Foundations of Semantic Knowledge Graphs

Prof. Dr. Stefan Linus Zander

What is Knowledge ?

What is knowledge and how can it be utilized in IS ?

Knowledge can be defined from many perspectives

Philosophically

- Rooted in epistemology
- Huge disconsensus in philosophy about the different conceptions and definitions
- Knowledge is a subset of all true believes
- One largely accepted definition is *Justified* True Belief (JTB)
- The american philosopher Edmund Gettier disapproved the JTB by providing a number of counter examples – also known as the Gettier Cases

Pragmatically

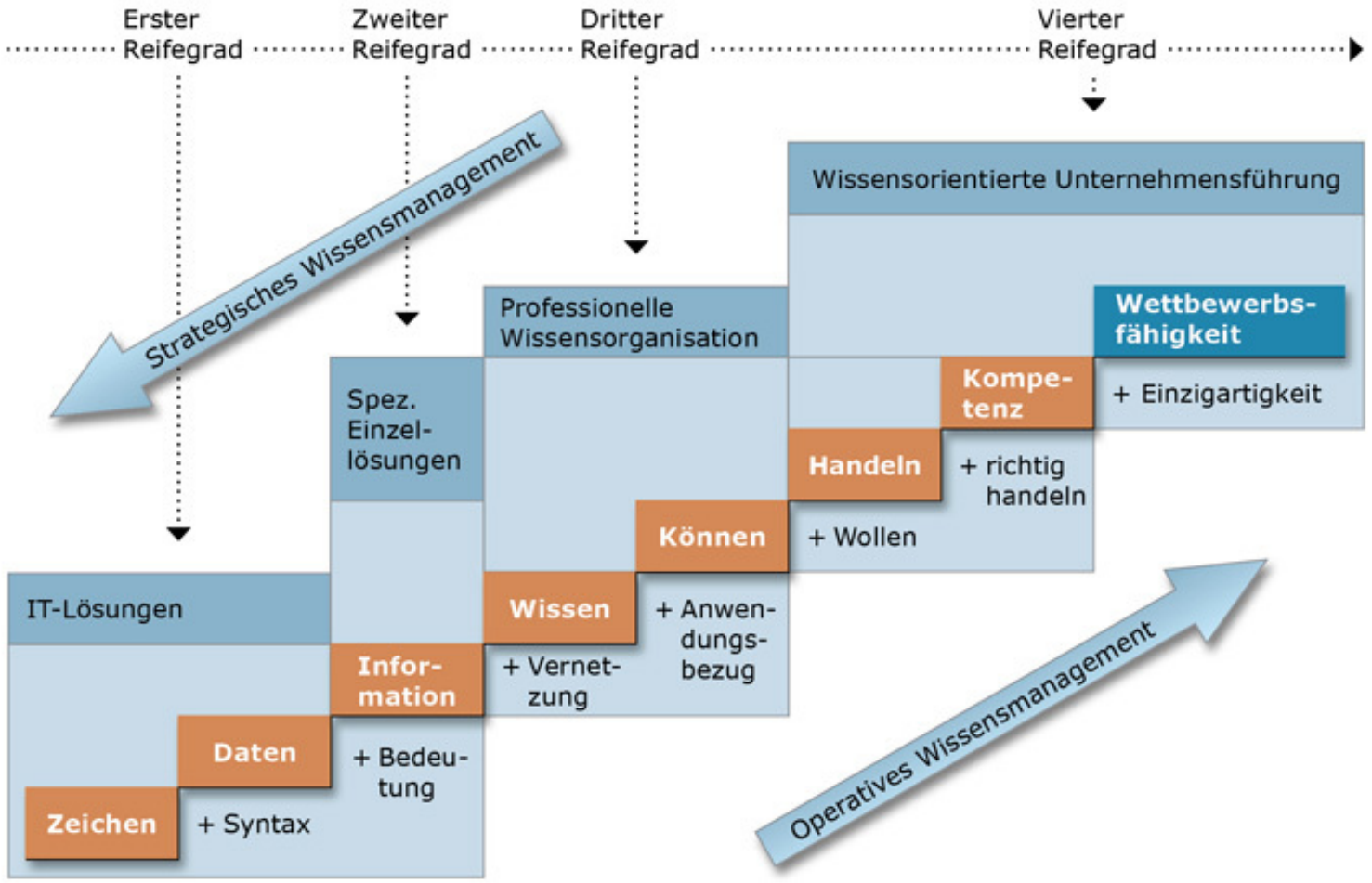
- several models have been proposed to explain the nature of knowledge, mostly in the context of certain scenarios (e.g. CPS, Industry 4.0, Innovation etc.)
- The most prominent ones among others are
  - The "Wissenstreppe 4.0" by Klaus North
  - The SECI-Model by Nonaka and Takeuchi
  - The Knowledge Pyramid by Ackoff, 1999

