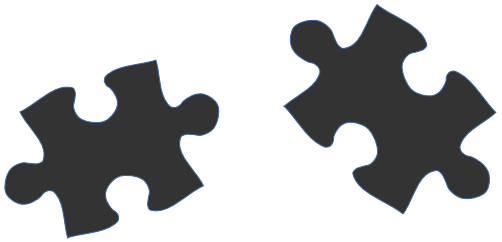
Data Analysis: Introduction

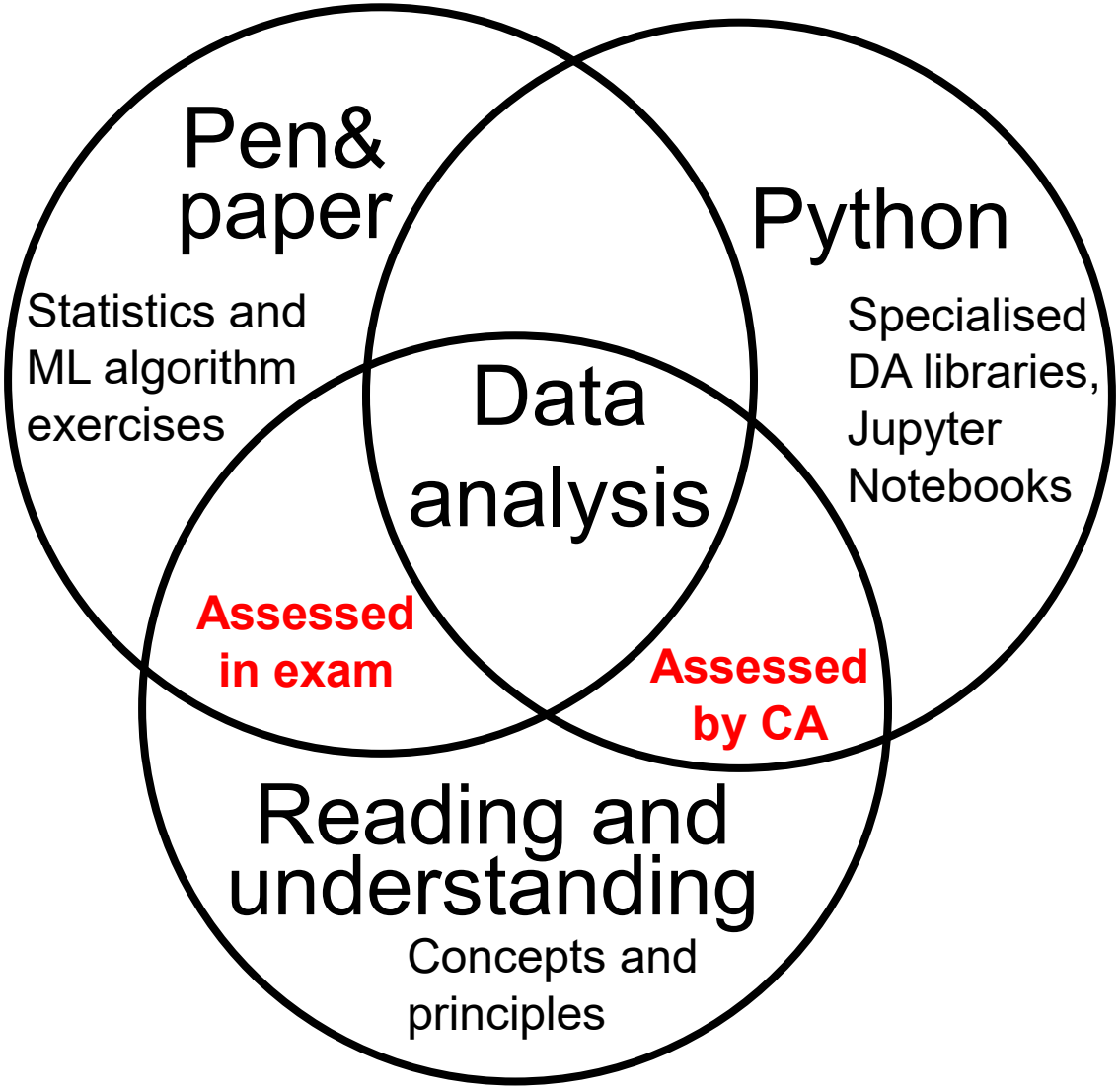
TU Dublin, Tallaght Campus

School of Enterprise Computing and Digital Transformation

In this module

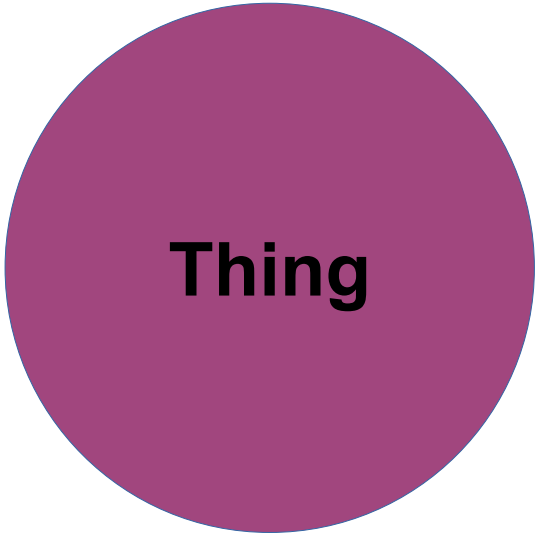


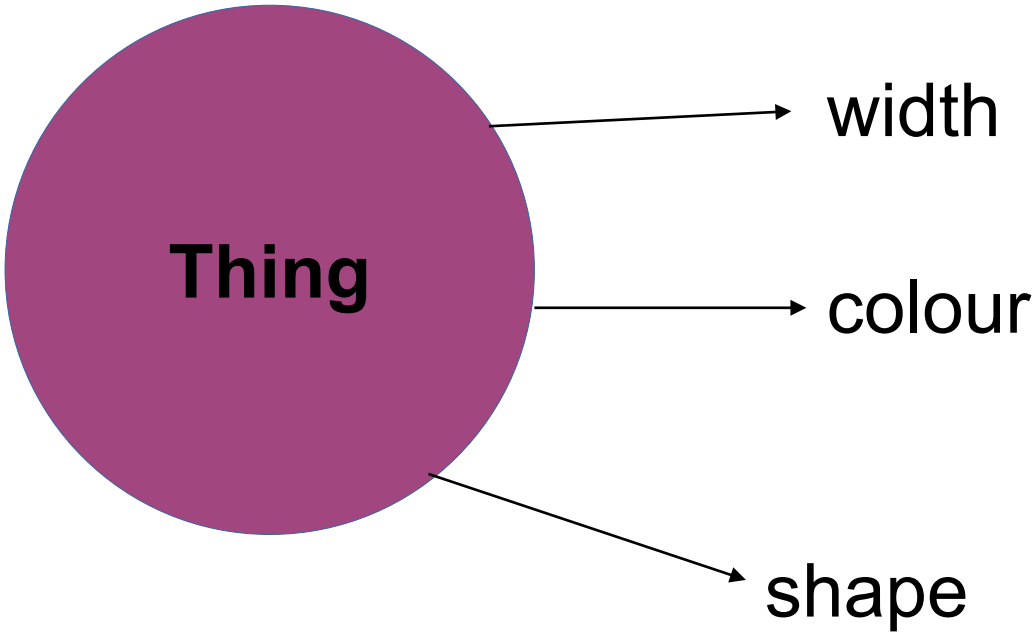
you will find

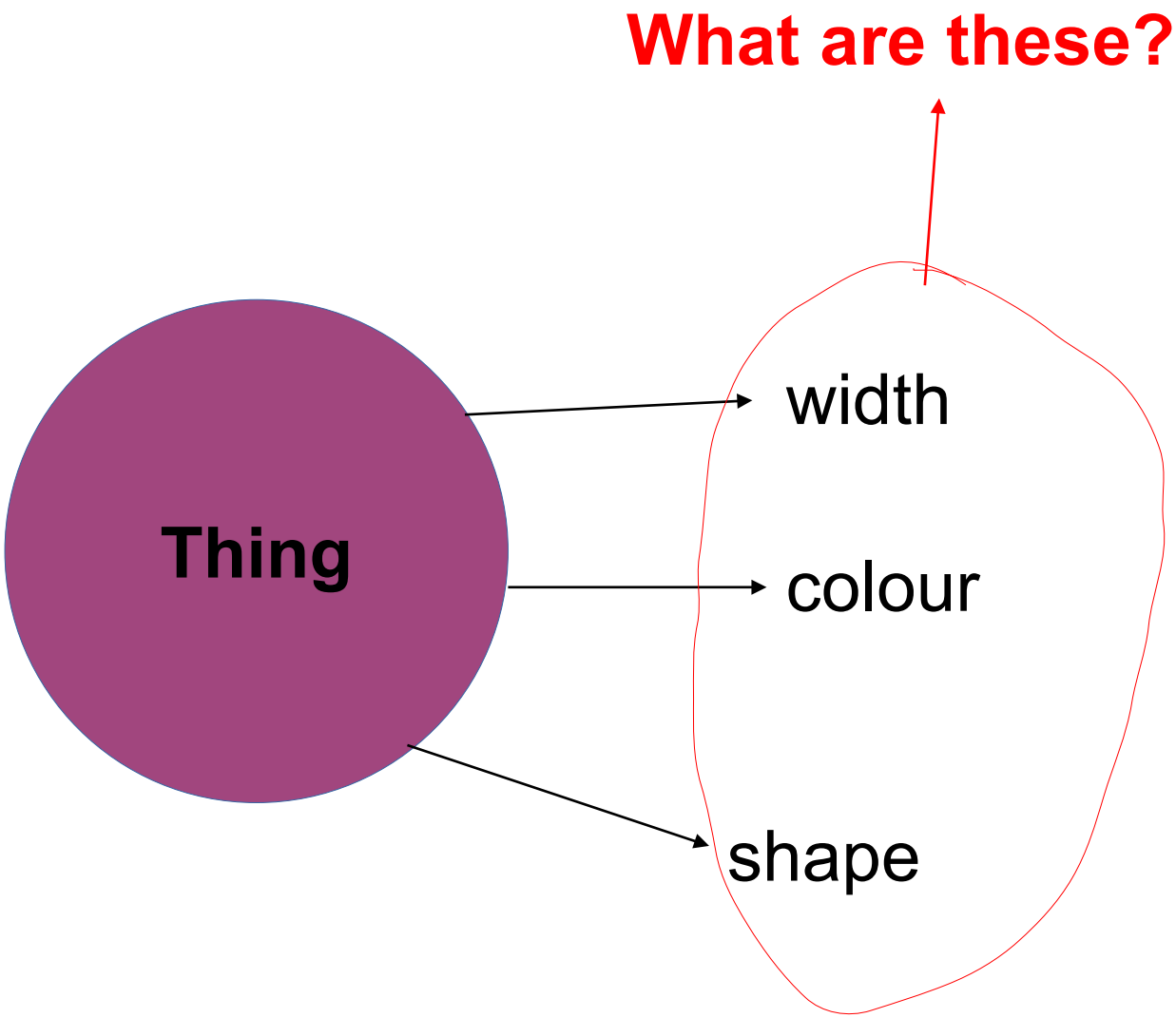

Pen&
paper
Statistics and
ML algorithm
exercises
Python
Specialised
DA libraries,
Jupyter
Notebooks
Data
analysis
Assessed
in exam
Assessed
by CA
Reading and
understanding
Concepts and
principles

