SIM Global Education

# Topic 6
# Retrieving data from databases using query languages

## Learning Outcomes

After completing this topic and the recommended reading, you should be able to:

- Describe the structural elements of a relational database such as tables, columns and relations.
- Write simple SQL queries to read and write data from a relational database into Python using an SQL library.
- Select and use appropriate data structures to store data obtained from relational databases.

# 1. Database

## *Database*

- An organised collection of structured information or data.
- Stored electronically in a computer system.

## *Relational Databases*

- A type of database that stores and provides access to data points that are related to one another.
- Store data in structured, tabular form.
- The columns of the table hold **attributes** of the data.
- The rows of the table hold **records** (**tuples**), and each record usually has a value for each attribute.

## *Nonrelational Databases*

- Often called **NoSQL** databases.
- Store data in unstructured and semi-structured, non-tabular form.
- Graph database
  - Stores data in terms entities (nodes) and relationships (edges) between entities.
- Document-oriented database
  - Stores data in the form of JSON-like documents.
  - Stores all information for a given object in a single instance in the database.
  - Every stored object can be different from another.
- Examples:
  - *MongoDB*: uses JSON-like documents with optional schemas.

## *Database Management System (DBMS)*

- A database is usually controlled by a DBMS.
- The data can then be easily accessed, managed, modified, updated, controlled and organised.

## *Relational Database Management System (RDBMS)*

- A system used to maintain relational databases.
- Stores data in a row-based table structure which connects related data elements.
- Using **Structured Query Language (SQL)** to access the database.
- Includes functions that maintain the security, accuracy, integrity and consistency of the data.

## *RDBMS Terminology*

- **Relation (Table)**
  - Collection of rows and columns.
  - Each table usually represent an entity.

- **Attribute (Column)**
  - Each attribute has a type or domain.

- **Tuple (Row)**
  - Each tuple represent a record, a set of attribute values.

- **Schema**
  - The description on how the database table is constructed.

- **Primary Key**
  - The attribute which is the unique identifier (**ID**) for each tuple/record.
  - The set of attributes whose combine values are unique.
  - Cannot have null values.

- **Foreign Key**
  - The primary key that is used in another table that provides a link/relationship between data in two tables.

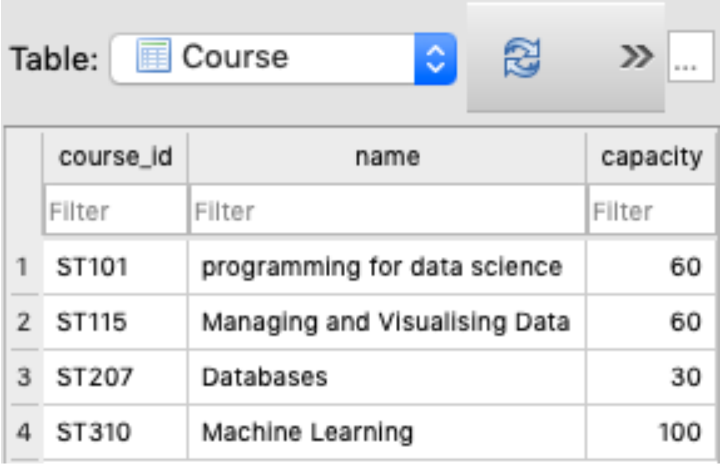


Table: Course

| | course_id | name | capacity |
|---|---|---|---|
| | Filter | Filter | Filter |
| 1 | ST101 | programming for data science | 60 |
| 2 | ST115 | Managing and Visualising Data | 60 |
| 3 | ST207 | Databases | 30 |
| 4 | ST310 | Machine Learning | 100 |

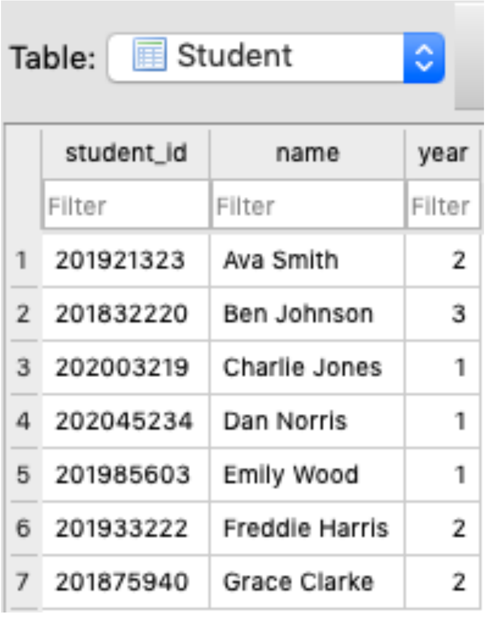


Table: Student

| | student_id | name | year |
|---|---|---|---|
| | Filter | Filter | Filter |
| 1 | 201921323 | Ava Smith | 2 |
| 2 | 201832220 | Ben Johnson | 3 |
| 3 | 202003219 | Charlie Jones | 1 |
| 4 | 202045234 | Dan Norris | 1 |
| 5 | 201985603 | Emily Wood | 1 |
| 6 | 201933222 | Freddie Harris | 2 |
| 7 | 201875940 | Grace Clarke | 2 |