Technically

- Knowledge needs a form of manifestation to be represented in machine-processable models
- This area is denoted as (formal) knowledge representation
- It makes extensive use of different logical theories to represent knowledge in formal, unambiguous ways while being able to draw inferences on the model's constituents

As we will see, there is no universally accepted definition of/for 'Knowledge'

Examples: The "Wissenstreppe" from Klaus North



Quelle: http://qib.f-bb.de/wissensmanagement/thema/wissen/wissenstreppe.rsys

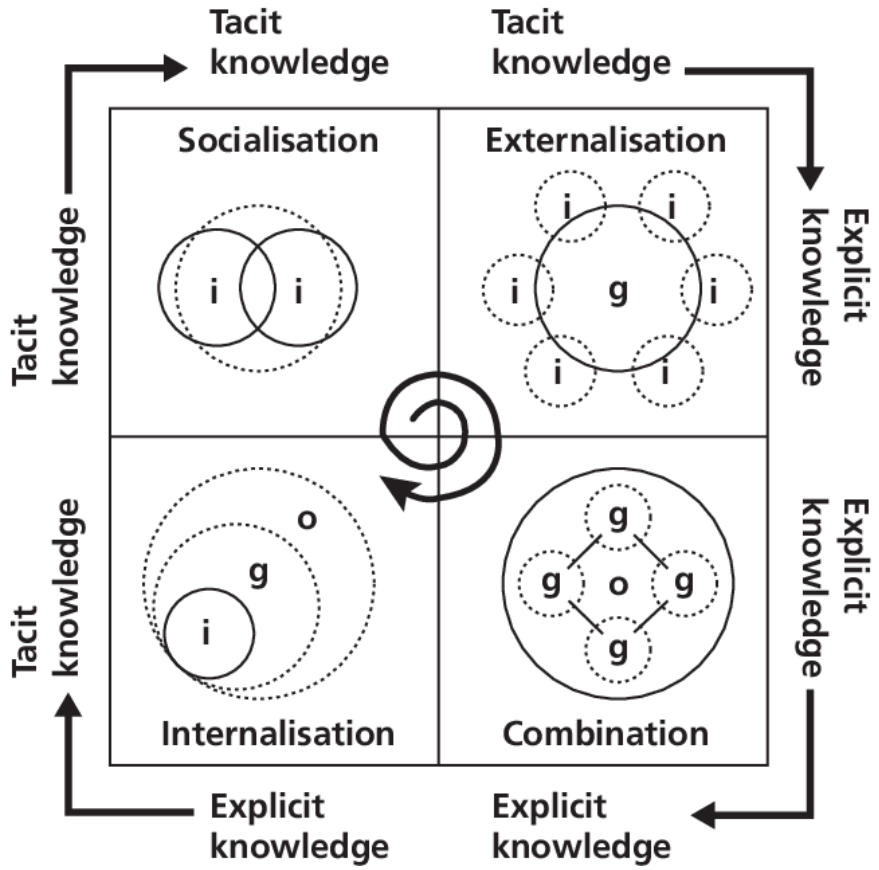
Excursus: The SECI-Model (in German)

Das SECI-Modell stellt das implizite, d.h., **Personen-gebundene** und **schwer verbalisierbare Erfahrungswissen** von Mitarbeitern in den Mittelpunkt. Es erläutert, wie dieses Wissen für eine Organisation aktiviert werden kann.

Es unterscheidet sich von anderen Wissensmanagementmodellen dadurch, dass es den Fokus auf eine einzige Fragestellung lenkt, nämlich – wie neues Wissen in Organisationen entsteht.

