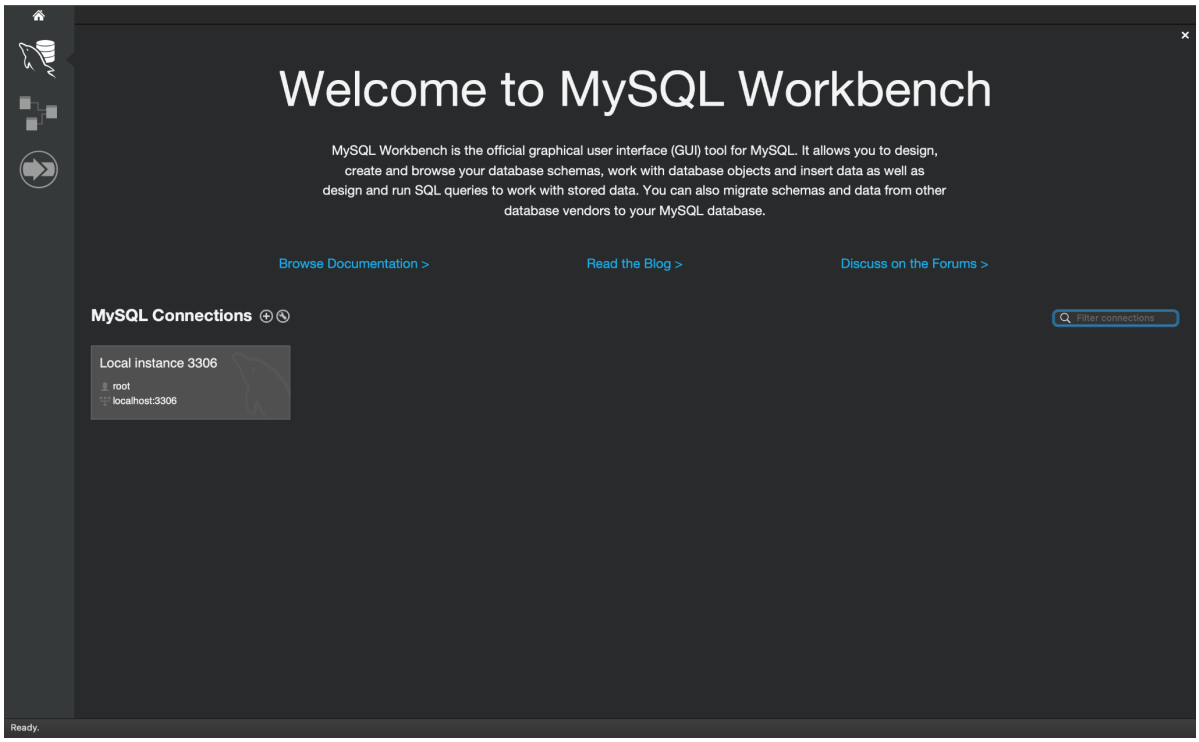
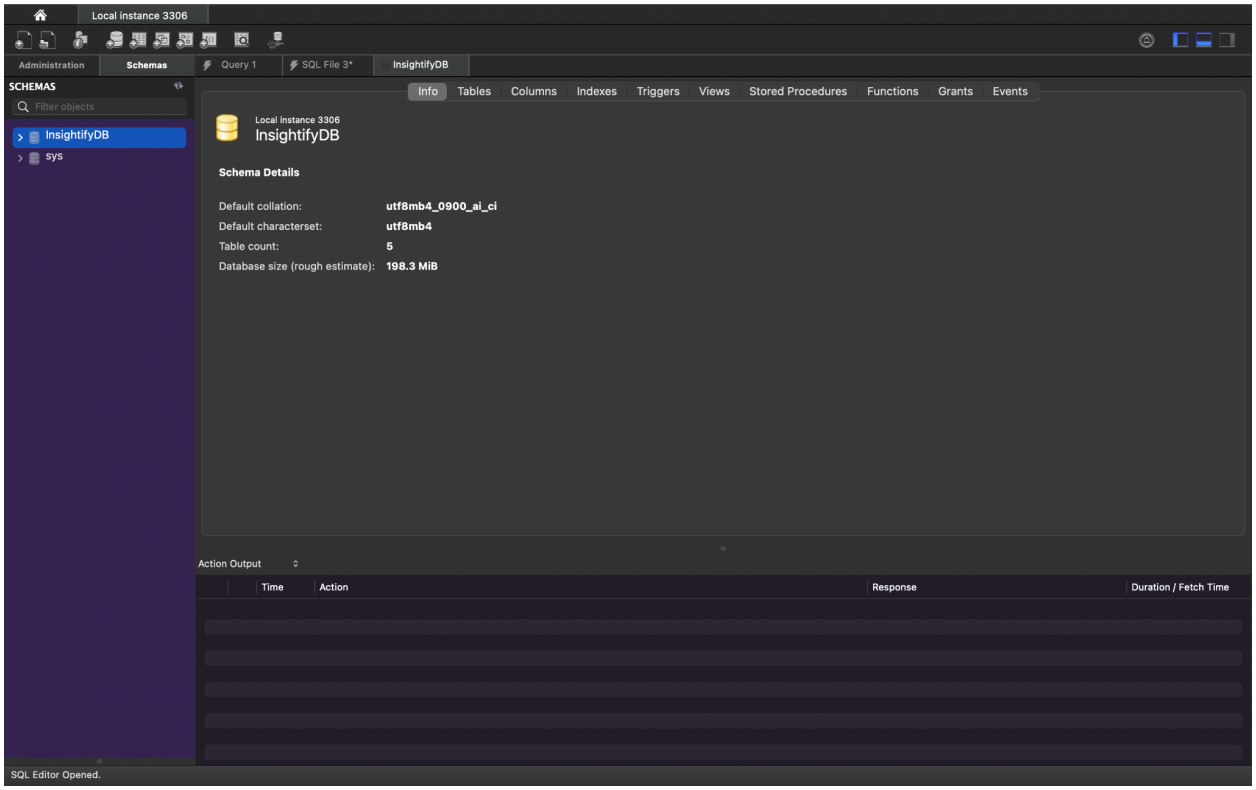
Database Design and Implementation