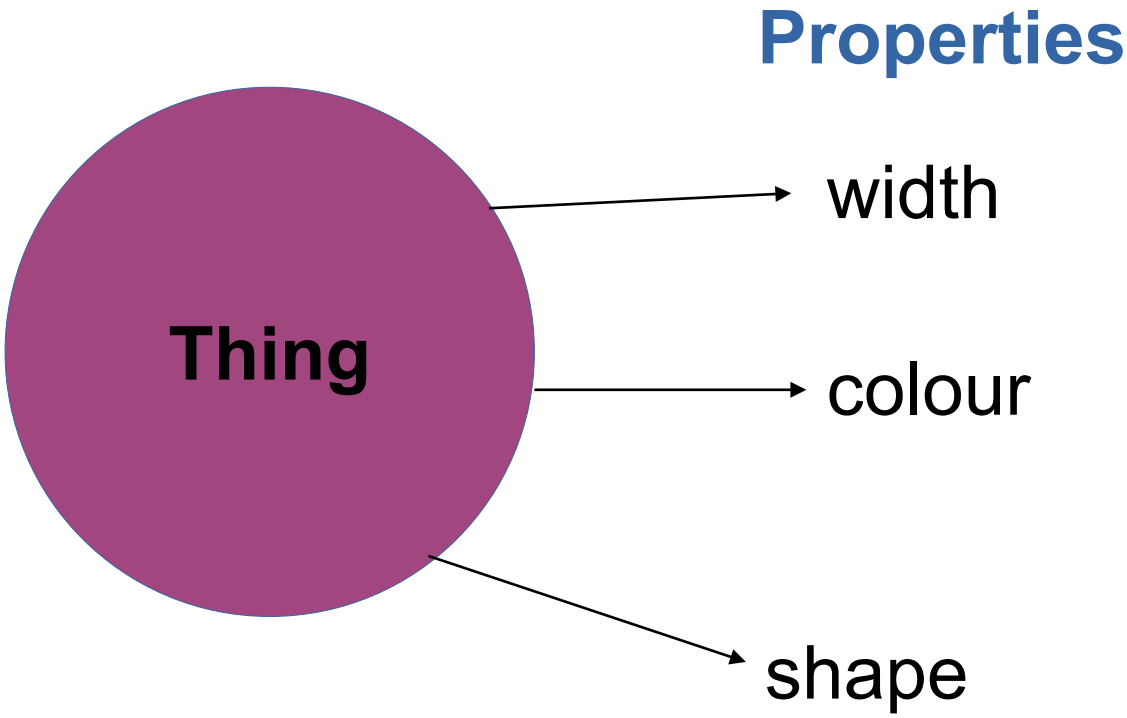
What are we dealing with

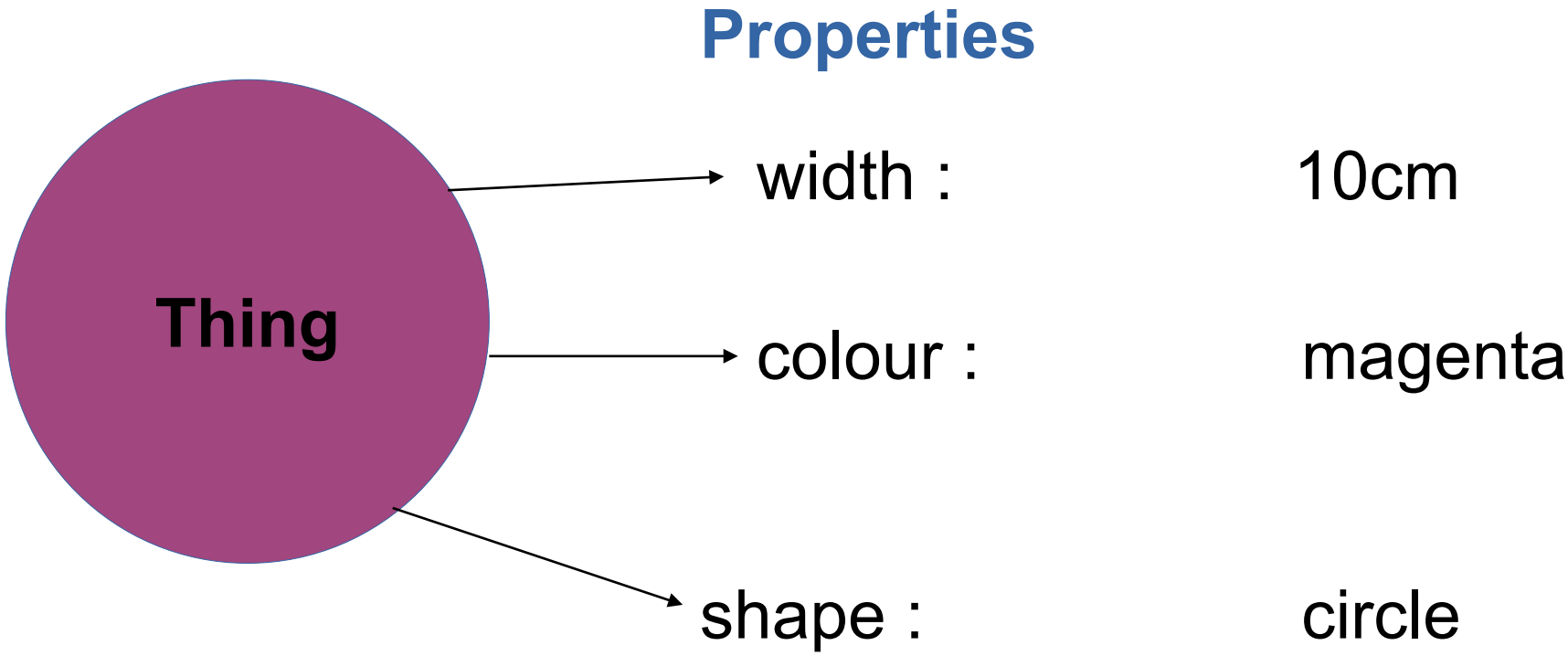
?

