Database design

- The learning objectives for this week are:
  - Knowing what **database development lifecycle** is and from which phases it consists of
  - Knowing what **conceptual database design** is
  - Knowing what is **entity-relationship modeling**
  - Knowing how to implement and interpret **entity-relationship diagrams**

Database development lifecycle

- So far we have explored and written SQL queries for existing databases, such as the Takkula database
- We have been able to successfully retrieve all kinds of relevant information from the database
- What we might not have thought is that **why** the Takkula database structured as it is
  - Why does it have these specific tables and columns?
  - Why does it have these relationships between tables?
- The end result is an output of the **database development lifecycle**

Database development lifecycle

- The **database development lifecycle** is a step-by-step process of implementing a database for certain set of requirements
- It consists of the following phases:
  1. Database planning
  2. System definition
  3. Requirements collection and analysis
  4. Database design
  5. Database implementation
  6. Data conversion and loading
  7. Testing
  8. Operational maintenance

Database design

- Once the users’ requirements are identified after the **requirements collection and analysis phase**, the **database design** phase can start
- **Database design** is a the process of creating a design that will meet the **data requirements** of the enterprise and support its operations
- For example, this is could be one data requirement in the Takkula database:
  - "University has courses. Each course has multiple course instances which are taught during a certain time period. Each course instance has a teacher"

Database design

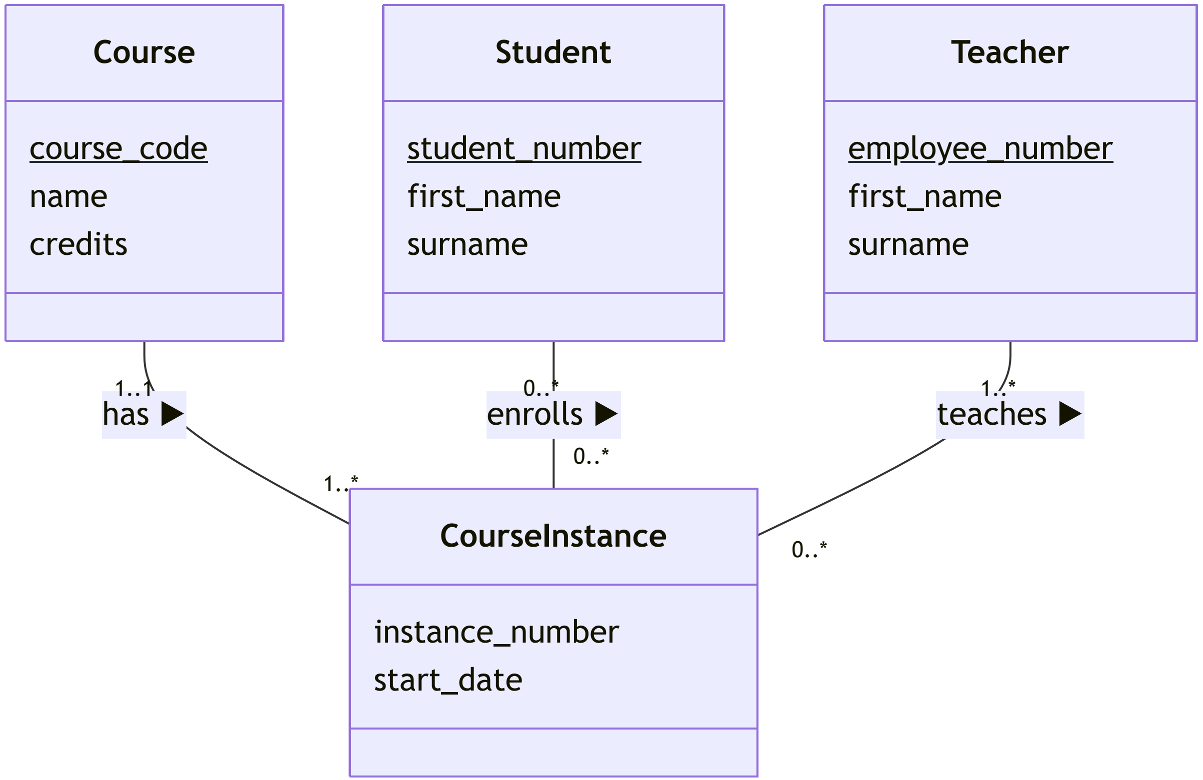
- A common approach in database design, is the **top-down** approach
- We start from the "top", with the development of high-level conceptual data model with few high-level entity types (for example "Course", "Course instance" and "Teacher")
- Then we move down to the "bottom" by adding details step-by-step until we have developed the physical data model with all the tables, columns and other details about the database schema
- The typical main phases in a systematic top-down database design process are:
  1. Conceptual database design
  2. Logical database design
  3. Physical database design