Neues Wissen entsteht in einem **kontinuierlichen Transformationsprozess** zwischen dem impliziten und dem expliziten Wissen, d.h., die Wissengenerierung beruht auf einem Prozess der dynamischen Transformation von implizitem zu explizitem Wissen und vice versa.

Entscheidend bei dem Modell von Nonaka & Takeuchi ist die **Transformation von individuellem in kollektives Wissen**, d.h., von einem personenbezogenen in ein allgemein zugängliches Wissen (=die Wissensbasis der Organisation).



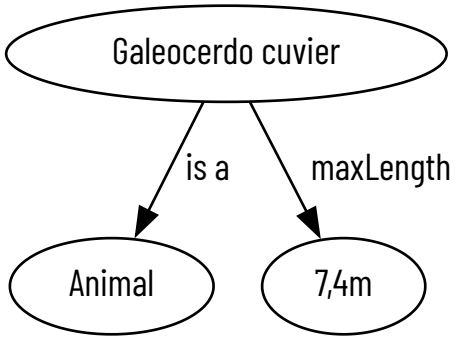
So what do we do now...?

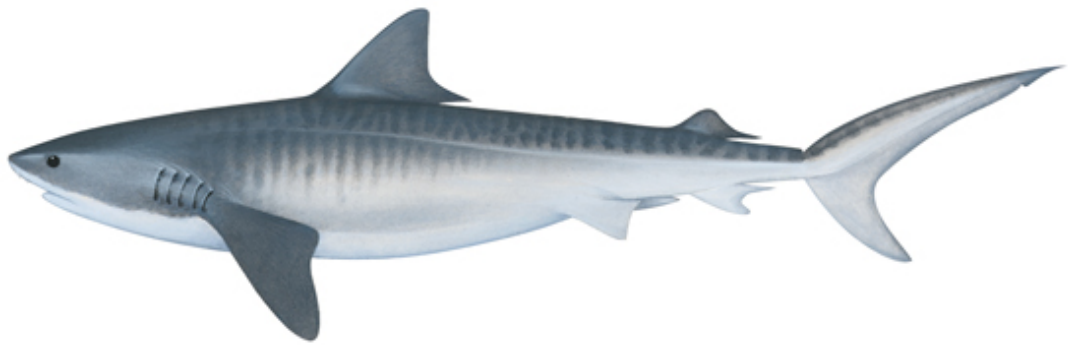
The simplest approach for defining knowledge is to define it on the basis of a continuum of increasing meaning and value in terms of the intentions and actions an agent can perform based on the contemplation of elements being constituents of

Knowledge is best explained through a Continuum of increasing Specificity and Meaningfulness

Symbols → Data → Information → Knowledge

$\{a, b, 4, 7, \theta, \sigma, \ldots\}$ → 7,4 → 7,4 m →





$$\text{Galeocerdo cuvier} \sqsubseteq \text{Animal} \sqcap \forall \text{maxLength}.7,8$$

Data

- Data is raw.
- It simply exists and has no significance beyond its existence (in and of itself).
- It can exist in any form, usable or not.

Information

- Information is data that has been given **meaning** by way of **relational connection**.
- This "meaning" can be useful, but does not have to be.
- Information is **contained in descriptions**.
- Information answers to questions that begin with such words as who, what, when, where, and how many.

Knowledge

- **Knowledge** is the appropriate collection of information, such that it's intent is to be **useful**.
- **Wisdom** is the ability to make **sound judgments** and **decisions**.
- **Understanding** is a **continuum** that leads from data, through information and knowledge, and ultimately to wisdom.

Data transforms to **information** by convention, **information** to **knowledge** by cognition, and **knowledge** to **wisdom** by contemplation.