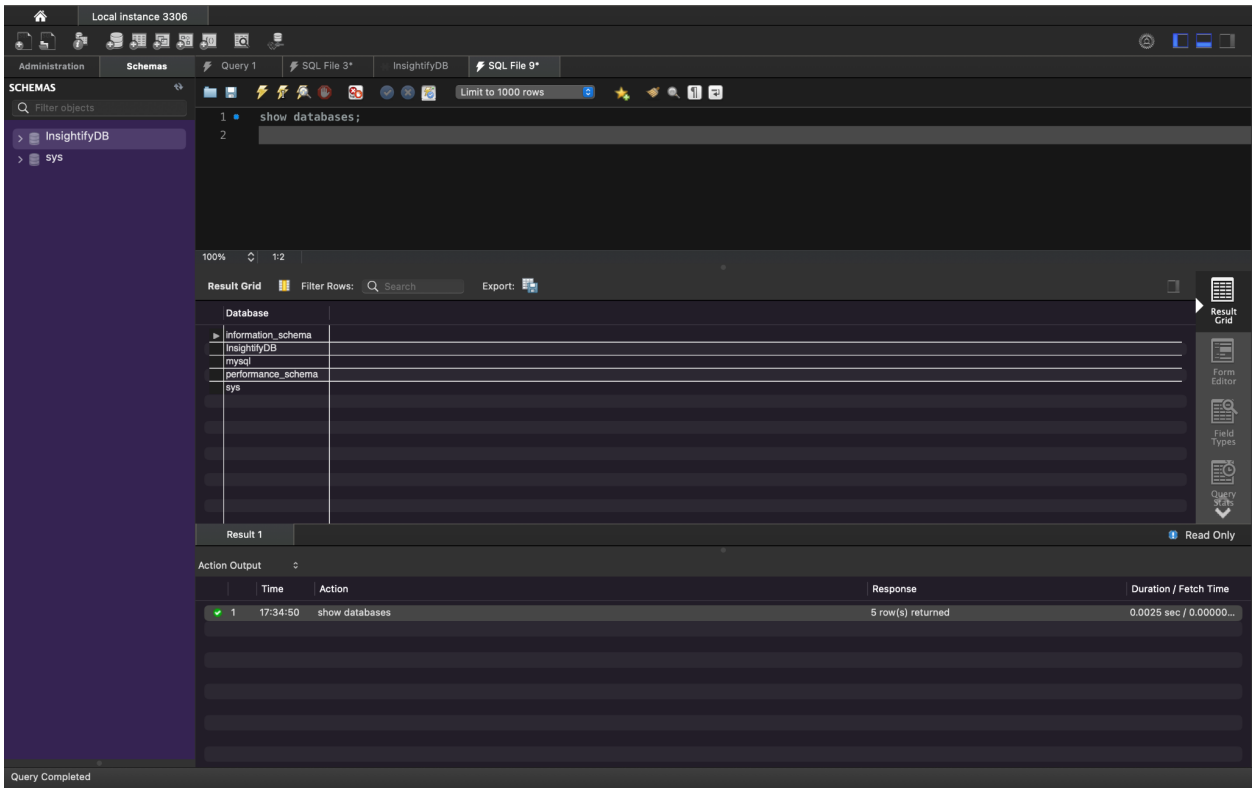
Database implementation

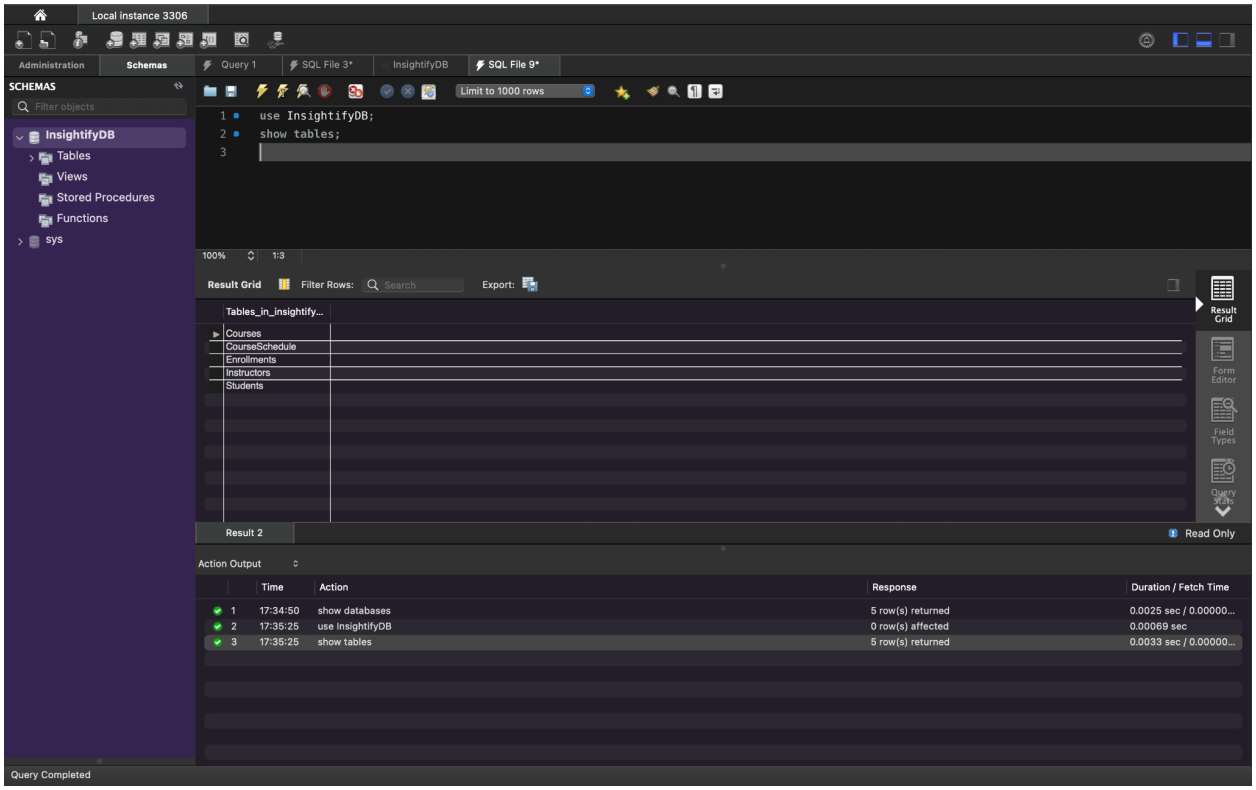
Currently, we implemented the entire database locally in MySQL. We used MySQL workbench to access and work on the database easily.

Here are the screenshots of the database (InsightifyDB):




Local instance 3306
Administration
Schemas
Query 1
SQL File 3*
InsightifyDB
SCHEMAS
Filter objects
InsightifyDB
sys
Info
Tables
Columns
Indexes
Triggers
Views
Stored Procedures
Functions
Grants
Events
Local instance 3306
InsightifyDB
Schema Details
Default collation: utf8mb4_0900_ai_ci
Default characterset: utf8mb4
Table count: 5
Database size (rough estimate): 198.3 MiB
Action Output
Time
Action
Response
Duration / Fetch Time
SQL Editor Opened.


Local instance 3306
Administration
Schemas
Query 1
SQL File 3*
InsightifyDB
SQL File 9*
SCHEMAS
Filter objects
InsightifyDB
sys
Limit to 1000 rows
1 show databases;
2
100%
1:2
Result Grid
Filter Rows:
Search
Export:
Database
information_schema
InsightifyDB
mysql
performance_schema
sys
Result Grid
Form Editor
Field Types
Query Stats
Result 1
Read Only
Action Output
Time
Action
Response
Duration / Fetch Time
1 17:34:50 show databases 5 row(s) returned 0.0025 sec / 0.00000...
Query Completed



Creating Tables

For this stage, we added the following five tables:

1) Courses
2) Students
3) Instructors
4) CourseSchedule
5) Enrollments

Here are the DDL commands we used for the creation of these tables:

```
CREATE TABLE Courses(
  CRN VARCHAR(7) NOT NULL PRIMARY KEY,
  Title VARCHAR(104) NOT NULL,
  Description VARCHAR(1384)
);
```