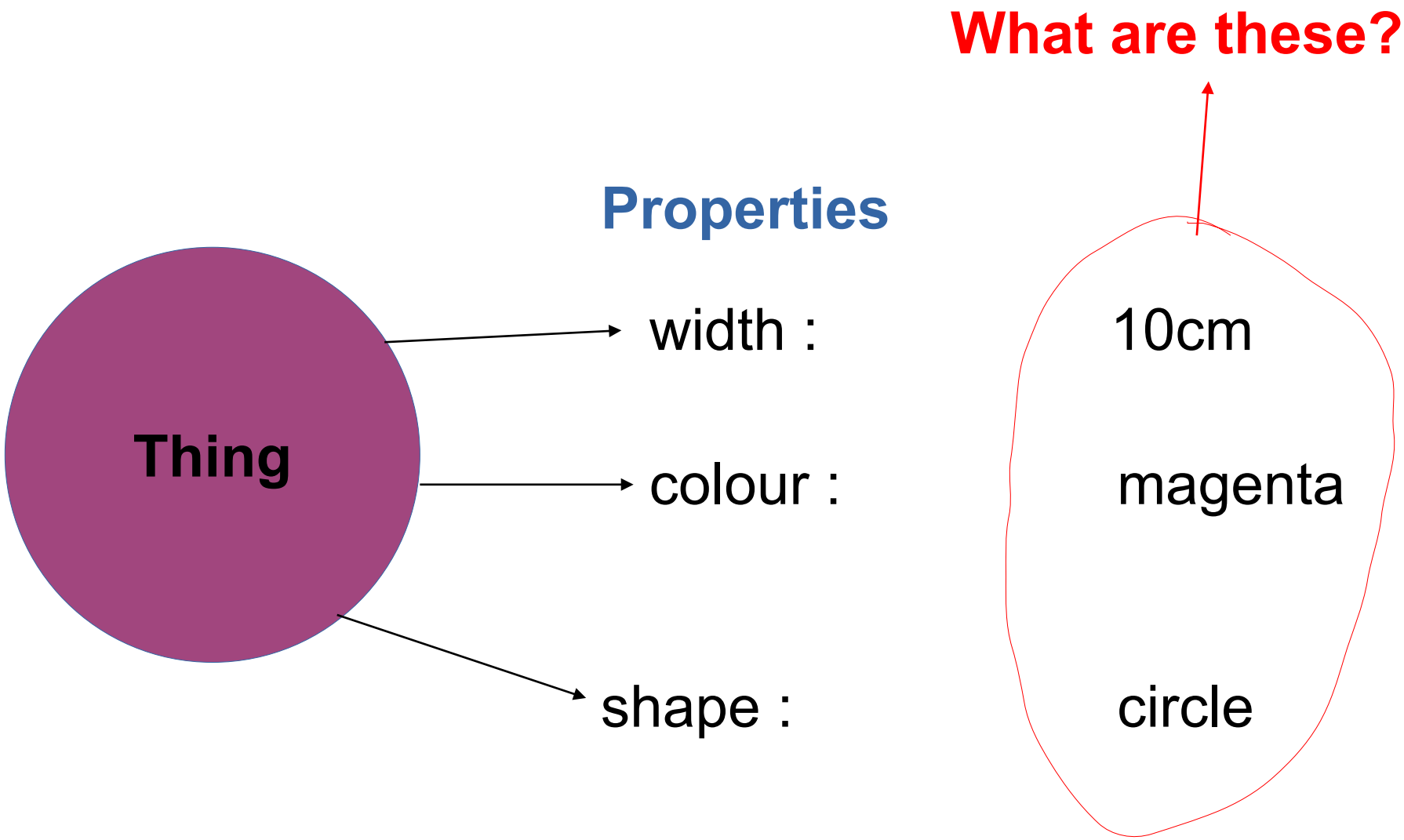

Thing

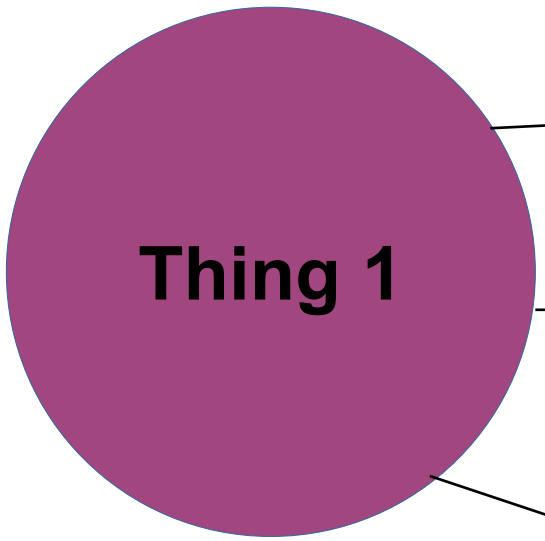

Thing
width
colour
shape


What are these?
Thing
width
colour
shape


Properties
Thing
width
colour
shape

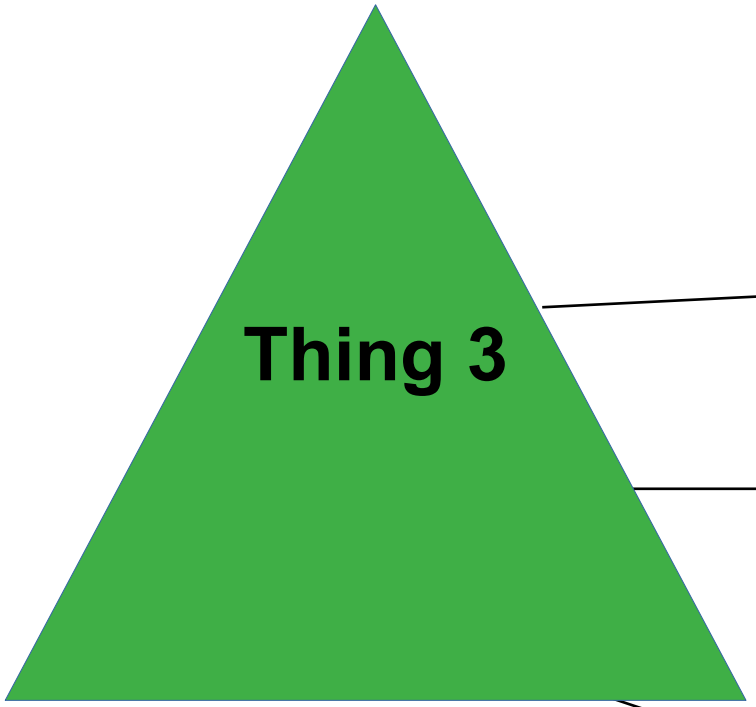

Properties
Thing
width :
10cm
colour :
magenta
shape :
circle


What are these?
Properties
Thing
width :
10cm
colour :
magenta
shape :
circle

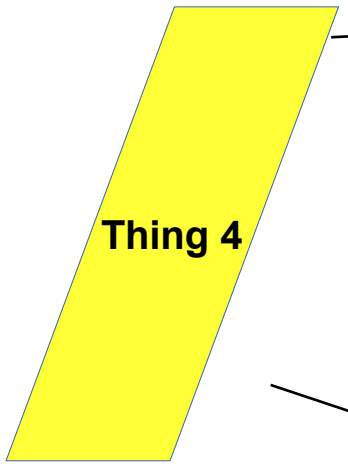


Properties	Values
width :	10cm
colour :	magenta
shape :	circle

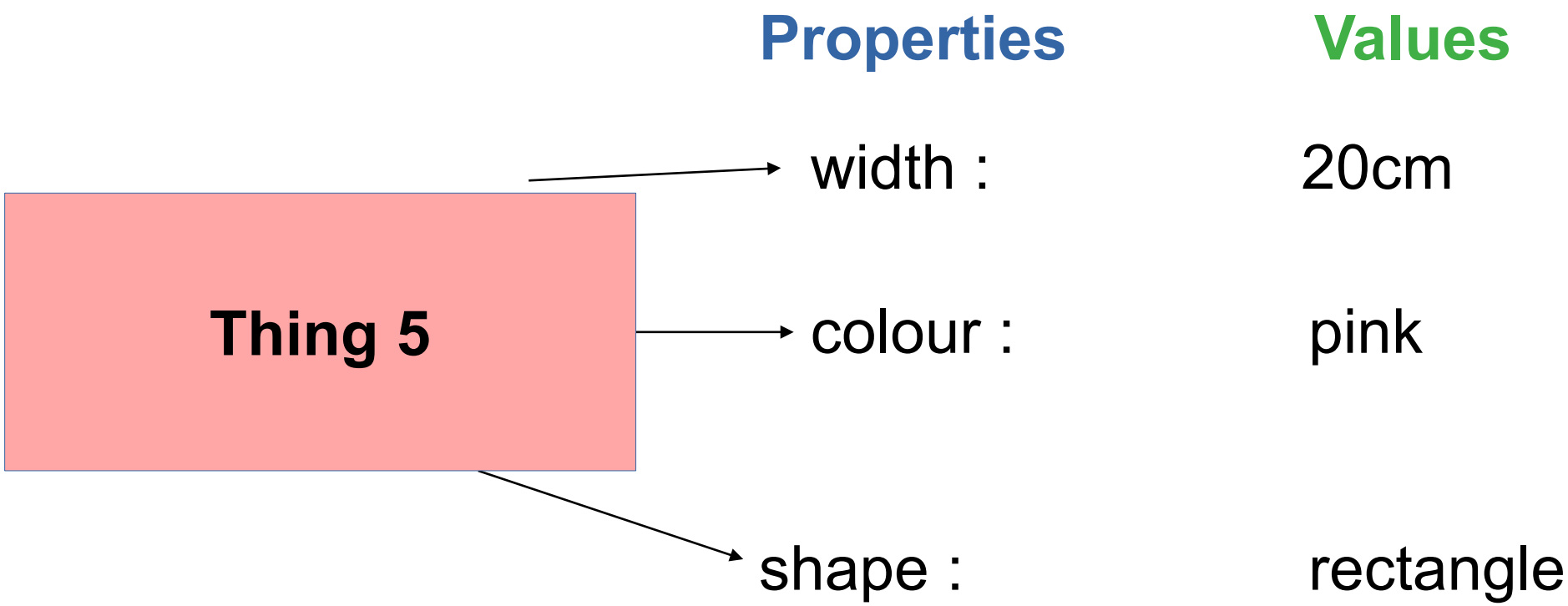
Properties	Values
width :	10cm
colour :	blue
shape :	rectangle



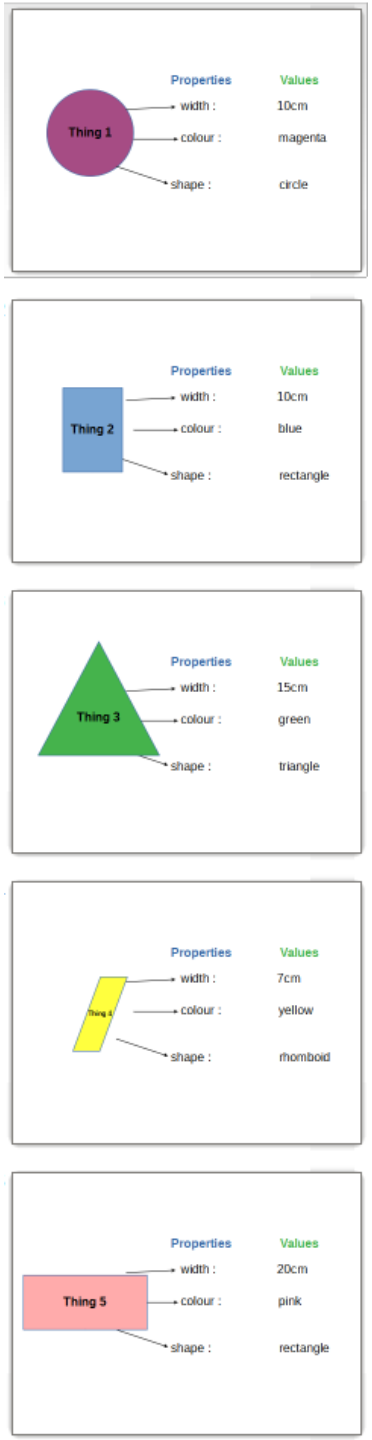
Properties	Values
width :	15cm
colour :	green
shape :	triangle



Properties	Values
width :	7cm
colour :	yellow
shape :	rhomboid


Properties
Values
Thing 5
width :
20cm
colour :
pink
shape :
rectangle

WE HAVE
5 things
(instances,
observations,
examples)

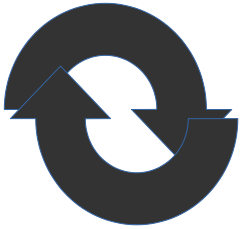


WE HAVE
4 properties (variables,
attributes, features)

