How to find the number of π with the Monte Carlo method in mathematical modeling

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Abstract: This article describes the history of π, the role of the number in the calculations of great scientists, and the positive results achieved by students using the educational technology “debate” method in uncovering ideas about how to find and program π using the Monte Carlo method in mathematical modeling.
Keywords: Mathematical modeling, history of number p, perimeter, diameter, the addition of fractions, invented fast algorithm, the idea of the method of Monte-Carlo method.

A scientific and practical approach to the topic of how to find the number p using the Monte Carlo method in mathematical modeling was carried out in two groups as a trial and experiment among the members of the student scientific society organized at the Department of "Informatics, Information Technologies" of Samarkand State Medical University.
- The number of students in the first group was 12, and the lesson was conducted traditionally.
- The number of students in the second group was 14, and the lesson was taught using the "Discussion-Debate" educational method.

The second group was given brief information about the "Discussion-debate" interactive learning method. We started our lesson by dividing into 2 groups, with 14 participants.

"DISCUSSION-DEBATE" METHOD is a method of training conducted through mutual debate and exchange of ideas with learners on a topic. Discussions are held in the way that the study group is divided into two or more small groups and the participants exchange their opinions on a topic. Debate is an effective way to discuss the issue being studied. It involves a group discussion of some controversial issue, during which the truth is revealed.

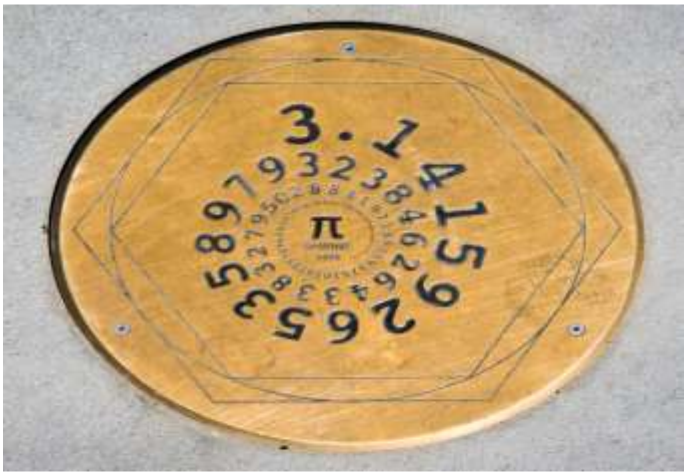
According to the expert pedagogue Ch. Kupisevich, "It consists of exchanging ideas between the teacher and students or only between students on a specific topic." These opinions may be your own or those of others. An effective discussion is characterized by different opinions, an effort to find the correct solution to a didactic problem, and the active participation of interlocutors in it. Compared to lectures and conversations, it creates a more favorable environment for activating students, influencing their psyche, in particular, their creative imagination. Debate requires students not to give a simple answer to a question, but rather a rational, emotionally colorful, and meaningful solution to a didactic problem, to clearly express their thoughts. It arouses strong emotional feelings in the participants, helps the emergence of socio-psychological phenomena in different groups, and develops teamwork skills and the ability to listen to the positions of other students.

Let each student give his example, in addition to the examples given in the practical texts. Student responses are graded based on the meaning and explanation of the given examples. Similar examples are not considered. Answers copied exactly from each other will not count.

Without fully explaining the topic to the students, we threw the topic as a problem between two groups. The students were evaluated as a result of the correct answers obtained as a result of the debate.

What is the number **π** (pi)?

π is used by many professionals in their professions, for example, architects, astronomers, physicists, chemists, etc.



πan irrational number cannot be expressed precisely as either a whole number or an arithmetic fraction. Represented by infinite and non-periodic decimals. The number p is the ratio of the circumference of a circle to its diameter and is approximately equal to 3.1415926535. The ancient Greek mathematician Archimedes calculated the value of π to three decimal places. Claudius Ptolemy expressed the value of π to the fourth decimal place. At that time, the value of π was expressed in equivalents, since then there was no decimal point. For the next 1,500 years, the Western world did not succeed in obtaining a more accurate value of π. However, at the same time in ancient China, on the contrary, there were significant advances in the field of calculating the value of the number π. Ancient Chinese mathematicians tried all kinds of methods to get an approximate value of π. One method was as follows: draw a circle, and inscribe a regular polygon on it.The more sides a polygon has, the smaller the difference between the area of the polygon and the area of the circle. The area of a circle is expressed by the formula πr^2, where r can be calculated accurately by measuring the radius. Thus, when the area of a polygon approaches the area of a circle, the approximate value of the number p is obtained. Archimedes inscribed a regular 96-degree angle in the circle, resulting in the following value: $3.140 < \pi < 3.142$. The calculation method of the ancient Chinese did not differ from Archimedes' method, but they obtained more accurate values. Liu Hui, who lived during the transition period of the Wei and Jin dynasties, calculated the value in the same way. During Liu Hui's time, people believed that the ratio of the circumference of a circle to its diameter was 3:1, which is the ratio of the perimeter of a regular 6-sided inscribed circle to the diameter of the circle, not the value of π. The calculated area of a circle based on a 3:1 ratio is not the actual area. At that time, people already knew that the area of a circle was calculated using the formula "semi-perimeter x diameter". The diameter is a straight line, and theoretically, its value can be calculated with an accurate measurement.So, to calculate the area of a circle, you need to know the area of the circle. However, a circle is a curve and cannot be measured directly. Therefore, instead of measuring the perimeter of the circle, people have come up with a simple 6-point method to fit the circle, but this method introduces an error in the solution. How to turn a curved line into a straight line? In this regard, Liu Hui noted: that as the number of sides of a regular polygon inscribed in a given circle increases infinitely, the length of its side tends to the perimeter of the circle. Therefore, the length of the sides of a regular polygon inscribed in a circle serves as a substitute for the perimeter of the circle. Liu Hui's method is called "split the circle". Liu Hui brought his idea to life: he used the method of "circular division" in the process of calculating the value of p. Starting with 6 angles, he repeatedly increased the sides of the polygon, resulting in 12 angles, 24 angles, 48 angles, 96 angles, and even 192 angles. So he got a π-value of 3.141024.

