students in two quarters, we were able to compare the effectiveness of KLAs to the effectiveness of the traditional lecturing. The results showed that KLAs are more effective, and the students gained more

knowledge. Furthermore, the survey, which was given to the students in spring 2014, demonstrated that the students enjoyed the KLA, and their comments were positive about this type of learning.

The middle 50% of students' pretest scores in the traditional lecture section is shown in table 4.1. Students #8 to #20 scored an average of 56.41% (6.77 out of 12) while the middle 50% posttest scores from students #7 to #17 scored an average of 85.6% (10.27 out of 12). By comparing the pretest and posttest scores, we can see that the learning gained through the traditional lecture increased by 29.19%. On the other hand, the middle 50% of students' pretest scores in the KLA section in table 4.1. from student #8 to #21 averaged 55.83% (6.7 out of 12), and the middle 50% posttests scores from student #7 to #17 averaged 90.3% (10.90 out of 12). By comparing the results of the tests, we can see that the students gained knowledge increased by 34.47% through KLA.

Respectively, by taking the ratio of the gained knowledge from both quarters, KLA was 1.2 times more effective than the traditional lecture method for the 50% middle students. The pretest scores were higher because of a previous disclosure of the algorithms in prerequisite courses.

From the scores shown in table 4.2, the middle 50% of Median of the Medians traditional lecture' pretests, which ranges from student #7 to #17, scored an average of 12% (0.36 out of 3), and the middle 50% for the posttest of the students' range from #7 to #17 scored an average of 21%. In contrast, the middle 50% of the pretest scores for the students from #8 to #20 in the KLA section scored an average of 30.7% (.92 out of 3). Furthermore, the middle 50% posttest scores of the students from #8 to #20 scored an average of 54% (1.62 out of 3). As a result, the students gained 23.3% knowledge from the KLA and 9% from the traditional lecture. Comparing the gained knowledge from both classes, there was a 14.3% increase through KLA.

As a result, after taking the ratio from both quarters for the two learning gains, KLA was 2.6 times more effective than the traditional lecture for the 50% middle students. Furthermore, most of the students were able to find the median of the medians in the pre/posttests, and only a few were not able to calculate the suitable number of the required subsets.

Lastly, the middle 50% pretests scores for the students ranged from #6 to #14 in the traditional lecture section scored an average of 1.38% (0.11 out of 8), and the average of the middle 50% of the students posttest scores from student #7 to #15 was 59.75% (4.78 out of 8). Thus, the students overall gained knowledge was about 59.25%. Moreover, the 50% middle pretest scores in the KLA section, which ranges from student #7 to student #17 averaged 0% (0 out 8), and the middle 50% of the posttest scores for the range of students from #8 to #20 scored an average of 67.37% (5.39 out 8). Accordingly, the middle 50% showed a big improvement, and their overall gained knowledge scored up to 67.37%.

	Traditional lecture		KLA	
Student	Pretest	Posttest	Pretest	Posttest
1	0	3	0	5
2	1	4	1	9
3	3	7	2	9
4	3	7	2	10
5	3	8	2	10
6	4	9	3	10
7	5	9	3	10
8	5	9	5	10
9	6	9	5	10
10	6	10	5	11
11	6	10	5	11
12	6	11	6	11
13	6	11	7	11
14	7	11	7	11
15	7	11	7	11
16	7	11	7	12
17	8	11	8	12
18	8	11	8	12
19	8	12	8	12
20	8	12	8	12
21	9	12	8	12
22	10	12	8	12
23	11	-	10	-
24	11	-	10	-
25	12	-	10	-
26	12	-	11	-
27	-	-	11	-
28	-	-	11	-
Average	6.61 51.3%	9.55 79.6%	6.35 53.3%	10.59 89%
Max	12 100%	12 100%	11 91.6%	12 100%
Min	0 0%	3 25%	0 0%	5 41.6%

Table 4.1 Tests Results for Sorting Algorithms

Consequently, after taking the ratio from both quarters for the two learning gains, KLA was 1.2 times more effective than the traditional lecture for the 50% middle students. The reason for such a high result is because all of the students contributed to the activity, as well as due to the repetitive nature of the exercise.