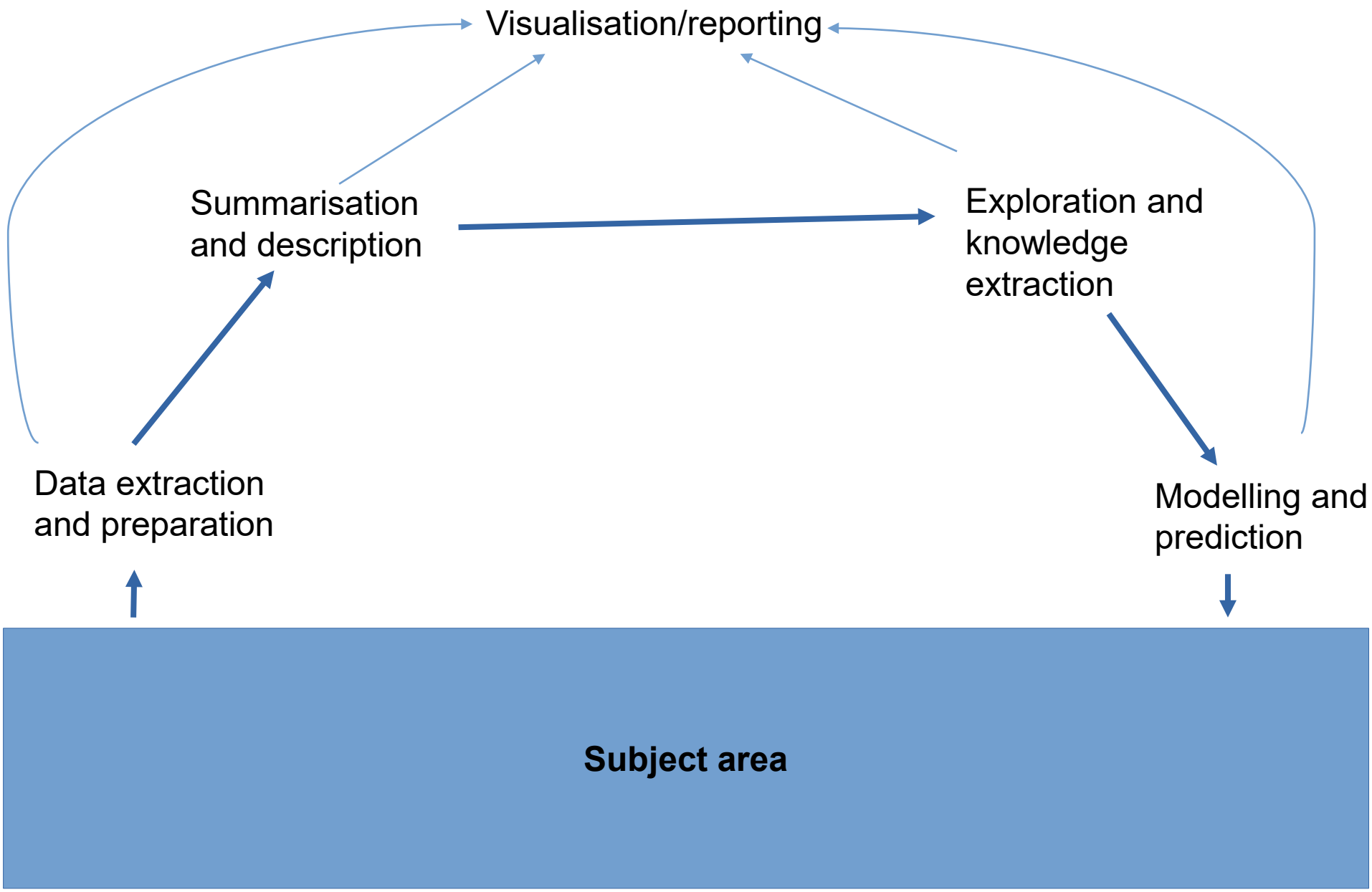
ID	width (cm)	colour	shape
1	10	magenta	circle
2	10	blue	rectangle
3	15	green	triangle
4	7	yellow	rhomboid
5	20	pink	rectangle