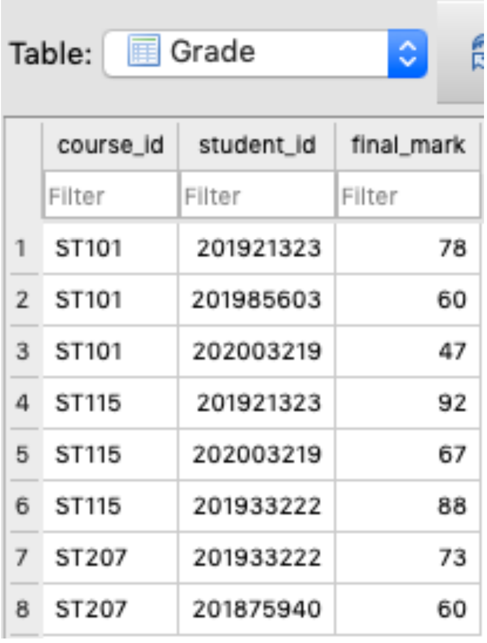
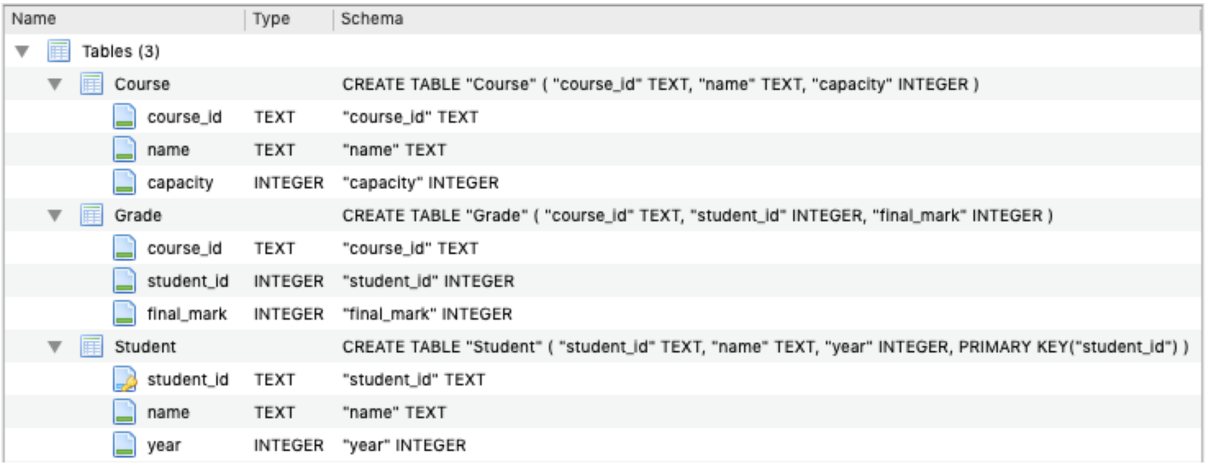


Table: Grade

| | course_id | student_id | final_mark |
|---|---|---|---|
| | Filter | Filter | Filter |
| 1 | ST101 | 201921323 | 78 |
| 2 | ST101 | 201985603 | 60 |
| 3 | ST101 | 202003219 | 47 |
| 4 | ST115 | 201921323 | 92 |
| 5 | ST115 | 202003219 | 67 |
| 6 | ST115 | 201933222 | 88 |
| 7 | ST207 | 201933222 | 73 |
| 8 | ST207 | 201875940 | 60 |



| Name | Type | Schema |
|---|---|---|
| Tables (3) | | |
| Course | | CREATE TABLE "Course" ( "course_id" TEXT, "name" TEXT, "capacity" INTEGER ) |
| course_id | TEXT | "course_id" TEXT |
| name | TEXT | "name" TEXT |
| capacity | INTEGER | "capacity" INTEGER |
| Grade | | CREATE TABLE "Grade" ( "course_id" TEXT, "student_id" INTEGER, "final_mark" INTEGER ) |
| course_id | TEXT | "course_id" TEXT |
| student_id | INTEGER | "student_id" INTEGER |
| final_mark | INTEGER | "final_mark" INTEGER |
| Student | | CREATE TABLE "Student" ( "student_id" TEXT, "name" TEXT, "year" INTEGER, PRIMARY KEY("student_id") ) |
| student_id | TEXT | "student_id" TEXT |
| name | TEXT | "name" TEXT |
| year | INTEGER | "year" INTEGER |

# 2. Structured Query Language

## *Structured Query Language (SQL)*

- A standardised domain-specific language used in programming and designed for managing data held in a RDBMS.
- Used to create, maintain (insert, update, delete), and retrieve (query) the relational database.