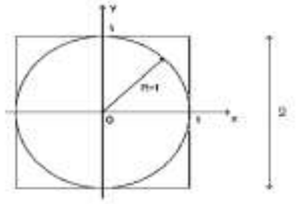
During the calculation, it used the value "3.14". To find the proof, he increased the sides of the polygon by 3072. The area of the 3072 angle drawn on the circle is closer to the actual area of the circle. Thus, Liu Hui obtained the value of *π*with an accuracy of 3.1416, which is much more accurate than the results obtained by the Greeks. The p-value obtained by Liu Huz was once the most accurate in the world. But Liu Hui's contribution was not only that. He contributed to the development of mathematics by creating a scientific method for calculating the value of p. Thanks to his work, a solid theoretical basis was created for the most in-depth study of the meaning of *π*. If descendants continue to calculate according to his method, they will have a more accurate value. In addition, his theory has a much clearer idea of linear and curvilinear transformations. Linear and curvilinear transformations are the source of the differential and integral calculus theory.

Currently, the Chudnovsky algorithm is used. The Chudnovsky brothers invented a fast algorithm for calculating the number *π*. It shows more than a trillion decimal places.

In the 1700s, mathematicians began using the Greek letter p, introduced by William Jones in 1706. The use of the symbol since 1737 was popularized by Leonard Euler, who adopted it. Leonard Euler, mathematician, born 1707.

How to find p with the Monte Carlo method in mathematical modeling

We show how to find the number - πusing the classic Monte Carlo method. For this, we need a circle inscribed in a square and let the circle's radius be equal to 1. This means that the side of the square is equal to 2, which is the diameter (or two radii) of the circle:



Into this square, we throw random grains of sand and see if they fall into the circle or not (but stay within the boundaries of the square). From this data set, we can calculate the ratio of all grains of sand falling on the circle to all grains of sand.

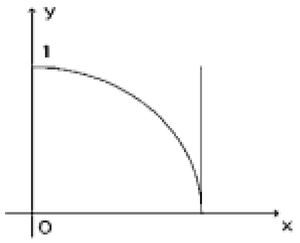
Now let's look at the formulas:

- The area of a square with 2 sides is four;
- The area of a circle with radius 1 is $\pi R^2 \rightarrow \pi \times 1^2 = \pi$.   is equal to

If we divide the area of the circle by the area of the square, we get π / 4. But we cannot yet calculate the area of the circle by condition, because we do not know the number p. Instead, we can divide some number of grains of sand by others—this is the essence of the Monte Carlo method.

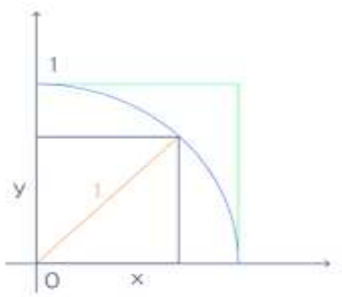
This ratio gives us the result-π / 4. It turns out that if we multiply this result by 4, we get the number π, and the more grains of sand we throw, the more accurate the result.

We throw grains of sand like this: we get random numbers from 0 to 1 as coordinates of x and y shots. This means that all numbers fall into only one quadrant — the upper right:



But since this quadrant is one-fourth of a circle and one-fourth of a square, the ratio of misses to hits is the same as if we threw grains of sand into a whole circle and a whole square.

To check that a grain of sand falls on a circle, we use the formula for the length of the hypotenuse: $x^2 + y^2 = 1$ (because the hypotenuse is the radius of the circle):



If the length of the hypotenuse is less than one, the point falls on the circle. As a result, we count the total number of points and points falling on the circle. Then we divide one by the other, multiply the result by 4, and get the approximate value of the numberπ.