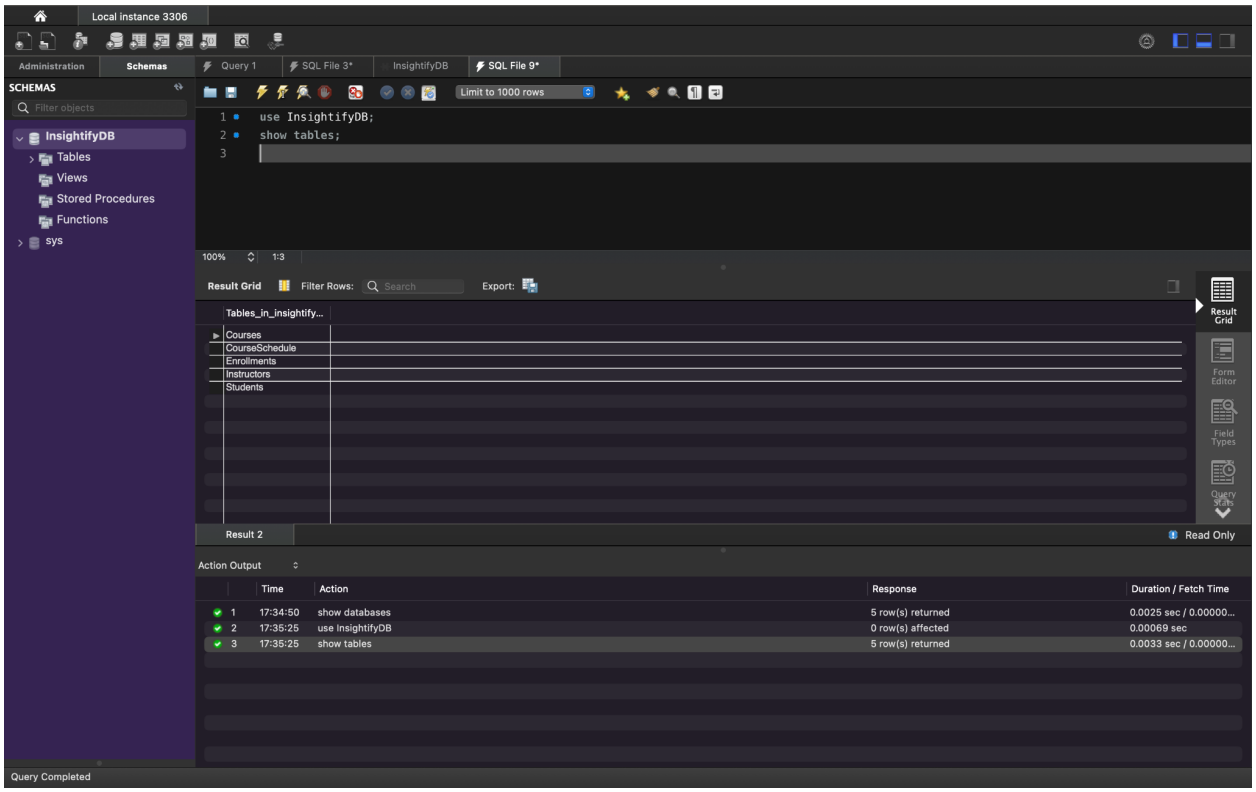
```sql
CREATE TABLE Students(
  Firstname VARCHAR(11) NOT NULL,
  Lastname  VARCHAR(11) NOT NULL,
  NetId     VARCHAR(15) NOT NULL PRIMARY KEY
);


CREATE TABLE Instructors(
  ID INTEGER  NOT NULL PRIMARY KEY,
  Instructor_name VARCHAR(25) NOT NULL
);

CREATE TABLE CourseSchedule(
  CRN VARCHAR(7) NOT NULL,
  YearTerm VARCHAR(11) NOT NULL,
  instructor_id INTEGER  NOT NULL,
  PRIMARY KEY(CRN,YearTerm),
  CONSTRAINT CourseSchedule_fk FOREIGN KEY (CRN) REFERENCES Courses(CRN),
  CONSTRAINT CourseSchedule_fk1 FOREIGN KEY (instructor_id) REFERENCES
Instructors(ID)
);

CREATE TABLE Enrollments(
  NetId VARCHAR(15) NOT NULL,
  CRN VARCHAR(7) NOT NULL,
  Term VARCHAR(11) NOT NULL,
  Credits INTEGER  NOT NULL,
  Grade VARCHAR(2) NOT NULL,
  Score NUMERIC(3,1) NOT NULL,
  PRIMARY KEY(NetId,CRN),
  CONSTRAINT enrollments_fk FOREIGN KEY (NetId) REFERENCES Students(NetId),
  CONSTRAINT enrollments_fk1 FOREIGN KEY (CRN) REFERENCES Courses(CRN)
);
```

Here are the screenshots of the tables:

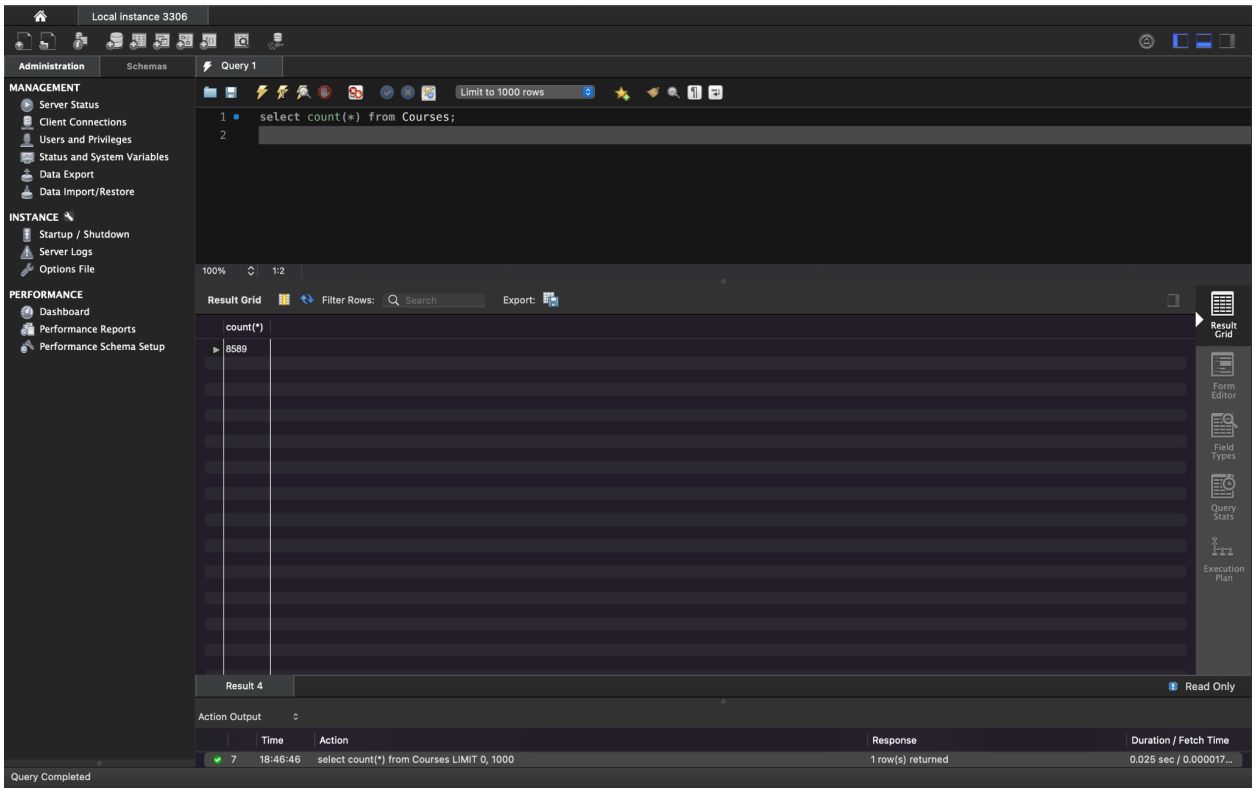


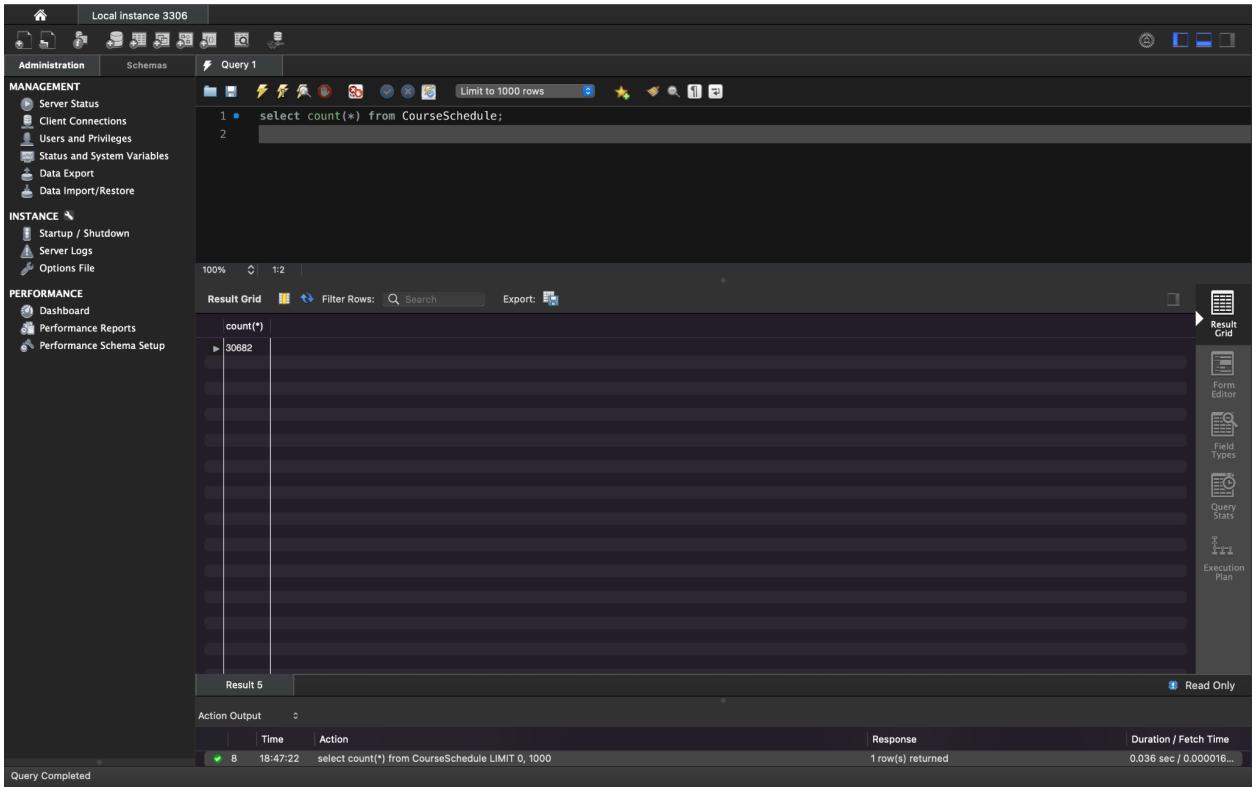
Inserting data into the Tables

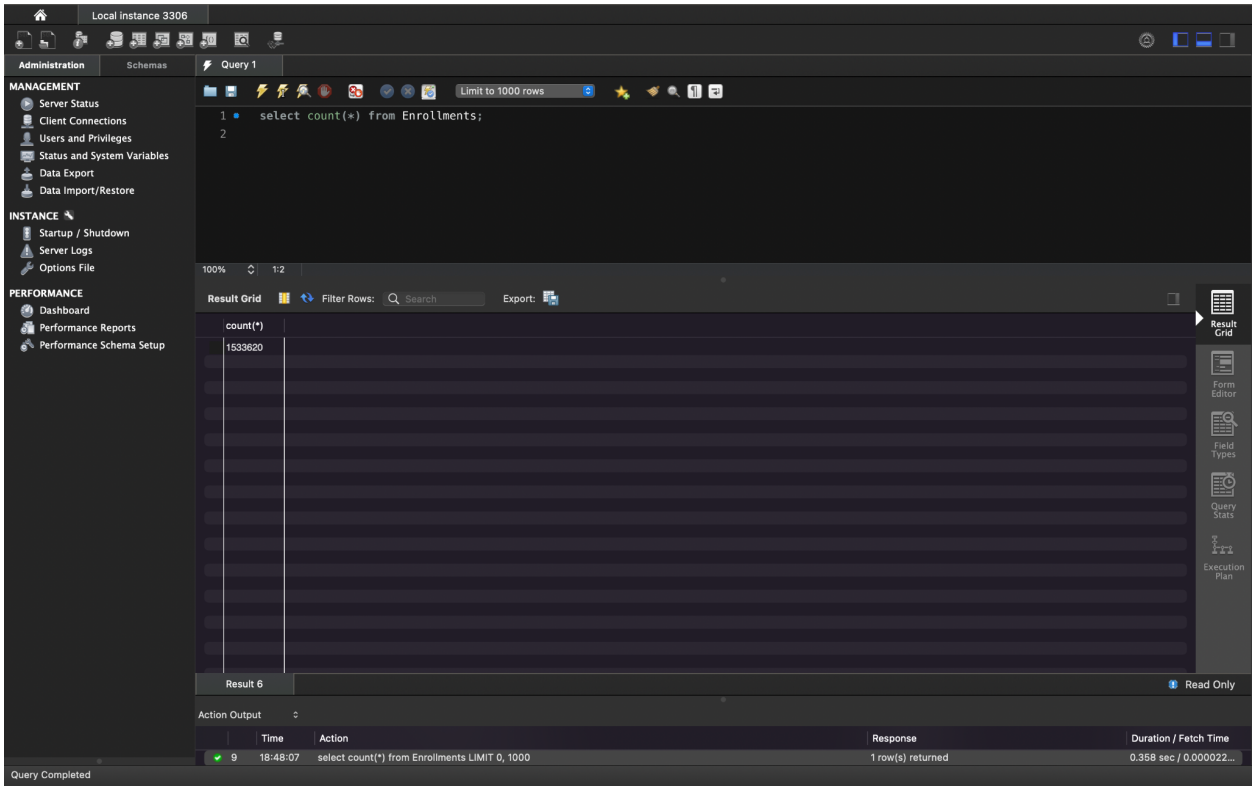
We inserted the data into the tables in the following way:

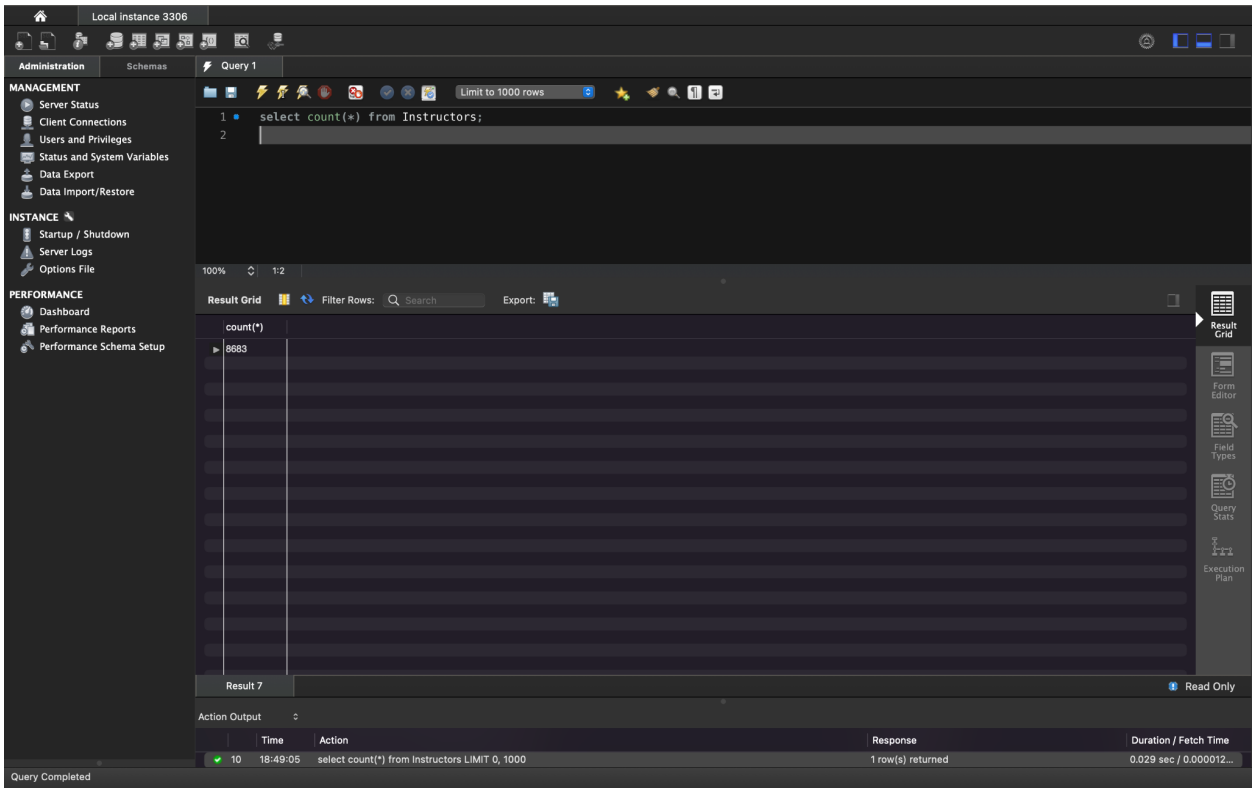
1. Courses:
    a. Source: https://github.com/chin123/gpa/blob/master/uiuc-course-catalog.csv
    b. #rows: 8589
2. Students:
    a. Source: Generated using faker package
    b. #rows: 48962
3. Instructors:
    a. Source: https://github.com/chin123/gpa/blob/master/uiuc-gpa-dataset.csv
    b. #rows: 8683
4. CourseSchedule:
    a. Source: https://github.com/chin123/gpa/blob/master/uiuc-gpa-dataset.csv
    b. #rows: 30682
5. Enrollments:
    a. Source: Generated using random package
    b. #rows: 1533620

