

### □ What does “learned weight matrix” mean?

In machine learning (including Transformers), a weight matrix is like a table of numbers that the model uses to transform input data.

#### □ “Learned” means:

- The model doesn’t start with fixed numbers.
- Instead, during training, it adjusts these numbers again and again to improve performance.

### □ Example in the Transformer

When creating the Query, Key, and Value vectors, we multiply the word embeddings by weight matrices:

$$Q = \text{Embedding} \times W^Q, K = \text{Embedding} \times W^K, V = \text{Embedding} \times W^V$$

Here:

- $W^Q, W^K, W^V$  are the learned weight matrices.
- They start with random numbers.
- As the model trains on data, it adjusts these numbers (using optimization algorithms like gradient descent) to reduce error and improve accuracy.

### □ Simple analogy

Think of the weight matrix like a recipe:

- Initially, you guess ingredient amounts (random weights).
- You taste the dish (check loss/error).
- You adjust the recipe (update weights).
- Over time, you learn the best combination for great results.

## □ Why is it important?

Without learning the weight matrix:

- The model would just apply fixed, useless transformations.
- With learning, the model adapts itself to the data, finding the best patterns to make good predictions.

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