## *SQLite*

- RDBMS contained in a C library.
- Lightweight, non-client-server database engine.

## *DB Browser for SQLite (DB4S)*

- Tool to create, design, and edit database files that are compatible with SQLite.
- https://sqlitebrowser.org

## *Basic SQLite Syntax (Creating & Manipulating Databases)*

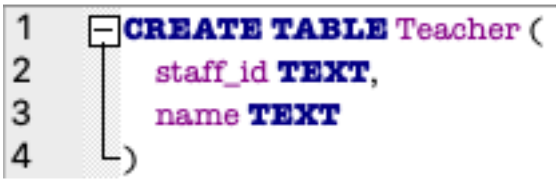
- **Add a Table**
  - CREATE TABLE *table_name* (

    *attribute1 datatype,*

    *attribute2 datatype,*

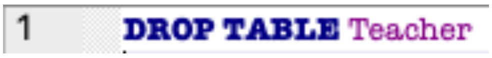
    …

    )



```
CREATE TABLE Teacher (
    staff_id TEXT,
    name TEXT
)
```

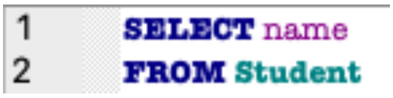
- **Delete a Table**
    - DROP TABLE *table_name*



```sql
DROP TABLE Teacher
```

- **Select Data**
    - SELECT *attribute1, attribute2, …*

      FROM *table_name*

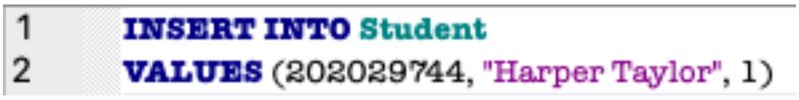


```sql
SELECT name
FROM Student
```

- **Insert Tuples/Rows**
    - INSERT INTO *table_name* (*attribute1, attribute2, …* )

      VALUES (*value1, value2, …*)
    - INSERT INTO *table_name*

      VALUES (*value1, value2, …*)

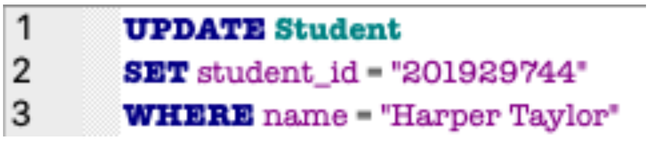


```sql
INSERT INTO Student
VALUES (202029744, "Harper Taylor", 1)
```

- **Update Tuples/Rows**
    - UPDATE *table_name*

      SET *attribute1* = *value1*, *attribute2* = *value2*, …

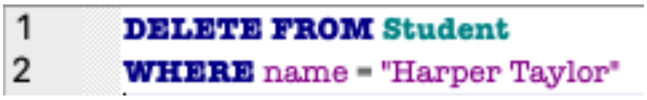
      WHERE *conditions*



```sql
UPDATE Student
SET student_id = "201929744"
WHERE name = "Harper Taylor"
```

- **Delete Tuples/Rows**
    - DELETE FROM *table_name*

      WHERE *conditions*



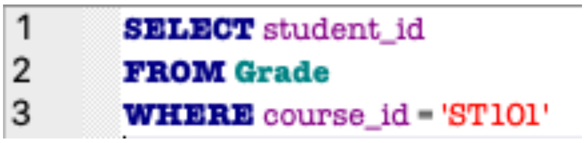
```
DELETE FROM Student
WHERE name = "Harper Taylor"
```

## *Basic SQLite Queries*

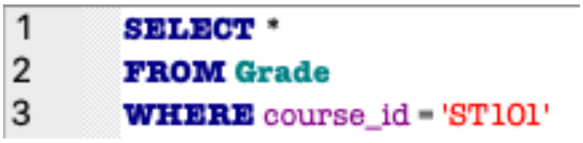
- **Conditions**
    - SELECT *attribute1, attribute2, …*

      FROM *table_name*

      WHERE *conditions*



```
SELECT student_id
FROM Grade
WHERE course_id = 'ST101'
```