Conceptual database design

- During the **conceptual database design** phase, a high-level conceptual model of the data requirements of the enterprise is constructed
- The model represents the entities and their relationships
- The model is **independent of all physical considerations**, for example how the data is actually organized into database tables
- The end result is a **conceptual database schema**

Example of conceptual database schema

- Here's an example of the conceptual database schema for a course enrollment database:



Conceptual database design

- The objective of conceptual database design is:
  - To assist in understanding the meaning (semantics) of the data
  - To facilitate communication about the data requirements
  - To understand the requirements (**what** should be done), well enough before moving to any technical considerations (**how** to do it)
- A conceptual data model is used to summarise the designer's understanding of the data requirements, to support communication within the development team and to support communication between the designers and users

Logical database design

- During the **logical database design** phase, the conceptual schema is translated into a logical database structure based on a specific data model (for example the relational model)
- The model represents details about the entities, such as relations, attributes, primary and foreign key contraints and other type of constraints
- The model is **independent of a particular DBMS product** and other physical considerations
- The end result is a **logical database schema**

Example of logical database schema

- Here's an example of the logical database schema for the course enrollment database:

```
Course(course_code, name, credits)
Teacher(employee_number, first_name, surname)
Student(student_number, first_name, surname)

CourseInstance(course_code, instance_number, start_date)
  FOREIGN KEY (course_code) REFERENCES Course(course_code)

Enrollment(course_code, instance_number, student_number)
  FOREIGN KEY (course) REFERENCES Course(course_code)
  FOREIGN KEY (course_code, instance_number)
  REFERENCES CourseInstance(course_code, instance_number)
  FOREIGN KEY (student_number) REFERENCES Student(student_number)
```

Physical database design

- During the **physical database design** phase, a description of the physical implementation of the database is produced
- The model describes the implemention using a **particular DBMS product**
- The model includes tables, columns, column types and all other DBMS specific details
- The end result is a **physical database schema**

Example of physical database schema

- Here’s an example of the physical database schema for the course enrollment database:

```sql
CREATE TABLE Course (
    course_code VARCHAR(10) PRIMARY KEY,
    name VARCHAR(100) NOT NULL,
    credits INT NOT NULL
);

CREATE TABLE CourseInstance (
    course_code VARCHAR(10),
    instance_number INT,
    start_date DATE NOT NULL,
    PRIMARY KEY (course_code, instance_number),
    FOREIGN KEY (course_code) REFERENCES Course(course_code)
);

-- ...
```

User views

- Different database users have a different requirements for the database
- A **user view** defines what is required of a database system from the perspective of a particular job role (such as manager or supervisor) or enterprise application area (such as marketing or human resources)
- Each user view defines from its own perspective **what data is held in the database** and **what the user will do with the data** (user transactions)
- We need to able to manage **multiple user views** during the design process
- There is three main approaches to solve this problem: the **centralised**, the **user view integration** and the **combined approach**