	Traditional Lecture		KLA	
Student	Pretest	Posttest	Pretest	Posttest
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
6	0	0	0	1
7	0	0	0	1
8	0	0	0	1
9	0	0	1	1
10	0	0	1	1
11	0	1	1	1
12	0	1	1	1
13	0	1	1	2
14	1	1	1	2
15	1	1	1	2
16	1	1	1	2
17	1	1	1	2
18	1	1	1	2
19	1	1	1	2
20	1	1	1	2
21	2	1	1	2
22	3	2	1	2
23	-	3	1	2
24	-	-	1	2
25	-	-	1	3
26	-	-	2	3
27	-	-	-	3
Average	0.54 18%	0.69 23%	0.73 24.3%	1.5 49.4%
Min	0 0%	0 0%	0 0%	0 0%
Max	3 100%	3 100%	2 66.6%	3 100%

Table 4.2 Tests Results for Median of Medians

	Traditional lecture		KLA	
Student	Pretest	Posttest	Pretest	Posttest
1	0	0	0	1
2	0	0	0	1
3	0	0	0	1
4	0	0	0	1
5	0	1	0	2
6	0	1	0	2
7	0	2	0	2
8	0	3	0	3
9	0	3	0	3
10	0	5	0	3
11	0	6	0	4
12	0	6	0	4
13	0	6	0	5
14	1	6	0	6
15	1	6	0	7
16	1	7	0	7
17	2	7	0	7
18	2	7	0	7
19	-	8	0	7
20	-	-	0	7
21	-	-	0	7
22	-	-	1	7
23	-	-	-	8
24	-	-	-	8
25	-	-	-	8
26	-	-	-	8
Average	0.38 4.75%	3.89 48.6%	0.04 0.5%	4.84 60.5%
Min	0 0%	0 0%	0 0%	1 12.5%
Max	2 25%	8 100%	1 12.5%	8 100%

Table 4.3 0/1 Knapsack problem tests results

Table 4.4 demonstrates the learning gains for both teaching methods for the counted 50% middle students, and the ratios showing the effectiveness of KLA in comparison to the traditional lectures.

Method	Sorting Algorithms	Median of the Medians	0/1 Knapsack
Lecture	21.78 %	10.3%	54.12%
KLA	34.47%	22.3%	70.25%
Ratio:	1.2	2.6	1.2

Table 4.1 Ratios of the learning gains lecture vs. KLA for the 50% middle students

When we focus on the whole class's performance, Figures 4.1 - 4.3 illustrate the improvements of the pretest' and posttest' averages for both quarters. We expected the pretests averages to be low because they were given to the students to have an idea what they already know about the concepts they will learn before they learn it. However, some topics were not entirely new for some students as the case of the sorting algorithms in Figure 4.1.