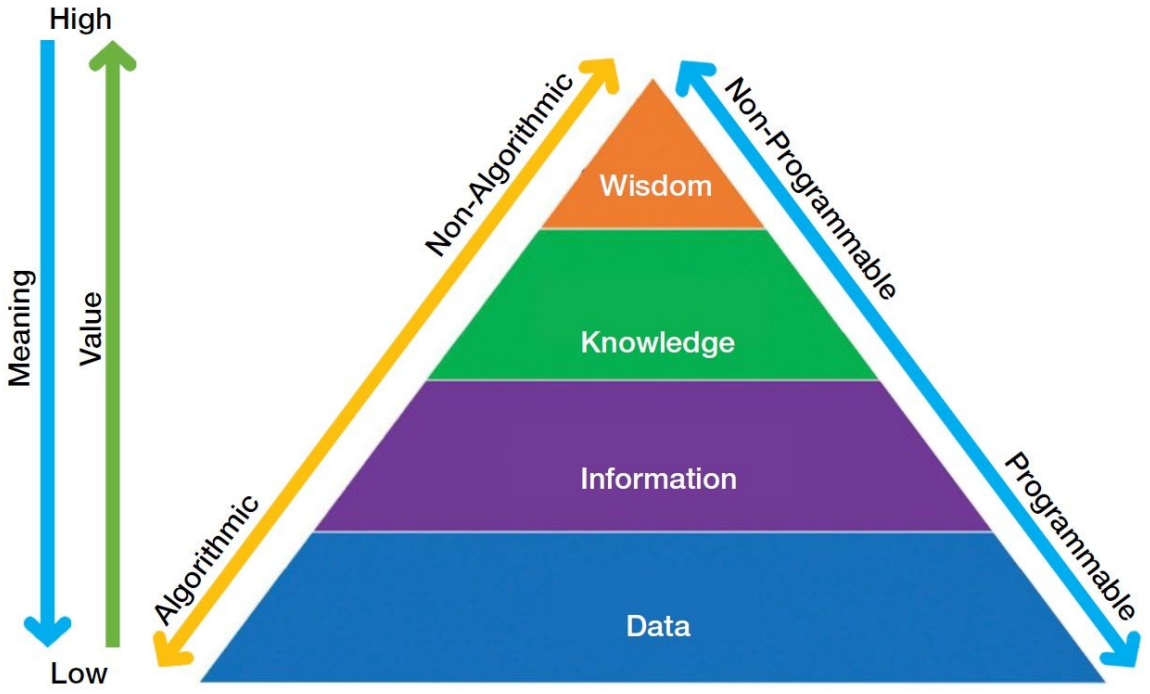


FIG. 1: DIKW (data, information, knowledge and wisdom) pyramid.

Source: Ackoff, Russell (1989). "From Data to Wisdom". Journal of Applied Systems Analysis. 16: 3–9.

A 'nice' definition provided by ChatGPT

What is knowledge ?

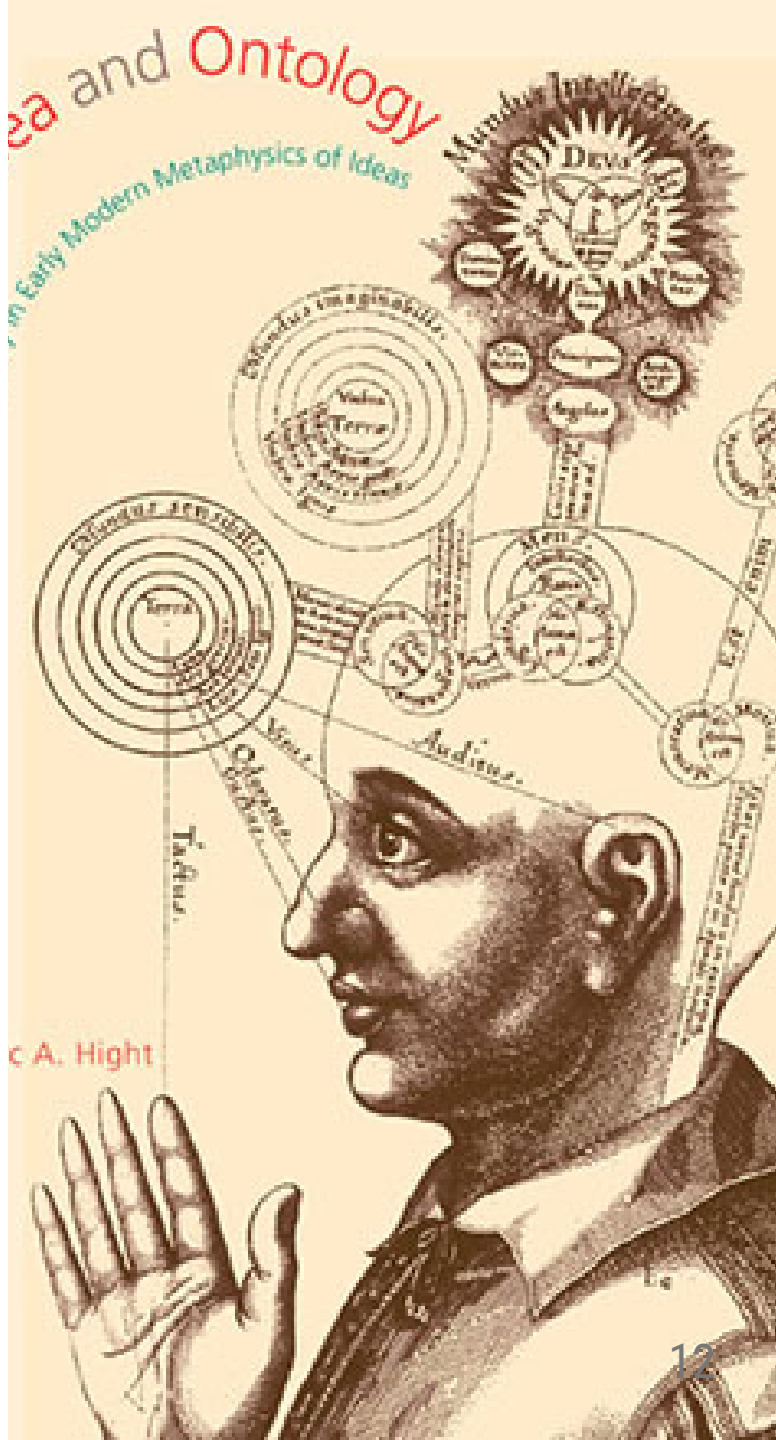
Knowledge is what we know about the world around us. It is what we have learned and understood, whether through experience, study, observation, or instruction. It includes facts, concepts, principles, ideas, and insights that help us understand the world and navigate it. Knowledge is what we have in our minds and can apply to solve problems, make decisions, and navigate various situations.