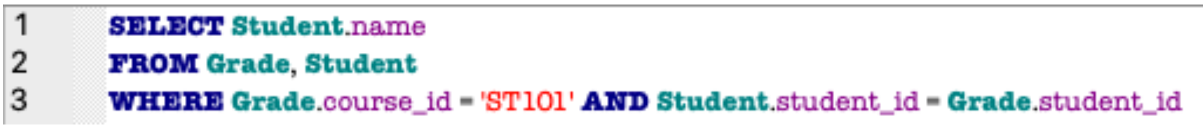


```
SELECT *
FROM Grade
WHERE course_id = 'ST101'
```

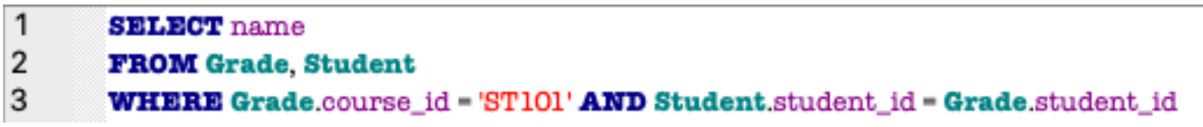
- **Several Tables**
    - SELECT *table.attribute1, table.attribute2, …*

      FROM *table1, table2, …*

      WHERE *condition1* AND/OR *condition2* …

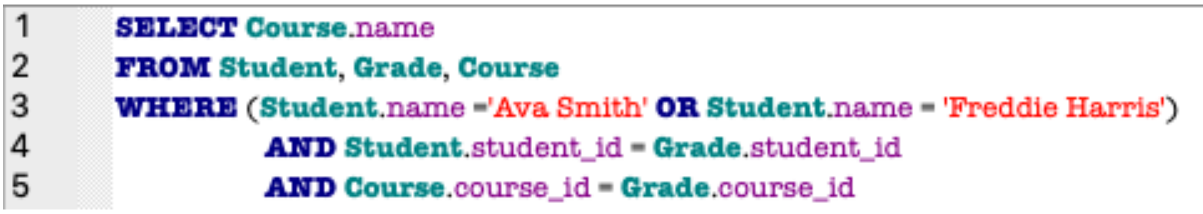


```
SELECT Student.name
FROM Grade, Student
WHERE Grade.course_id = 'ST101' AND Student.student_id = Grade.student_id
```



```
SELECT name
FROM Grade, Student
WHERE Grade.course_id = 'ST101' AND Student.student_id = Grade.student_id
```

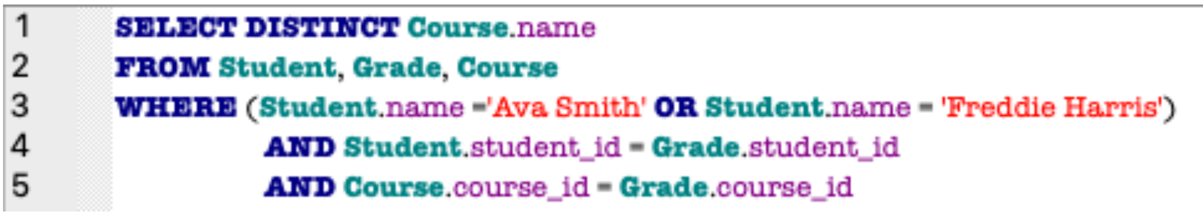
- **Multiple Conditions**



```
SELECT Course.name
FROM Student, Grade, Course
WHERE (Student.name ='Ava Smith' OR Student.name = 'Freddie Harris')
            AND Student.student_id = Grade.student_id
            AND Course.course_id = Grade.course_id
```

- SELECT DISTINCT *attribute1, attribute2, …*

  FROM *table_name*



```
SELECT DISTINCT Course.name
FROM Student, Grade, Course
WHERE (Student.name ='Ava Smith' OR Student.name = 'Freddie Harris')
            AND Student.student_id = Grade.student_id
            AND Course.course_id = Grade.course_id
```

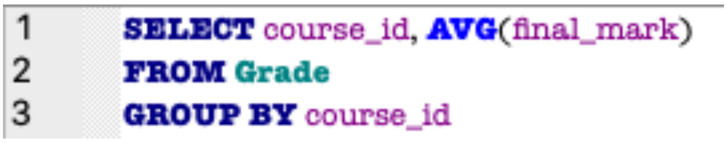
- **Aggregation**
  - SELECT *attributes, aggregation_functions* AS *column_name*