This table is what we
analyse

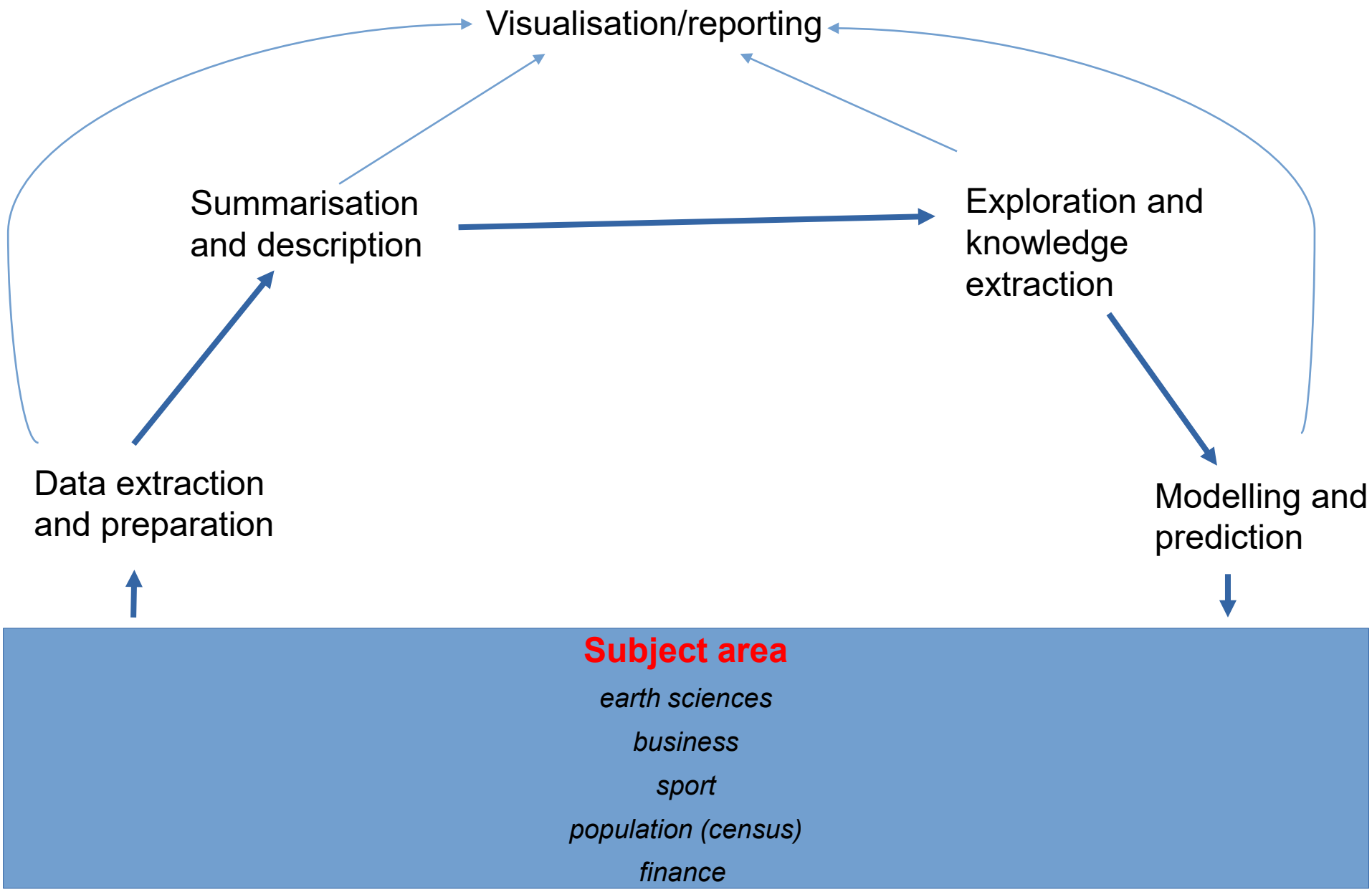
The analysis cycle



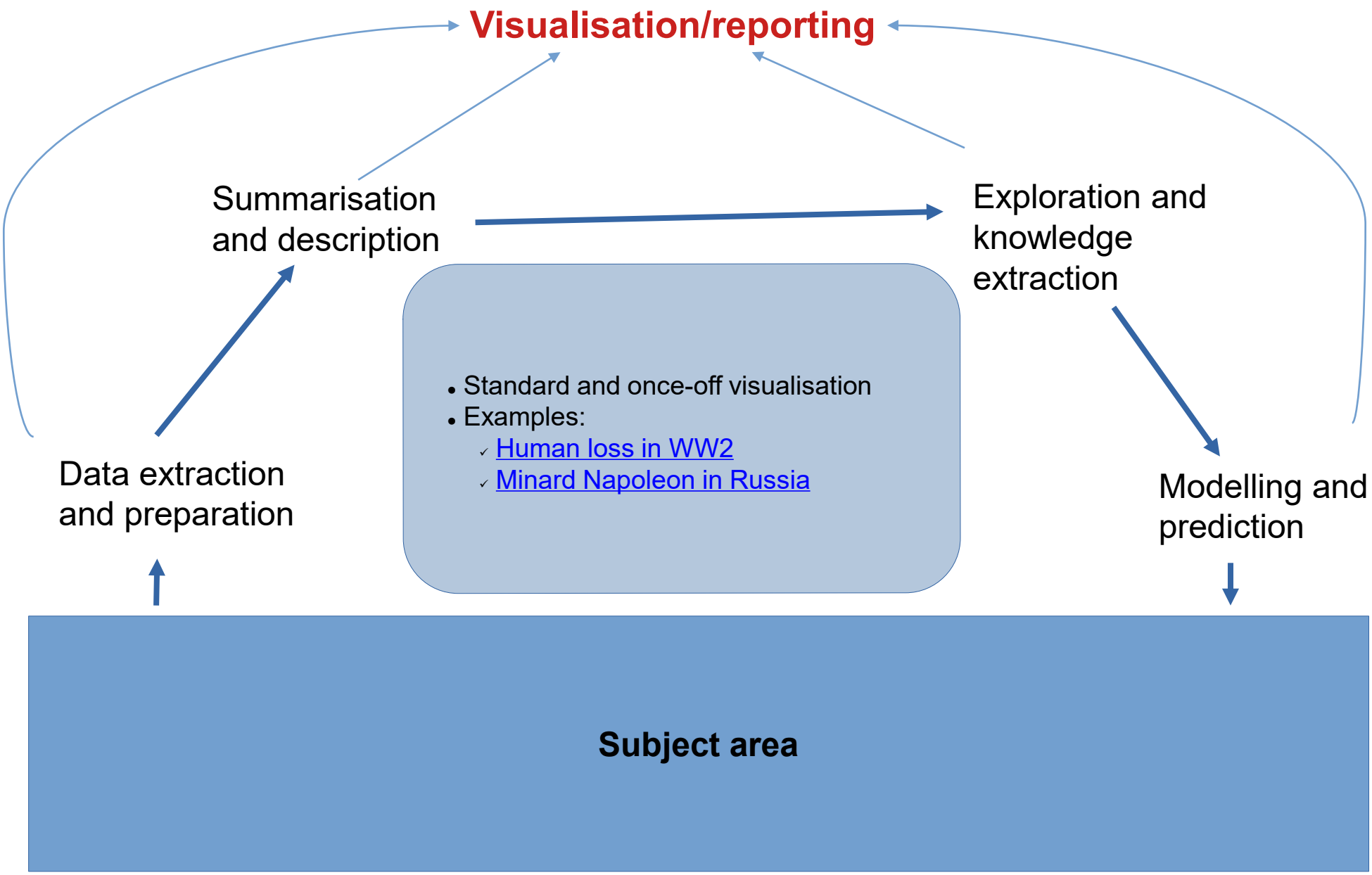
The data analysis cycle



The data analysis cycle

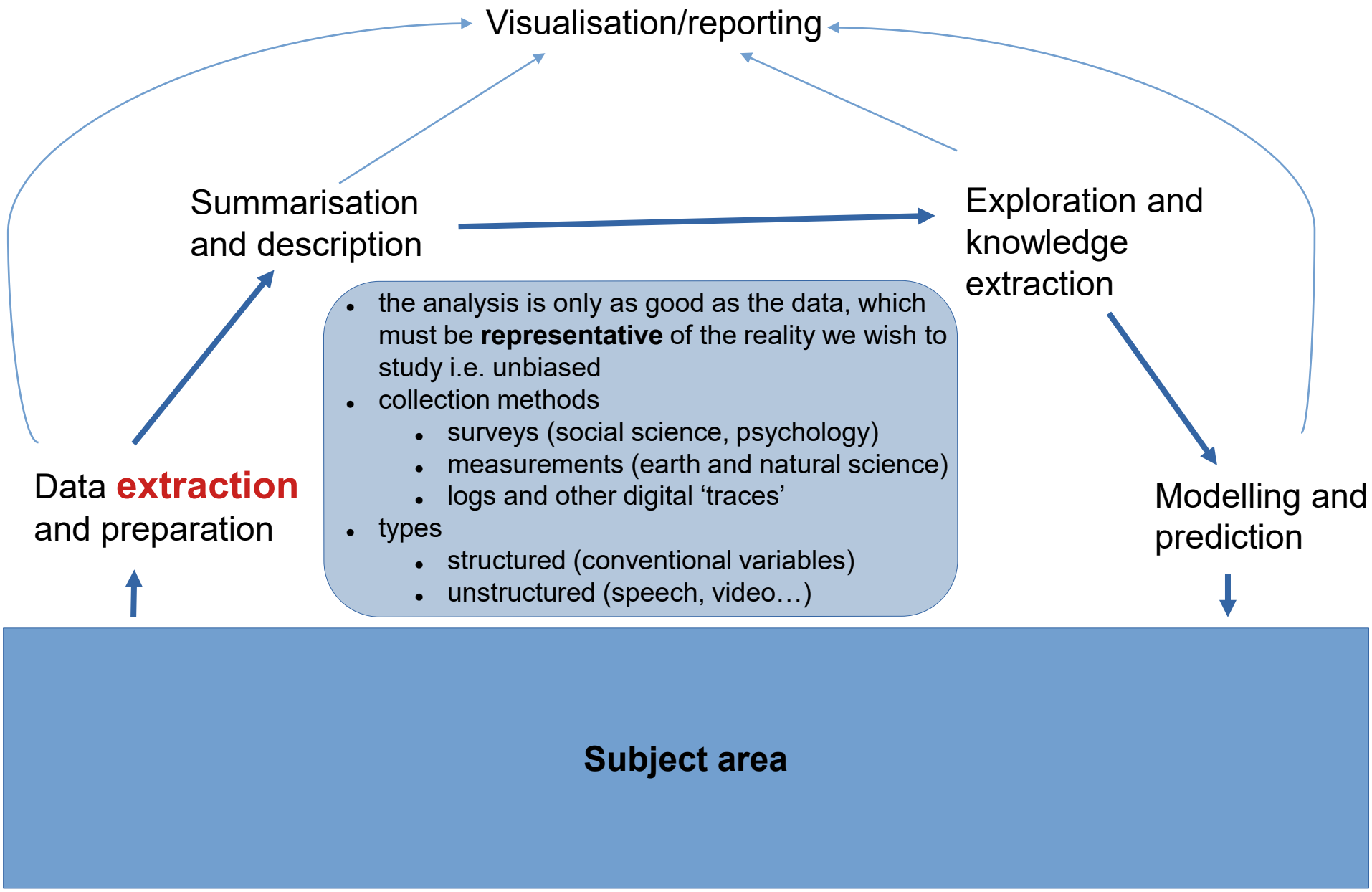


The data analysis cycle



- Standard and once-off visualisation
- Examples:
  - ✓ Human loss in WW2
  - ✓ Minard Napoleon in Russia

The data analysis cycle



- the analysis is only as good as the data, which must be **representative** of the reality we wish to study i.e. unbiased
- collection methods
  - surveys (social science, psychology)
  - measurements (earth and natural science)
  - logs and other digital 'traces'
- types
  - structured (conventional variables)
  - unstructured (speech, video…)

The data analysis cycle

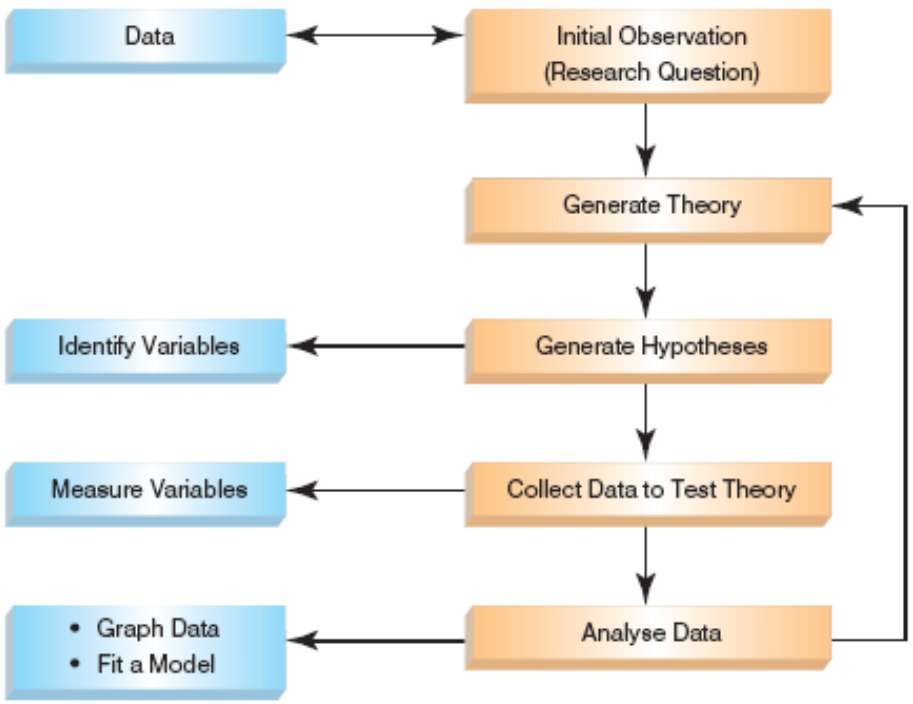
Visualisation/reporting

Summarisation and description

Exploration and knowledge extraction

- the analysis is only as good as the data, which must be **representative** of the reality we wish to study i.e. unbiased

Data **extraction** and preparation



Source: [DSR]

Often, data analysis is performed simply because **data are available**. This is the case with enterprise data warehouses, which are explored for knowledge hidden in data already available as a by-product of a company's commercial activity.

The standard scientific approach is to start with a theory that needs to be tested and collect data with that aim. The picture shows this process, which needs to be paralleled in **sampling assessment** for analysis, even if the data is pre-collected.

The data analysis cycle

Visualisation/reporting

Summarisation and description

Exploration and knowledge extraction

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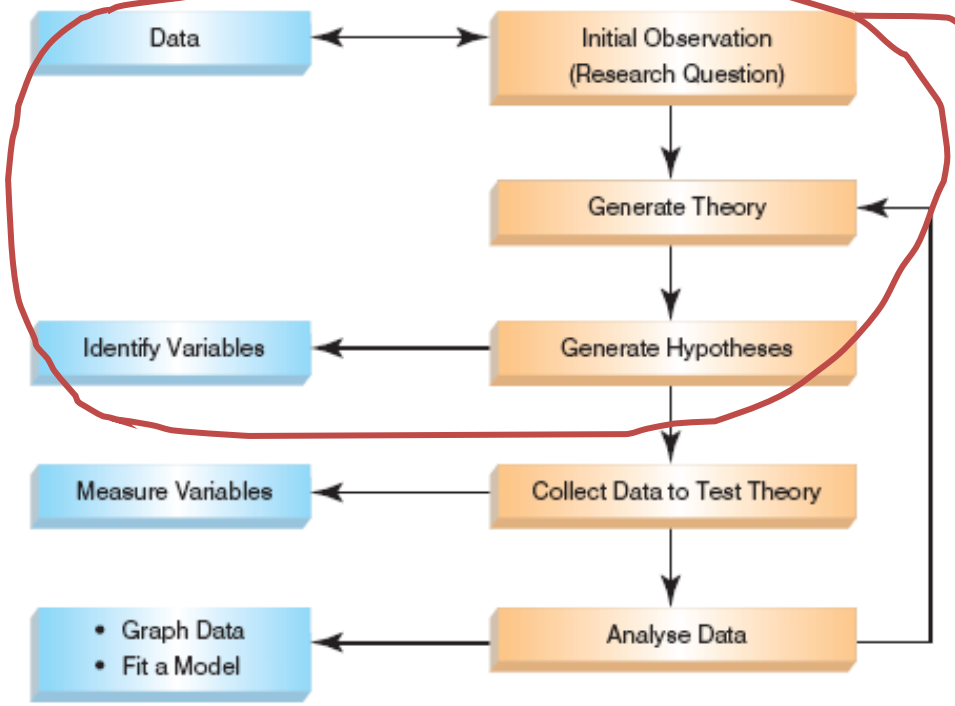

Source: [DSR]

The design of the data collection process (i.e. the **experiment)** must be grounded in **sound conceptual understanding** of the problem domain.

A **theory** is expressed in terms of domain concepts, e.g. 'TU Dublin attracts local students'. A **hypothesis** is expressed as a concrete prediction e.g. 'the majority of students grew up within 10km of Grangegorman'. **Falsification** occurs when a theory or hypothesis is disproved.