Generated by ChatGPT using the above phrase on January 15th, 2023

So, what is the meaning of 'Knowledge' in Knowledge Graphs ?

By knowledge, we refer to something that is "known".

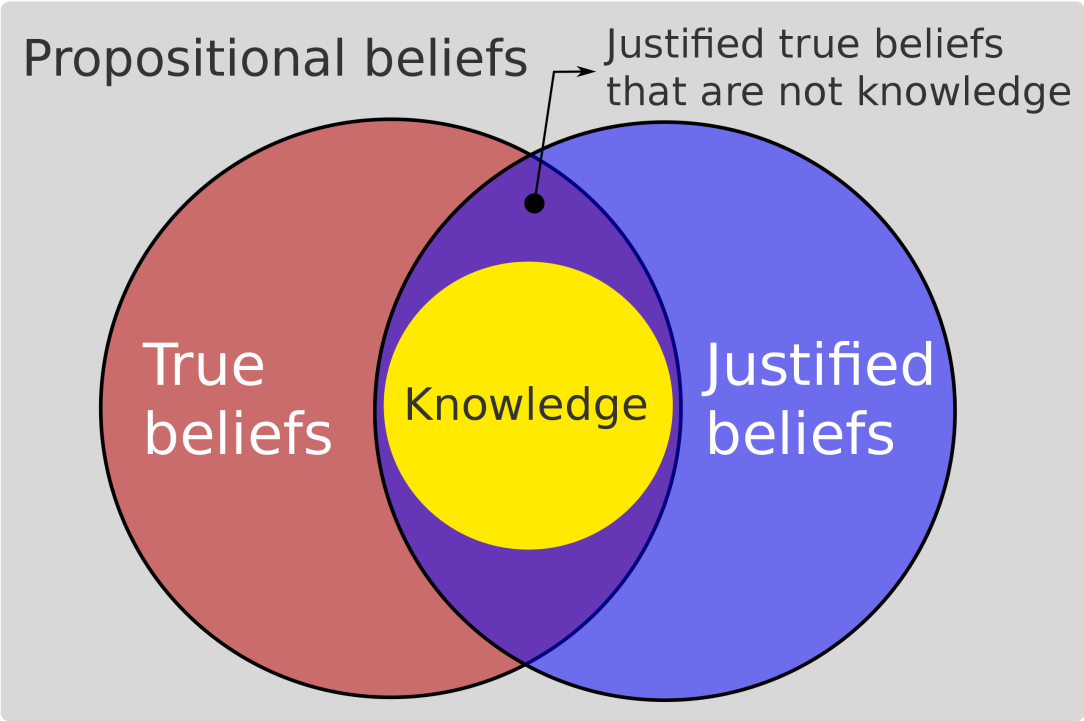
- Such knowledge may be accumulated from external sources, or extracted from the knowledge graph itself
- Knowledge may be composed of simple or quantified statements
  - "Santiago is the capital of Chile" (simple assertion)
  - "all capitals are cities" (quantified assertion)
- Simple statements can be accumulated as edges in the data graph
- The accumulation of quantified statements requires a more expressive way to represent knowledge such as ontologies or rules
- Deductive methods can be used to entail and accumulate further knowledge
  - e.g. "Santiago is a city"
- Additional knowledge – based on simple or quantified statements – can also be extracted from and accumulated by the knowledge graph using inductive methods