    FROM *table_name*

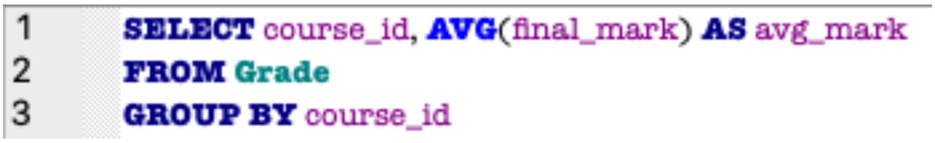
    WHERE *conditions*

    GROUP BY *attributes*

    ORDER BY *attributes*



```
SELECT course_id, AVG(final_mark)
FROM Grade
GROUP BY course_id
```



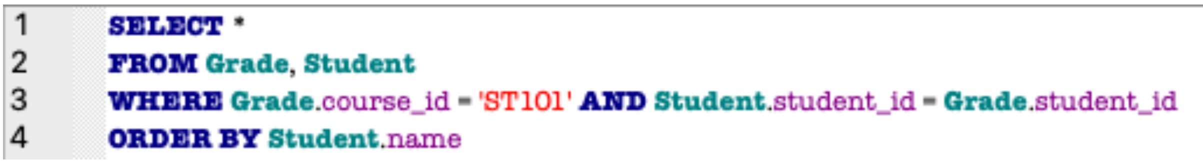
```
SELECT course_id, AVG(final_mark) AS avg_mark
FROM Grade
GROUP BY course_id
```

  - Aggregation functions
    - COUNT(), MAX(), MIN(), SUM(), AVG()

## *Basic SQLite Joins*

- A ***JOIN*** clause is used to combine rows from two or more tables, based on a related column between them.

- **Inner Join**
  - Selects records that have matching values in both tables

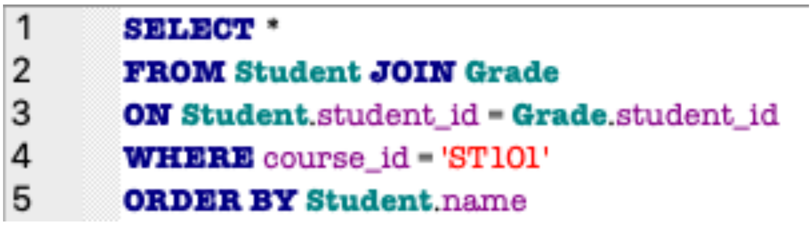


```
SELECT *
FROM Grade, Student
WHERE Grade.course_id = 'ST101' AND Student.student_id = Grade.student_id
ORDER BY Student.name
```

- SELECT *attributes*

  FROM *table1* JOIN *table2*

  ON *table1.attribute* = *table2.attribute*

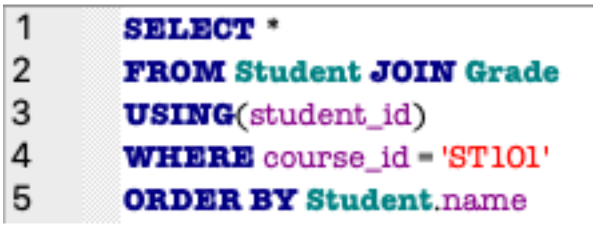


```
SELECT *
FROM Student JOIN Grade
ON Student.student_id = Grade.student_id
WHERE course_id = 'ST101'
ORDER BY Student.name
```

- SELECT *attributes*

  FROM *table1* JOIN *table2*

  USING(*attribute)*



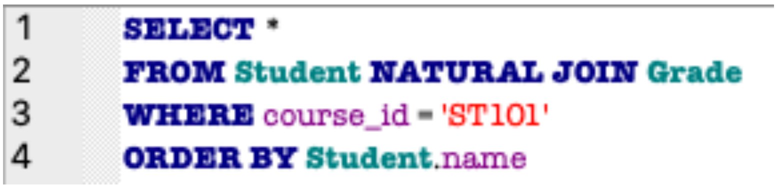
```
SELECT *
FROM Student JOIN Grade
USING(student_id)
WHERE course_id = 'ST101'
ORDER BY Student.name
```

- **Natural Join**
  - The join condition is automatically identified
  - SELECT *attributes*

    FROM *table1* NATURAL JOIN *table2*

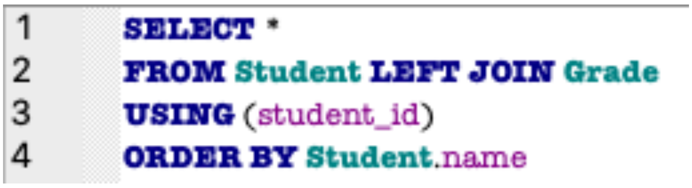
    WHERE *conditions*

    ORDER BY *attribute1*



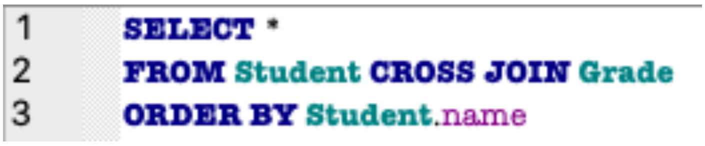
```
SELECT *
FROM Student NATURAL JOIN Grade
WHERE course_id = 'ST101'
ORDER BY Student.name
```