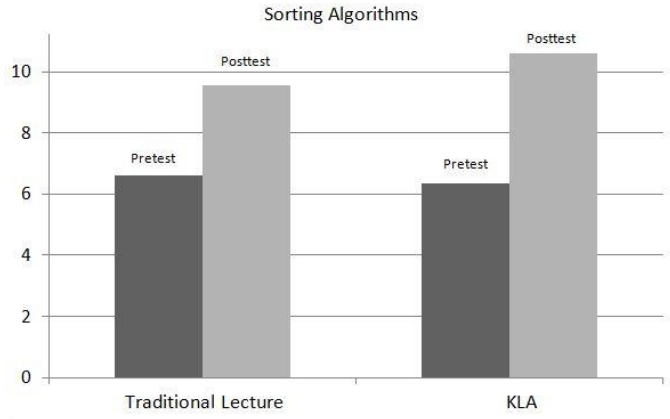

Figure 4.1 Sorting Algorithms average tests results

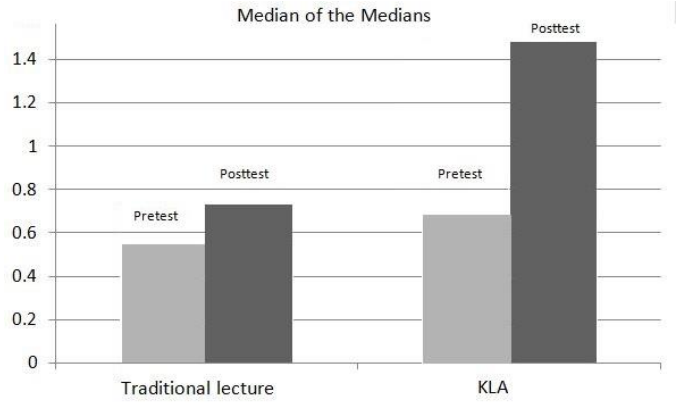

Figure 4.2 Median of the medians average tests results

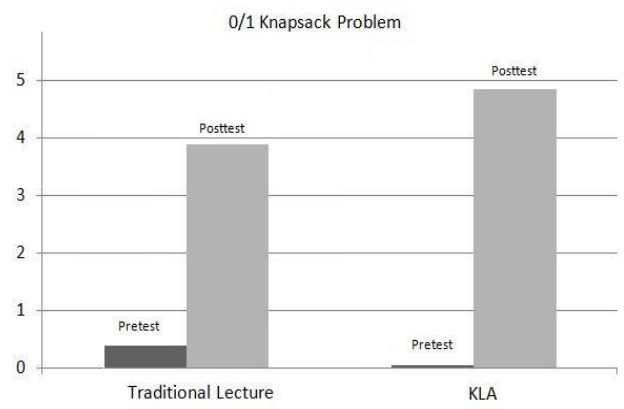

Figure 4.3 0/1 Knapsack problem tests average results

The posttests were given after the topics were taught to gauge the students' understating of the topic. Comparing the three figures, the sorting algorithms posttest averages among the two quarters were the highest. Once more, this was due to the students' previous exposure to the topic.

5. Survey Feedback:

In spring 2014, a total of 30 students reviewed the KLA with a one-page survey that consisted of short answers and liking scales. According to table 5.1, 46.6% of the surveyors chose kinesthetic learning as their preferred learning style, and 68% of them evaluated the KLA as a good teaching method. The last two questions in survey asked the students to write their opinion on what they liked and what they did not like about the KLA. One student wrote: "Just like all teaching techniques it is subjective." Usually, what makes a difference to a student's ability to learn is how the concept was taught, not what was being taught. Another student wrote regarding KLA: "Hard to lose focus during such activities." Because KLA depends on students' physical movements, students will not have a chance to lose focus or fall asleep. Another student said: "KLA is more interesting and makes things simpler to learn, but it can be rather time consuming." A well designed KLA and a prepared instructor are two factors that reduce the time wasted that KLA may cause.

Learning Style	Percentage
Visual	33.3 %
Auditory	3.3 %
Writing	0 %
Kinesthetic	46.6 %
I don't know	16.6%
Total	30

Table 5.1 Surveyors Learning Styles

6. Conclusion and Future Work:

Kinesthetic learning activities are more effective than the traditional lectures according to table 4.1. This result is similar to the results of Nguyen's study, Gunion, Begel, Garcia, and Wolfman. Moreover, the use of KLA is a beneficial tool for helping students to understand the elusive concepts of computer science. Furthermore, KLA can be a good solution for helping students to stay focused and not get distracted during the class. When utilyzed for a well designed activity and to focusing on the topic at hand, KLA can be a powerful tool to teach theoretical concepts in computer science.

Likewise, related studies can be done to determine the effects of a particular form of KLA activity and its effect' on the students' understanding of a topic. Also, applying this teaching method on different subjects can help support the results of this research.

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