The data analysis cycle

Visualisation/reporting

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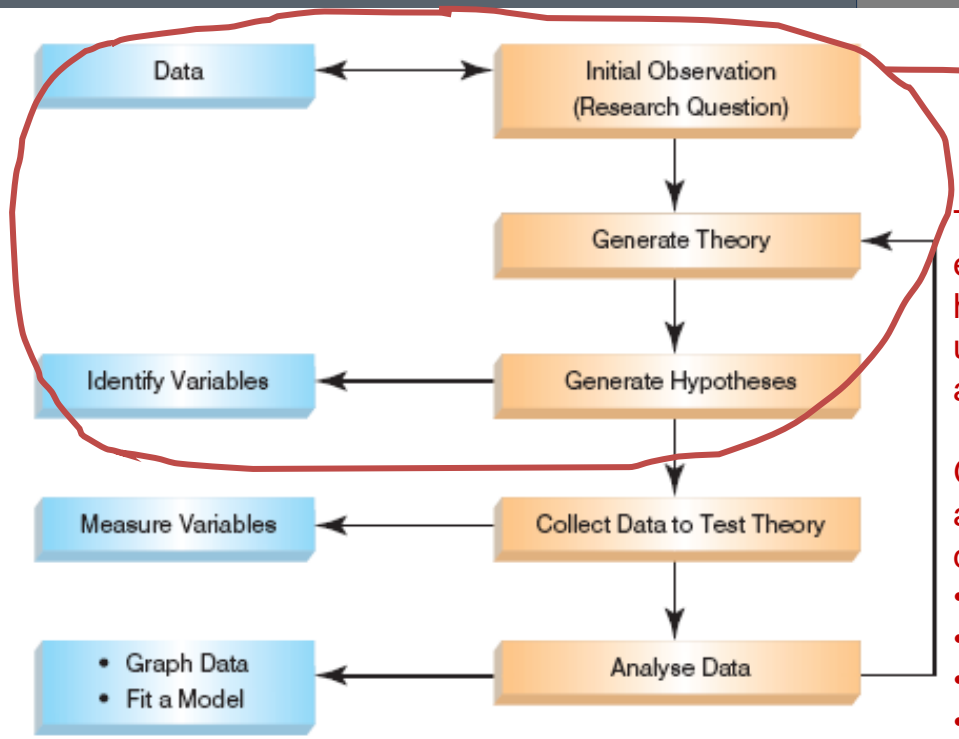

Source: [DSR]

The variables involved in the experiment are identified from the hypothesis (in the example already used these would be 'college name' and 'distance to home').

Good understanding of the domain and consequent good experimental design ensure:

- **reliability** (types)
- **validity** (types)
- **accuracy** of measurement
- absence of **confounding** variables

The data analysis cycle

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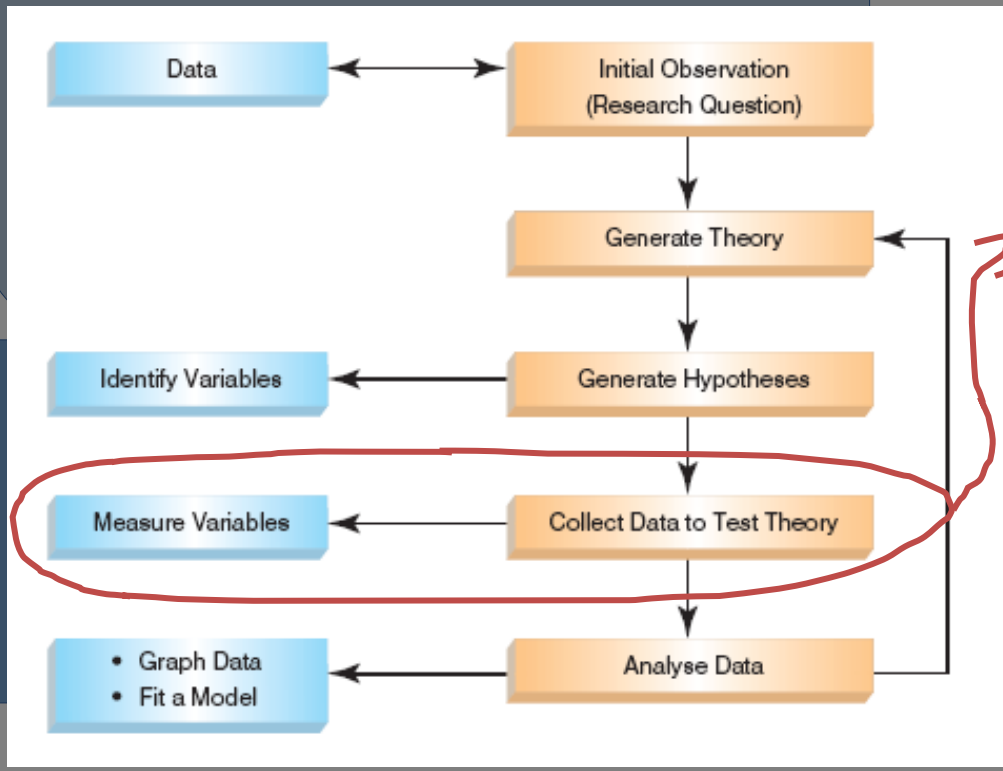
Data **extraction** and preparation



Source: [DSR]

The instances for which data is collected represent a **sample** of the **population** of all instances. Two important (but not only) factors in how unbiased a sample will be are its **size** and **sampling method.** Some type of random sampling is desirable but other methods can be acceptable (types).

Small samples may lead to wrong conclusions. Large samples can be wasteful.

The data analysis cycle

Visualisation/reporting

Summarisation and description

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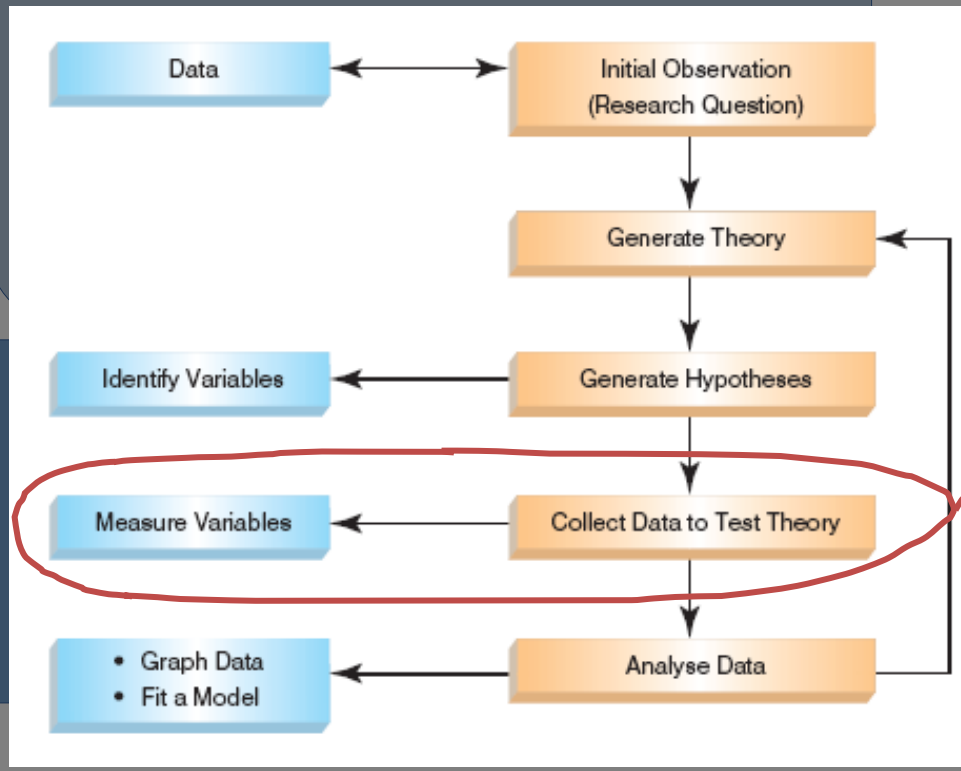
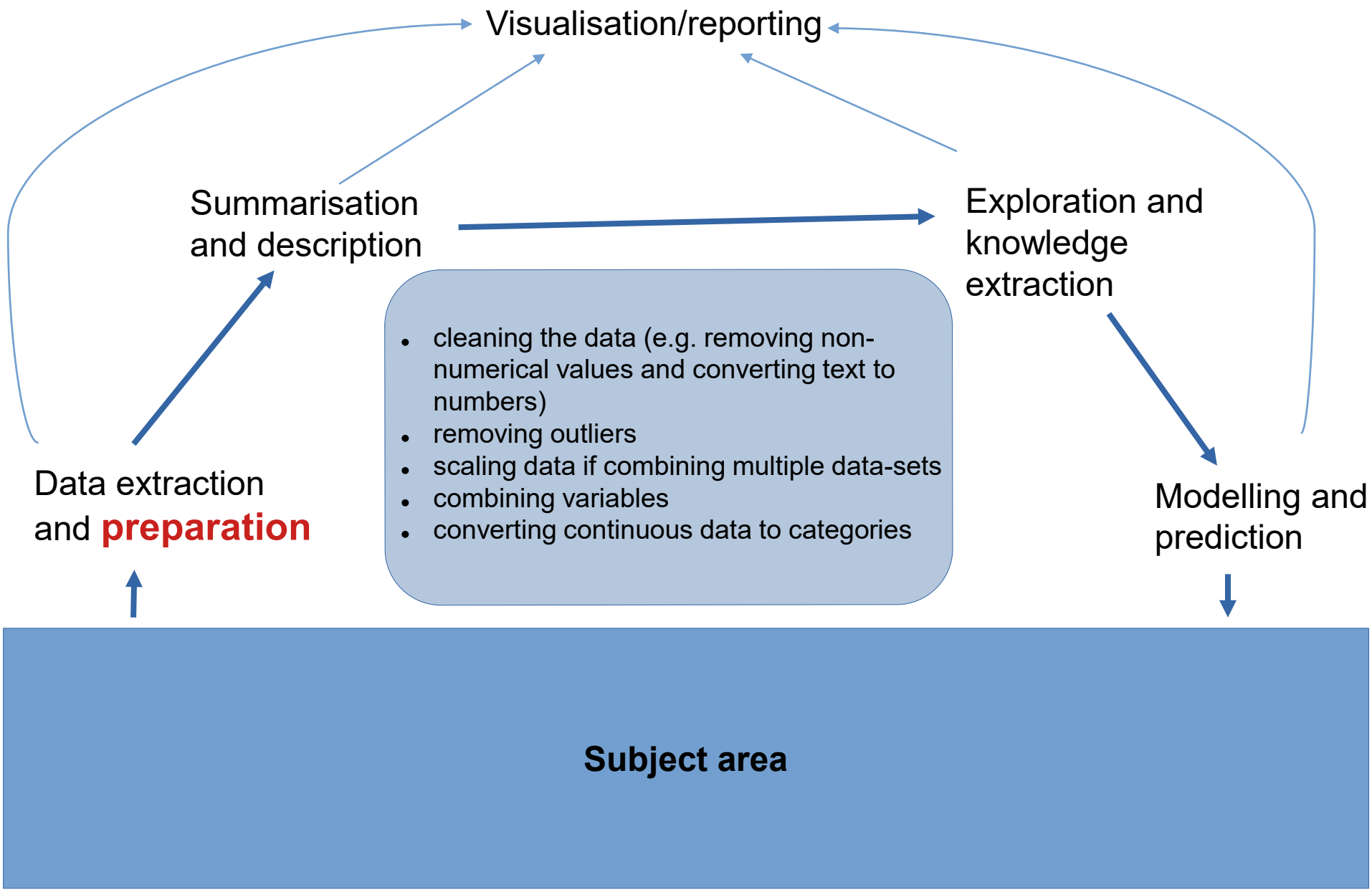
Data **extraction** and preparation