- **Left Join**
    - Returns all records from the left table (table1), and the matching records from the right table (table2)
    - *NULL* value for right table (table2) attributes with no corresponding record
    - SELECT *attributes*
      FROM *table1* LEFT JOIN *table2*
      USING (*attribute*)



```
SELECT *
FROM Student LEFT JOIN Grade
USING (student_id)
ORDER BY Student.name
```

- **Cross Join**
    - Returns all records when there is a match in left table (table1) or right table (table2) records
    - SELECT *attributes*
      FROM *table1* CROSS JOIN *table2*
      WHERE *conditions*
      ORDER BY *attribute1*



```
SELECT *
FROM Student CROSS JOIN Grade
ORDER BY Student.name
```

# 3. Using Databases with Python

## *Connecting to Databases in Python*

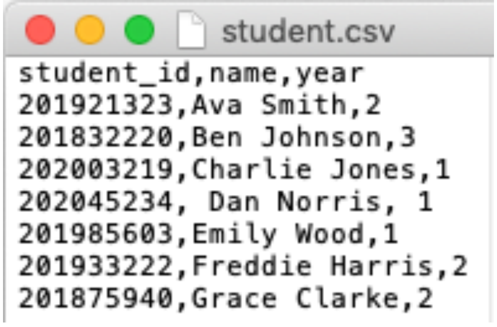
- Remove existing database
  - import os
    ```
    try:
        os.remove(‘University.db’)
    except OSError:
        pass
    ```

- Use “sqlite3” packages
  - import sqlite3

- Create connection to database
  - conn = sqlite3.connect(‘University.db’)

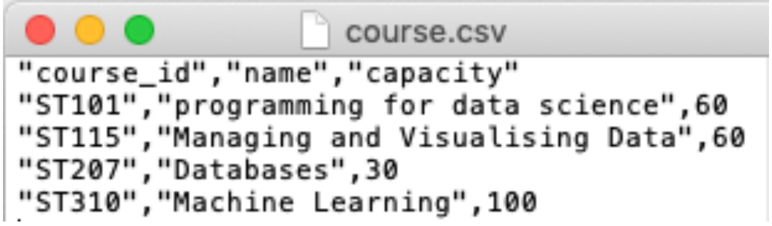
## *Creating Tables in Python*

- Read CSV files as data frames
  - import pandas as pd
  - student = pd.read_csv(“student.csv”)



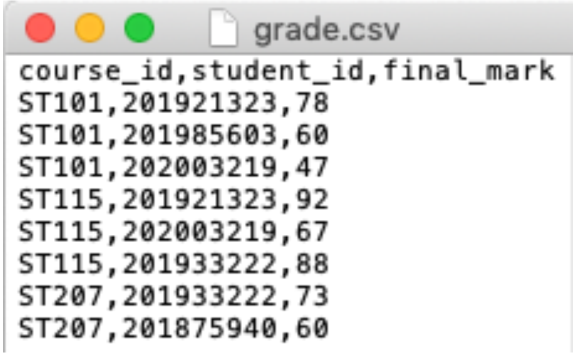
```
student_id,name,year
201921323,Ava Smith,2
201832220,Ben Johnson,3
202003219,Charlie Jones,1
202045234, Dan Norris, 1
201985603,Emily Wood,1
201933222,Freddie Harris,2
201875940,Grace Clarke,2
```

  - course = pd.read_csv(“course.csv”)



```
"course_id","name","capacity"
"ST101","programming for data science",60
"ST115","Managing and Visualising Data",60
"ST207","Databases",30
"ST310","Machine Learning",100
```

- ○ grade = pd.read_csv(“grade.csv”)



```
course_id,student_id,final_mark
ST101,201921323,78
ST101,201985603,60
ST101,202003219,47
ST115,201921323,92
ST115,202003219,67
ST115,201933222,88
ST207,201933222,73
ST207,201875940,60
```

- Copy data frames to database tables
  - ○ student.to_sql(‘Student’, con = conn, index = False)
  - ○ course.to_sql(‘Course’, con = conn, index = False)
  - ○ grade.to_sql(‘Grade’, con = conn, index = False)

## *Manipulating Data in Python*

- Create cursor object
  - ○ c = conn.cursor()