We program the search for the numberπ using the Monte Carlo method:

Python algorithm.

connect the random number module

```
import random
# function that will calculate pi
defcount_pi(n):
    # total number of throws
i = 0
    # How many of them fell into the circle
count = 0
   # until we reach the final throw
whilei< n:
       # randomly obtain x and y coordinates
       x = random.random()
       y = random.random()
       # check whether we are in the circle or not
if (pow (x, 2) + pow (y, 2)) < 1:
                          # If hit, increase the counter by 1
count += 1
              # In any case, increase the total counter
i += 1
   # count and return pi
return 4 * (count/n)
              # run the function
pi = count_pi (1000000)
# display the result
print(pi)
```

Result: In the first group, the topic of how to find the number p using the Monte Carlo method in mathematical modeling was described traditionally, and the positive results were as follows:

Proportion 12 - 100
1 - x,

X=100/12=8.33
8.33%*12=99.96% Mastery

(3 students 5th grade, 4 students 4th grade, 6 students 3rd grade, 1 student 2nd grade) with results.

8.33 %*3 students =24.49 %
8.33%*4 students =33.32 %
8.33% *6 students =49.98%
8.33%*1 student =8.33%

We achieved a positive rate of 57.81% through 99.96% absorption.

The following were the positive results obtained by explaining the methods of interactive education to the second group of students in the "Discussion-discussion" style.

Proportion 14 - 100
1 - x ,

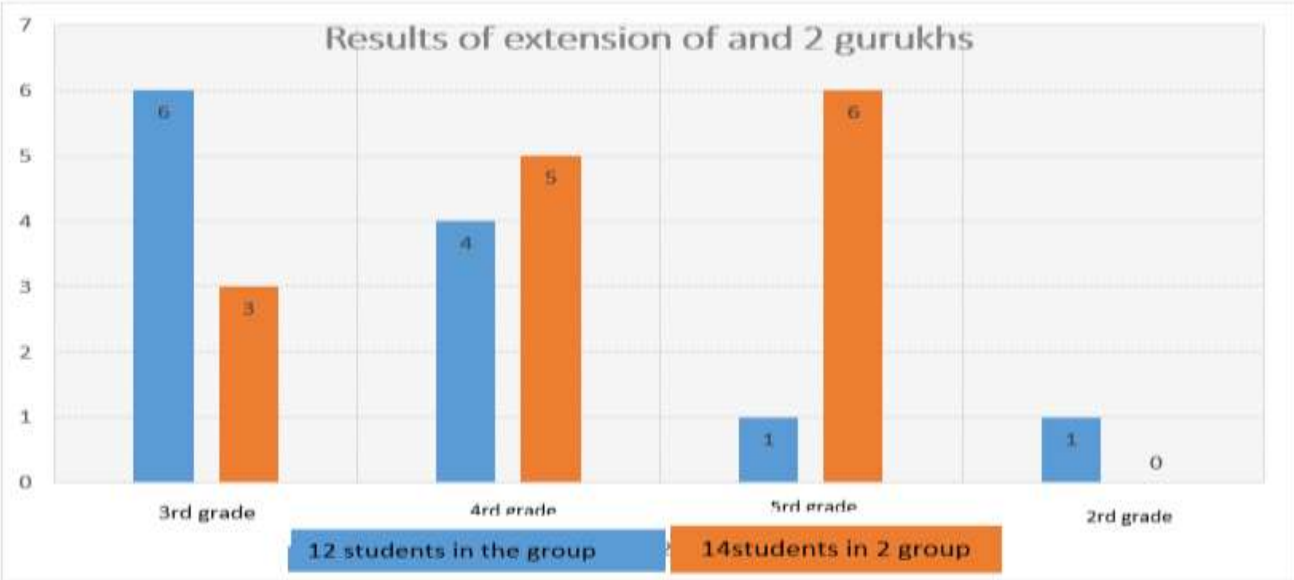
X=100/14=7.14
7.14%*14=99.96% Mastery

(6 students 5th grade, 5 students 4th grade, 3 students 3rd grade) with the result

7.14%*6 students =42.84%
7.14%*5 students =35.70 %
7.14% *3 students = 21.42%

We achieved a positive rate of 78.54% through 99.96% absorption.

The chosen method gave a good result, because in mathematical modeling, how to find the number$\pi$with the Monte Carlo method, there are many debates and discussions, and as a result of the students' discussion on the topic, it leads to a complete mastery of the topic. At the same time, the presentation of the topic
A vivid example of this is when students correctly answer additional questions.



Conclusion: How to find the number p with the Monte Carlo method in mathematical modeling, while explaining the topic of interactive educational methods using the "Debate-discussion" method. we will achieve positive results. If the discussion study group is divided into two or more small groups, during which the participants exchange ideas on a topic (pay attention), their activity and evaluation processes are announced. it is observed that they strive to show good results. This leads to an increase in positive results. When experimental tests were conducted in two groups of the student scientific society of Samarkand State Medical University, we were sure that the effectiveness of the lesson conducted using the " Debate-discussion " method was 20.73% higher than the traditional method. This article No. AM-PZ-2019062031 was written based on the pedagogical analysis of the materials prepared as part of the innovative project "Creation of multimedia textbooks for bachelors and masters in the fields of "Nuclear energy", "Nuclear medicine and technologies", "Radiation medicine and technologies" lib, we thank the authors of the textbooks.

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