Source: [DSR]

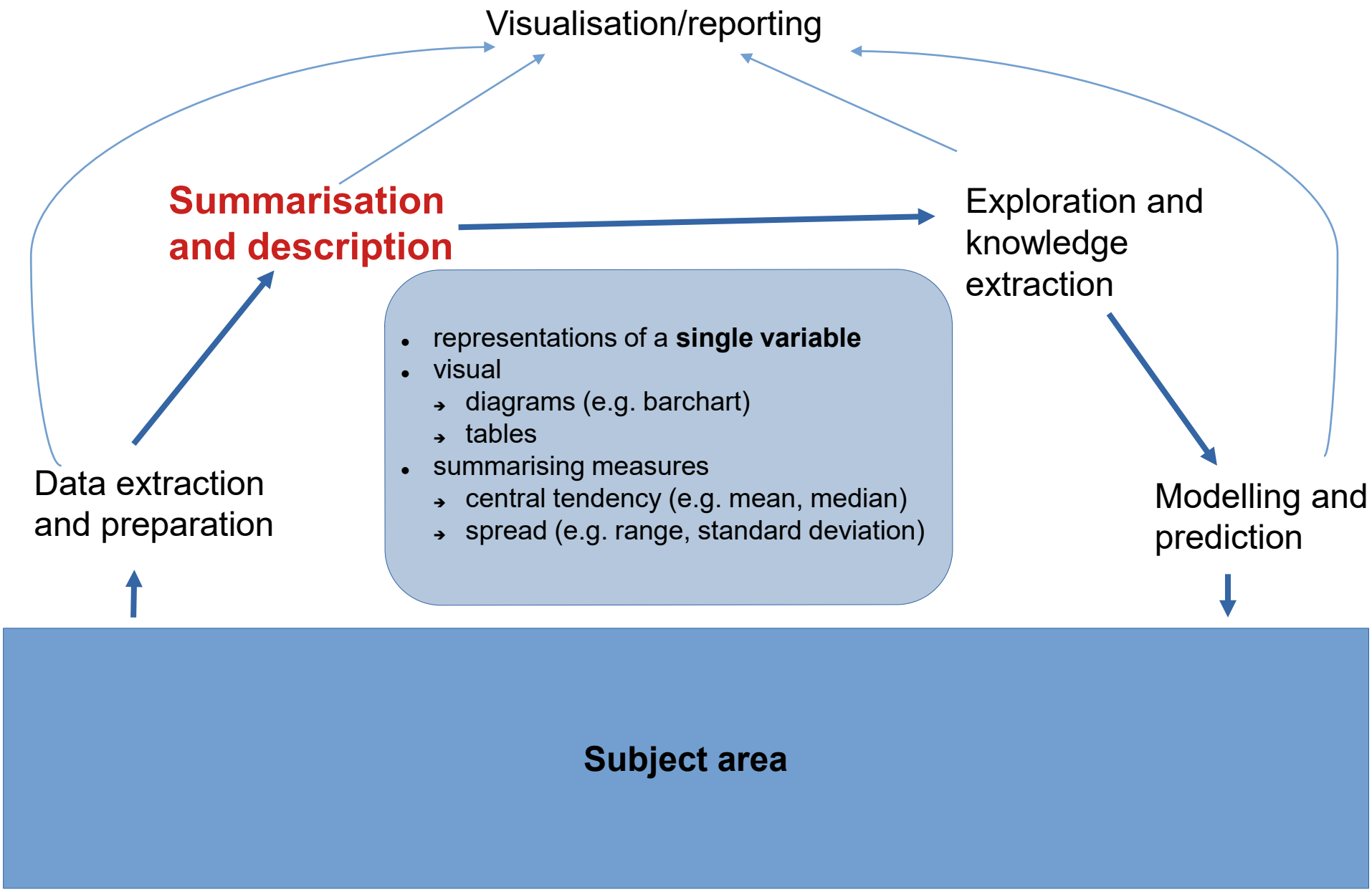
In the case of predictive models, an undesirable state of affairs, reflected in the data, can be **perpetuated** by a model that uses them (e.g. racism or misogyny). This, however, is a problem inherent in the data i.e. one of initial data selection rather than a problem in sampling.

The data analysis cycle

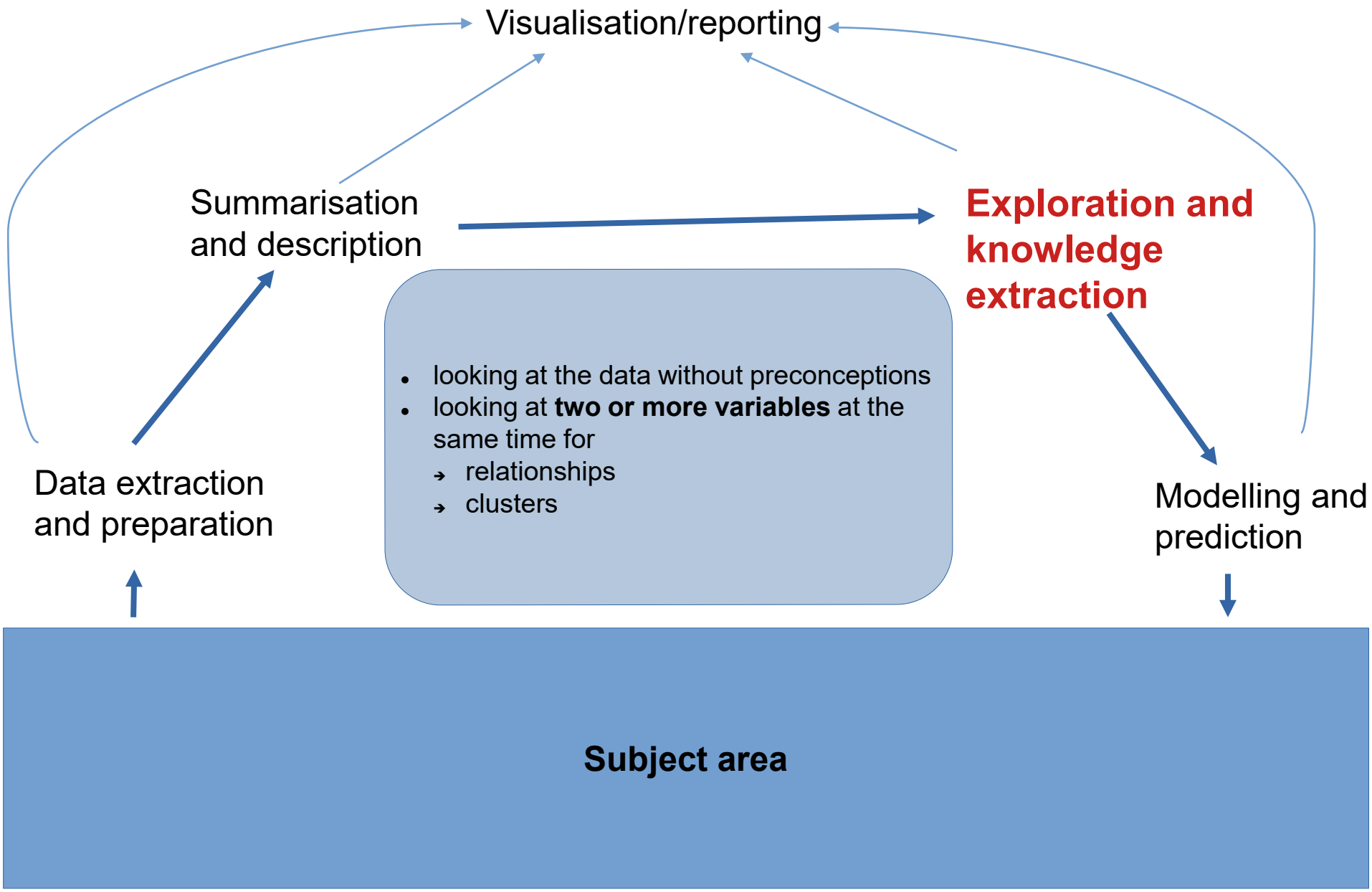


- cleaning the data (e.g. removing non-numerical values and converting text to numbers)
- removing outliers
- scaling data if combining multiple data-sets
- combining variables
- converting continuous data to categories