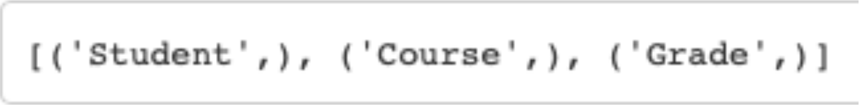
- Execute SQL commands to get all tables
  - ○ c.execute(‘‘‘ SELECT name

    FROM sqlite_master

    WHERE type=‘table’

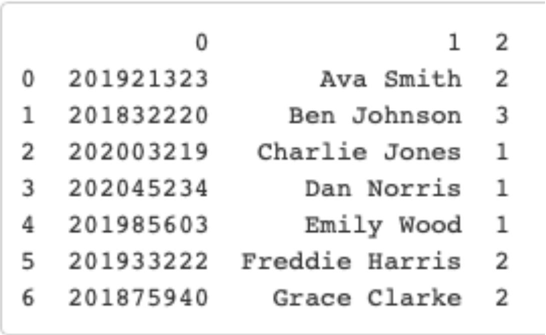
    ’’’)

- Fetch all tables
  - ○ c.fetchall()



```
[('Student',), ('Course',), ('Grade',)]
```

- Browse database table
  - q = c.execute(“SELECT * FROM Student”).fetchall()
  - pd.DataFrame(q)

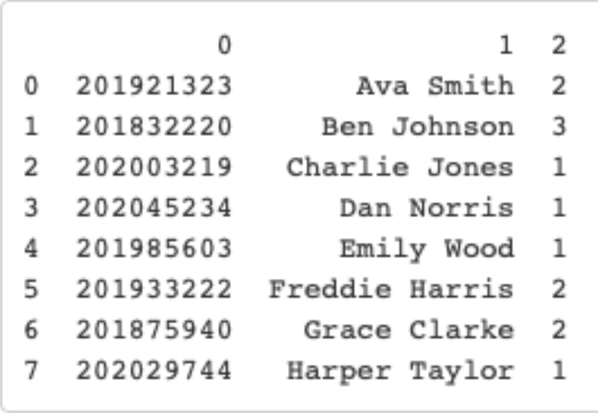


```
           0               1  2
0  201921323       Ava Smith  2
1  201832220     Ben Johnson  3
2  202003219   Charlie Jones  1
3  202045234      Dan Norris  1
4  201985603      Emily Wood  1
5  201933222  Freddie Harris  2
6  201875940    Grace Clarke  2
```

- Add a new table
  - c.execute(‘‘‘ CREATE TABLE Teacher  
    (staff_id TEXT PRIMARY KEY, name TEXT)  
    ’’’)
  - conn.commit()

- Delete a table
  - c.execute(“DROP TABLE Teacher”)
  - conn.commit()

- Insert tuples/rows
  - c.execute(‘‘‘ INSERT INTO Student  
    VALUES(202029744, ‘Harper Taylor’, 1)  
    ’’’)
  - conn.commit()



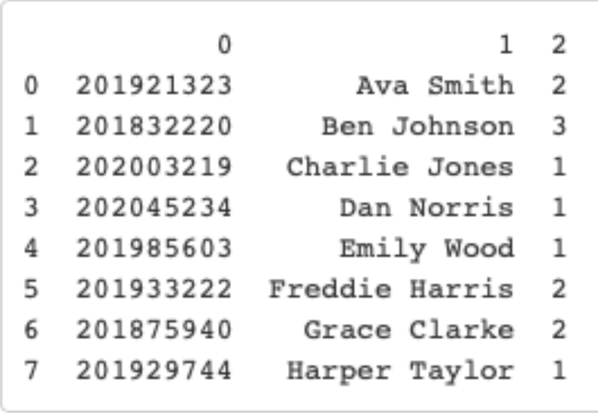
```
           0               1  2
0  201921323       Ava Smith  2
1  201832220     Ben Johnson  3
2  202003219   Charlie Jones  1
3  202045234      Dan Norris  1
4  201985603      Emily Wood  1
5  201933222  Freddie Harris  2
6  201875940    Grace Clarke  2
7  202029744    Harper Taylor  1
```

- Update tuples/rows
  - c.execute(‘‘‘ UPDATE Student

    SET student_id = “201929744”

    WHERE name = “Harper Taylor”

    ’’’)
  - conn.commit()