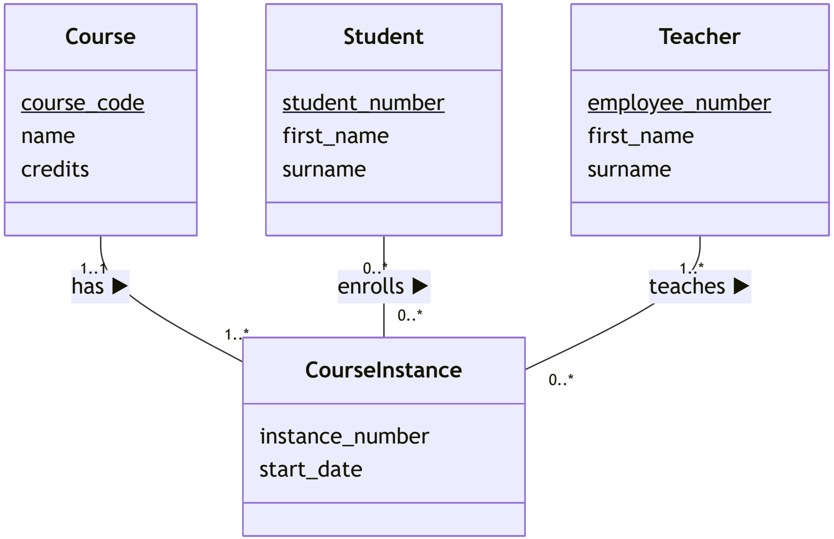
Managing multiple user views

- With the **centralised approach**, we first merge requirements for all user views into a **single set of requirements** and then create a **single data model** that represents all user views
- With the **user view integration approach**, we first create **a separate data model** for each user view and then merge these data models into a **single data model**
- With the **combined approach**, we first, merge some user views and then continue with user view integration approach
- Out of these three approaches, the user view integration approach is preferred when the system is more complex and there are significant differences between user views

Entity-relationship modeling

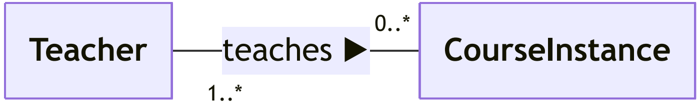
- **Entity-relationship modeling** (ER) is a conceptual database design approach to visually represent the data structures and their relationships within a system
- Entity-relationship model is commonly visualized as a **entity-relationship diagram** consisting of **entities**, **attributes** and **relationships** between different entities
- **Entities** are real-world objects or concepts that can be distinctly identified. For example "Course", "CourseInstance" and "Student"
- **Attributes** are characteristics or properties of an entity. For example "Course" entity has attributes "name" and "credits"
- **Relationships** are connection or association between entities. For example "Teacher teaches CourseInstance" and "Student enrolls CourseInstance"

Entity-relationship diagram



- This ER diagram contains four entities: "Course", "CourseInstance", "Teacher" and "Student"
- Entities are visualized as boxes and entity's attributes are listed inside the box and **primary key is underlined**
- Relationships are visualized as lines between the entity boxes
- Relationship specifies the number of instances of one entity that can be associated with instances of another and optionally a description of the relationship

Entity-relationship diagram

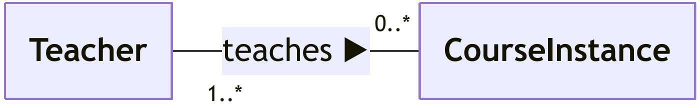


- The **multiplicity constraints** describes the number of instances of one entity that can be associated with instances of another
- Multiplicity constraints are represented as **min…max** ranges as below:

Multiplicity constraint	Meaning
0…1	zero or one
1…1	exactly one
0…*	zero or many
1…*	one or many

- We can also define more specific numbers, for example "5…*" would mean "at least 5"

Relationships in entity-relationship diagrams



- While interpreting the number of instances associated with the entity, we look at the multiplicity constaint on the **opposite side of the relationship**
- For example, "teacher teaches **zero or more** (0…*) course intances". Here we look at the multiplicity constaint on the opposite side of the "Teacher" entity box
- We always interpret a relationship type in both directions, so, for example the **"teaches"** relationship is interpreted as follows:
  - Each teacher teaches on **zero or more** (0…*) course instances
  - Each course instance is taught by **one or more** (1…*) teachers