The data analysis cycle

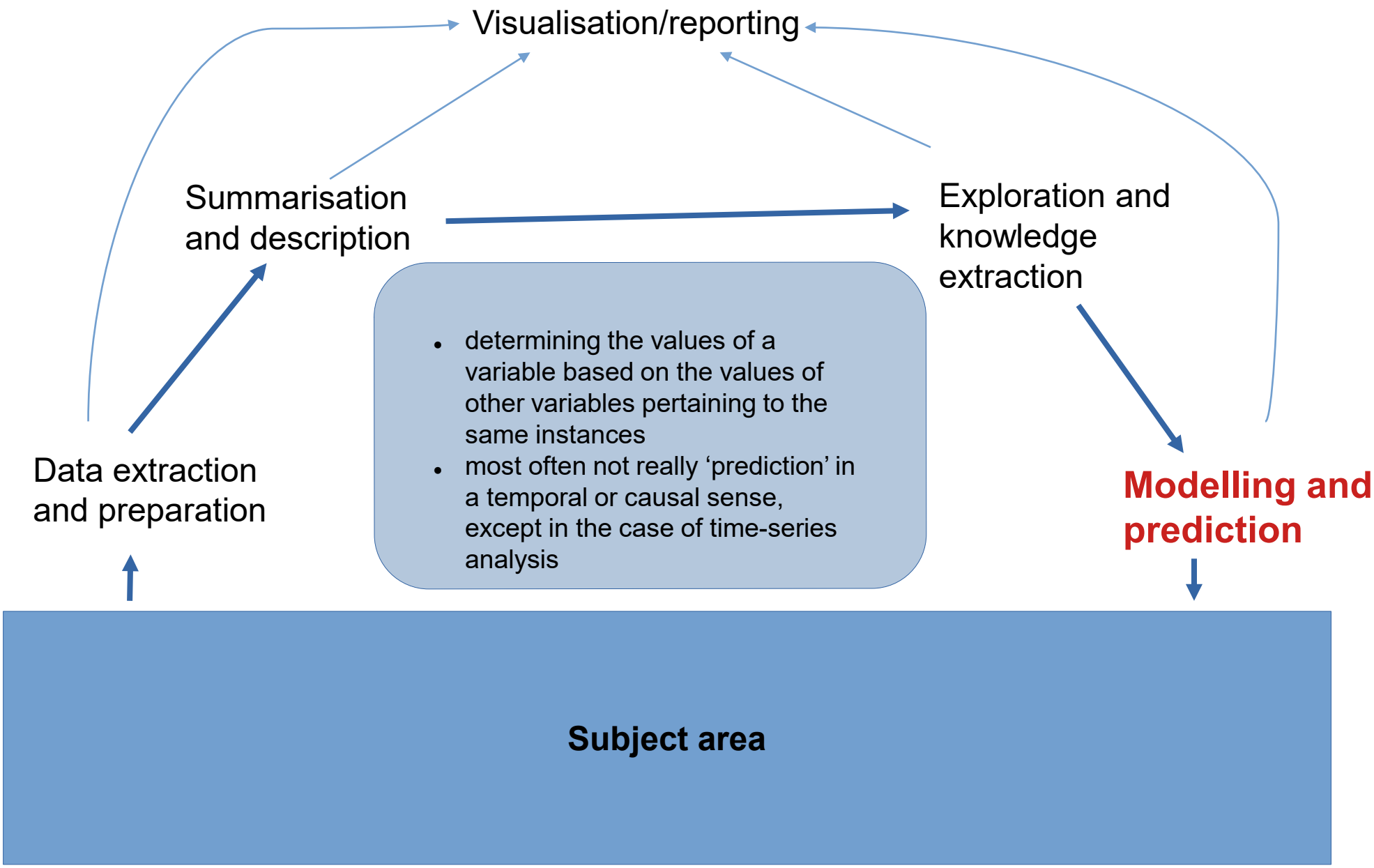


The data analysis cycle



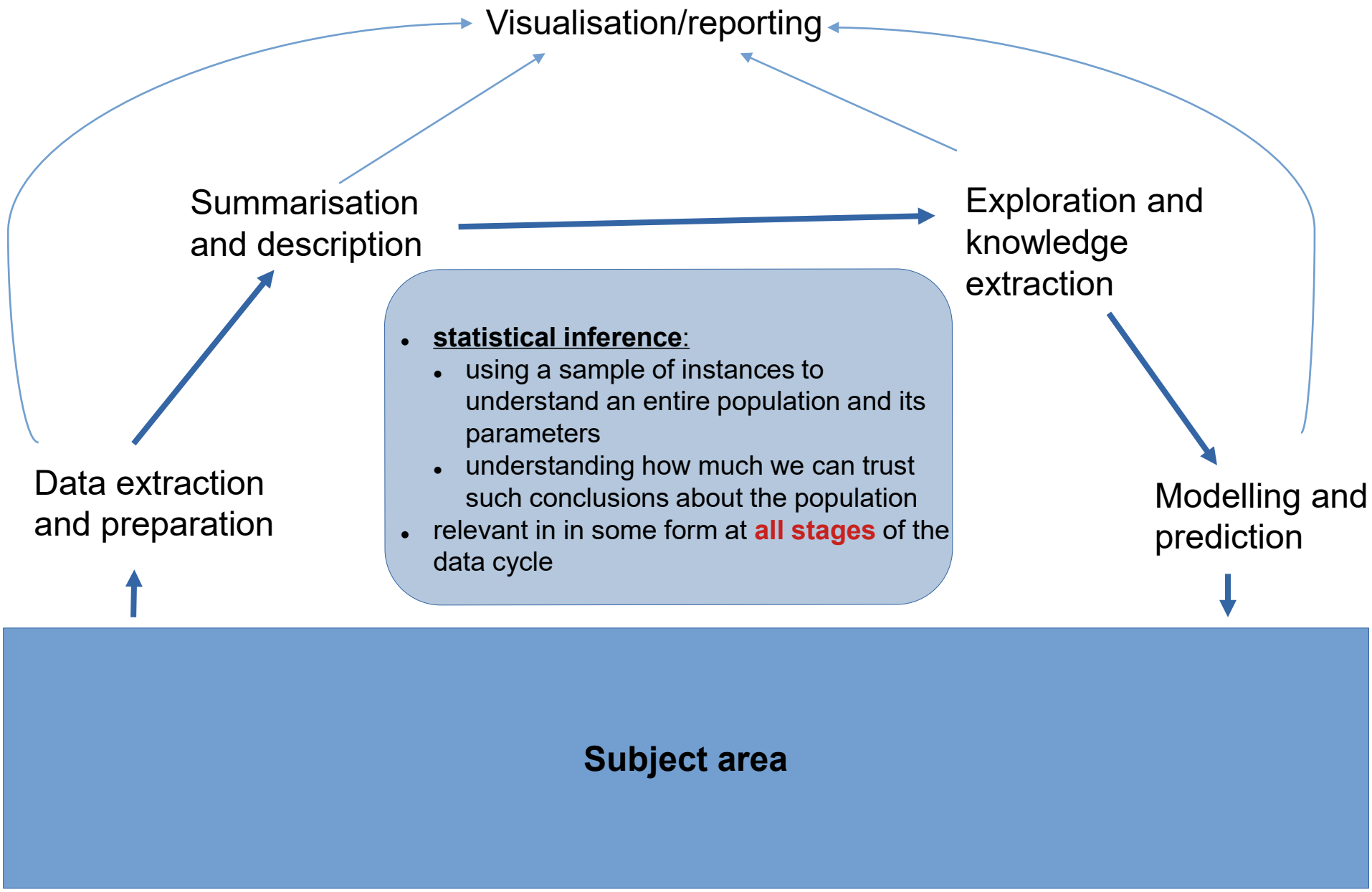
- looking at the data without preconceptions
- looking at **two or more variables** at the same time for
  - relationships
  - clusters

The data analysis cycle



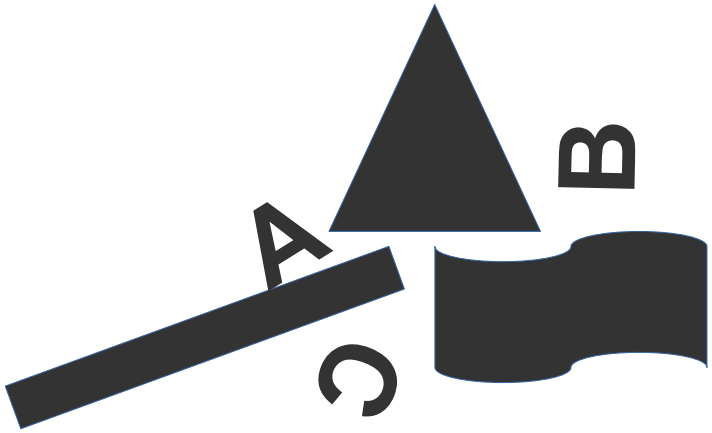
- determining the values of a variable based on the values of other variables pertaining to the same instances
- most often not really ‘prediction’ in a temporal or causal sense, except in the case of time-series analysis

The data analysis cycle



- **statistical inference**:
  - using a sample of instances to understand an entire population and its parameters
  - understanding how much we can trust such conclusions about the population
- relevant in in some form at **all stages** of the data cycle

The landscape and terminology of data analysis



The data analysis landscape

Data science, including theory behind statistics and machine learning

underlies

Statistics: mathematically-based description of and inquiry into data

Machine learning: computationally-based algorithms, for predictive modelling and exploration

operate on

Prepared data

Landscape and terminology

- Sets out the principles and theory for understanding and using data
- Studies how these principles and techniques should be applied in each individual case

Data science, including theory behind statistics and machine learning

underlies

Statistics (based on mathematics)

Machine learning (based on computational algorithms)

operate on

Prepared data

Landscape and terminology

- The science and practice of analysing numerical data, particularly with the purpose of understanding the properties of a large population by analysing a representative sample.

Data science, including theory behind statistics and machine learning

underlies

Statistics (based on mathematics)

Machine learning (based on computational algorithms)

operate on

Prepared data

Landscape and terminology

Data science, including theory behind statistics and machine learning

underlies

- Supervised learning – goal is prediction based on past data (e.g. classification, regression)
- Unsupervised learning – exploratory (e.g. association rules, clustering)

Statistics (based on mathematics)

Machine learning (based on computational algorithms)

operate on

Prepared data

Landscape and terminology

- Analytics – techniques and activities based around using data in a problem domain e.g. business analytics, financial analytics (the middle of the ‘sandwich’ below).

Data science, including theory behind statistics and machine learning

underlies

Statistics (based on mathematics)

Machine learning (based on computational algorithms)

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Landscape and terminology

- Analytics – techniques and activities based around using data in a problem domain e.g. business analytics, financial analytics (the middle of the ‘sandwich’ below).
- Data analysis – the activity of analysing data in any way.

Data science, including theory behind statistics and machine learning

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Landscape and terminology

- Analytics – techniques and activities based around using data in a problem domain e.g. business analytics, financial analytics (the middle of the ‘sandwich’ below).
- Data analysis – the activity of analysing data in any way.
- Data mining – exploration of (predominantly) enterprise data warehouses (1990s)

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Landscape and terminology

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- Big data (on next page)

Data science, including theory behind statistics and machine learning

underlies

Statistics (based on mathematics)

Machine learning (based on computational algorithms)

operate on

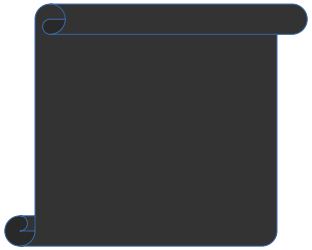
Prepared data

Big Data

- In the last 20 years the data cycle is ‘intensifying’
- Growing processing power
- Almost limitless storage capacity
- Connectivity with large bandwidths
- Techniques have developed on this new wave of possibilities

- Big data is at a scale that cannot be processed with conventional technologies.
- 4 Vs
- IBM 4Vs of Big Data
- New technologies:
  - Hadoop (Apache)
  - MapReduce (Google)
  - MongoDB etc.
- The data science principles are the same as ‘normal sized’ data

In this module



you will learn

to…

Ask **questions** that can be answered by data analysis

Design and assess the **sampling and data collection** processes

Inspect and **prepare data** for analysis

Statistically **describe and summarise data** to quantify properties of things

Understand and conduct **exploratory analysis** to investigate property interrelations

Understand and conduct **predictive analysis** by making use of the interrelations

Interpret the outcomes of data analysis and draw appropriate conclusions

Report on the findings of data analysis

References

Some pictures in this presentation were taken from the following books. They are cited using the keys shown in square brackets.

[DSR] *Discovering Statistics Using R*, by Andy Field, Jeremy Miles and Zöe Field, Sage, 2012.