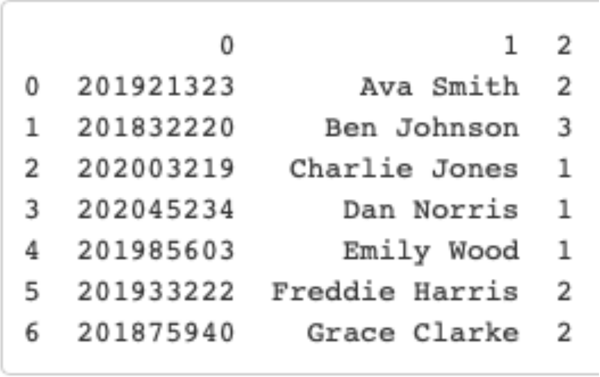


```
           0               1  2
0  201921323       Ava Smith  2
1  201832220     Ben Johnson  3
2  202003219   Charlie Jones  1
3  202045234      Dan Norris  1
4  201985603      Emily Wood  1
5  201933222  Freddie Harris  2
6  201875940    Grace Clarke  2
7  201929744    Harper Taylor  1
```

- Delete tuples/rows
  - c.execute(‘‘‘ DELETE FROM Student

    WHERE name = “Harper Taylor”

    ’’’)
  - conn.commit()

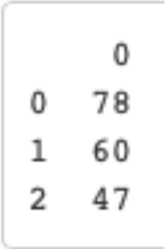


```
           0              1  2
0  201921323      Ava Smith  2
1  201832220    Ben Johnson  3
2  202003219  Charlie Jones  1
3  202045234     Dan Norris  1
4  201985603     Emily Wood  1
5  201933222 Freddie Harris  2
6  201875940    Grace Clarke  2
```

- Disconnecting from database
  - conn.close()

## *Querying Databases in Python*

- Get query results in data frame
  - q1 = c.execute(‘‘‘ SELECT final_mark
    FROM Grade
    WHERE course_id = ‘ST101’
    ’’’).fetchall()
  - pd.DataFrame(q1)

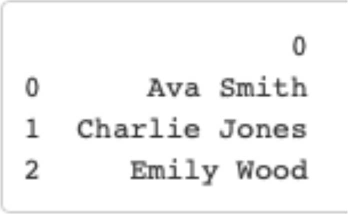


```
    0
0  78
1  60
2  47
```

- Get results in alphabetical order
  - q2 = c.execute(‘‘‘ SELECT Student.name
    FROM Grade, Student
    WHERE Grade.course_id=‘ST101’ AND
    Student.student_id=Grade.student.id

```
                        ORDER BY Student.name
                        ’’’).fetchall()
```

- pd.DataFrame(q2)

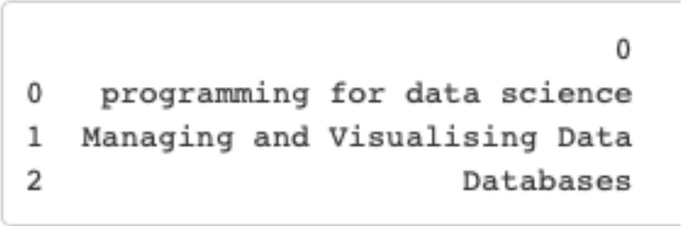


```
             0
0      Ava Smith
1  Charlie Jones
2     Emily Wood
```

- Get distinct results

```
q3 = c.execute(‘‘‘ SELECT DISTINCT Course.name
                    FROM Student, Grade, Course
                    WHERE (Student.name = ‘Ava Smith’ OR
                           Student.name = ‘Freddie Harris’) AND
                           Student.student_id = Grade.student_id
                    AND Course.course_id = Grade.course_id
                    ’’’).fetchall()
```

- pd.DataFrame(q3)

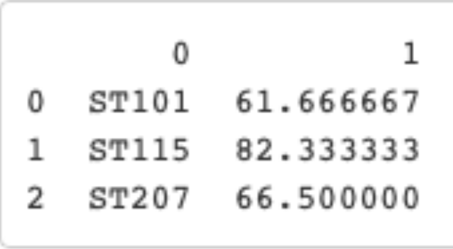


```
                               0
0    programming for data science
1  Managing and Visualising Data
2                      Databases
```

- Get calculated results

```
q4 = c.execute(‘‘‘ SELECT course_id, AVG(final_mark)
                    AS avg_mark
                    FROM Grade
                    GROUP BY course_id
                    ’’’).fetchall()
```

- pd.DataFrame(q4)



```
       0          1
0  ST101  61.666667
1  ST115  82.333333
2  ST207  66.500000
```

# 4. Exercises

## *6.107 Getting started with SQL*

- Refers to "6.107 SQL_Basics.html"

## *6.109 More SQL and file handling*

- Refers to "6.109 SQL_CSV.html"

## 5. Practice Quiz

- Work on *Practice Quiz 06* posted on Canvas.

# Useful Resources

- 
    - http://