Additional information for interested parties

Knowledge as Justified true belief (JTB)

- The JTB account of knowledge is the claim that knowledge can be conceptually analyzed as justified true belief, which is to say that the meaning of sentences such as "Smith knows that it rained today" can be given with the following set of conditions, which are necessary and sufficient for knowledge to obtain:
- An agent S knows that a proposition P is true if and only if:
  i. P is true, and
  ii. S believes that P is true, and
  iii. S is justified in believing that P is true
- The concept of justified true belief states that in order to know that a given proposition is true, one must not only believe the relevant true proposition, but also have justification for doing so.



The Gettier problem is motivated by the idea that some justified true beliefs do not amount to knowledge; they are the result of lucky coincidents.

Sources: (1) https://en.wikipedia.org/wiki/Gettier_problem and (2) https://en.wikipedia.org/wiki/Definitions_of_knowledge#Justified_true_belief

Knowledge as justified true belief (JTB)

Truth

- Knowledge implies truth
  - i.e. one cannot know things that are not true even if the corresponding belief is justified and rational.
  - e.g. nobody can know that Hillary Clinton won the 2016 US Presidential election since this did not happen.
- Knowledge is a relation through which a person stands in cognitive contact with reality.
- This contact implies that the known proposition is true.

Belief

- Knowledge is usually understood as a form of belief: to know something implies that one believes it.
  - e.g. an agent accepts the proposition in question.
- Belief is interpreted as a commitment to something being true.
- A few epistemologists hold that true belief by itself is sufficient for knowledge.
- Despite various different conceptions there is a common and shared agreement among philosophers that knowledge is a form of belief.

Justification

- Justification is based on the idea that having a true belief is not sufficient for knowledge since it implies more than just being right about sth.
- Beliefs based on dogmatic opinions, blind guesses, or erroneous reasoning do not constitute knowledge even if they are true.
  - e.g. if someone believes that Machu Picchu is in Peru because both expressions end with 'u', this true belief doesn't constitute knowledge.
- True beliefs that are based on good justification constitute knowledge
  - e.g. a person visiting peru knows that Machu Picchu is in Peru

A classic example of JTB

One classic example of justified true belief is the following scenario:

> ***Example***
> *Imagine that you look at your watch and see that it's currently 2:00 PM. You believe that it's 2:00 PM, and this belief is true, because it matches what you see on your watch. However, your belief is not based on a mere guess or a hunch - it's justified, because you have several reasons to believe that your watch is accurate. For example, you may have set your watch to the correct time earlier in the day, and you may have checked it against another reliable timepiece.*

- So in this example, you have a justified true belief that it's currently 2:00 PM.
- Your belief is true, because it corresponds to reality, and it's justified, because you have good reasons to believe it.

Another example of JTB

Example

Suppose you have a friend named Sarah who you know to be a reliable source of information. One day, Sarah tells you that it's currently raining outside. You believe Sarah's statement to be true, because you trust her and have no reason to doubt her. Additionally, when you look outside, you see that the ground is wet and people are carrying umbrellas, which confirms Sarah's statement.

- In this scenario, you have a justified true belief that it's raining outside.
- Your belief is true, because it corresponds to reality, and it's justified, because you have good reasons to believe it.
- You trust your friend Sarah, and you can see that the ground is wet and people are carrying umbrellas.