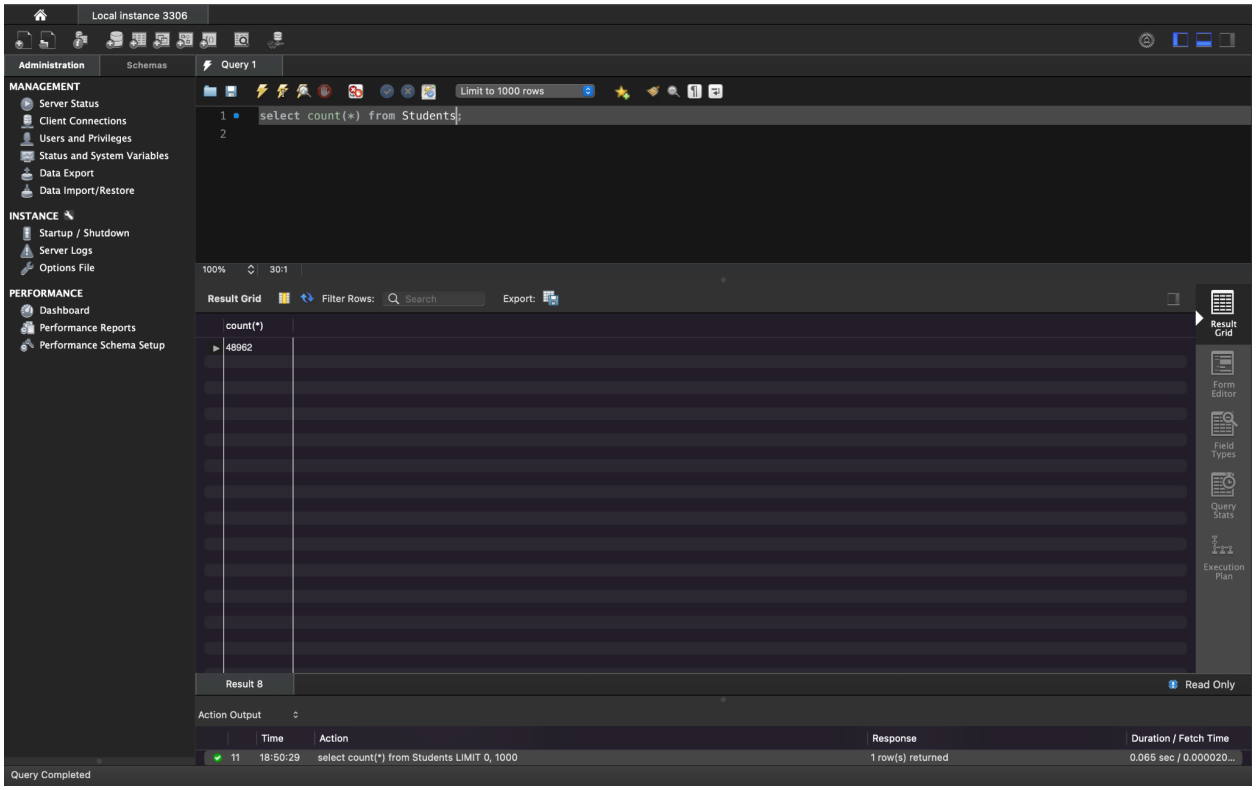
Here are the screenshots showing the count of rows in each table:






Local instance 3306
Administration
Schemas
Query 1
MANAGEMENT
Server Status
Client Connections
Users and Privileges
Status and System Variables
Data Export
Data Import/Restore
INSTANCE
Startup / Shutdown
Server Logs
Options File
PERFORMANCE
Dashboard
Performance Reports
Performance Schema Setup
Limit to 1000 rows
1 select count(*) from Enrollments;
2
100%
1:2
Result Grid
Filter Rows:
Search
Export:
count(*)
1533620
Result 6
Read Only
Action Output
Time
Action
Response
Duration / Fetch Time
9
18:48:07
select count(*) from Enrollments LIMIT 0, 1000
1 row(s) returned
0.358 sec / 0.000022...
Query Completed


Local instance 3306
Administration
Schemas
Query 1
MANAGEMENT
Server Status
Client Connections
Users and Privileges
Status and System Variables
Data Export
Data Import/Restore
INSTANCE
Startup / Shutdown
Server Logs
Options File
PERFORMANCE
Dashboard
Performance Reports
Performance Schema Setup
Limit to 1000 rows
1 select count(*) from Instructors;
2
100%
1:2
Result Grid
Filter Rows:
Search
Export:
count(*)
8683
Result 7
Read Only
Action Output
Time
Action
Response
Duration / Fetch Time
10
18:49:05
select count(*) from Instructors LIMIT 0, 1000
1 row(s) returned
0.029 sec / 0.000012...
Query Completed



Advanced Queries

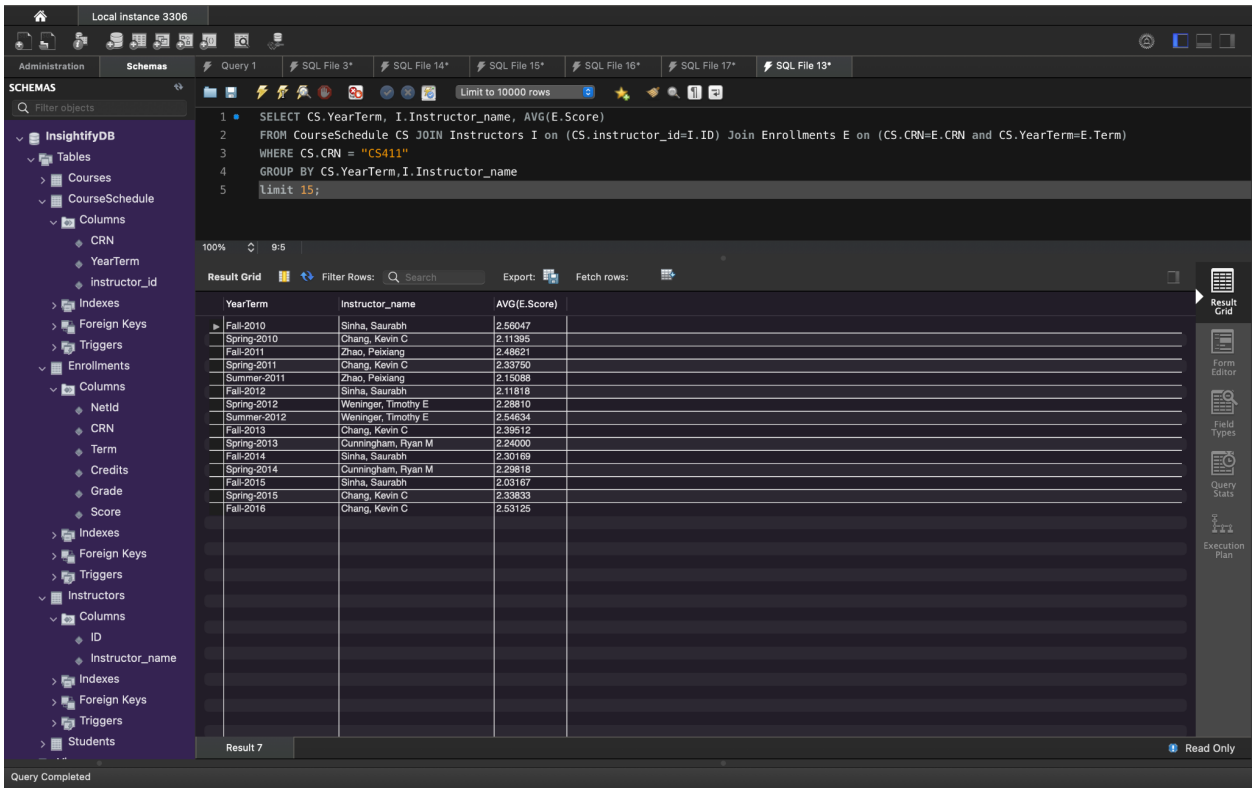
Here are the 2 advanced queries and their explanation:

Query 1

```
SELECT CS.YearTerm, I.Instructor_name, AVG(E.Score)
FROM CourseSchedule CS JOIN Instructors I on (CS.instructor_id=I.ID) Join
Enrollments E on (CS.CRN=E.CRN and CS.YearTerm=E.Term)
WHERE CS.CRN = "CS411"
GROUP BY CS.YearTerm,I.Instructor_name
limit 15;
```

Explanation: This query finds the list of all terms and the instructor for that term and the average score that term given a particular course (CRN). In our application, CRN is the course number (like CS411). In our application, the student first selects a course and then we display the term, instructor and average score data. In the query, we are assuming the given CRN as “CS411”. The student can check more details than this, but for now we are implementing this feature.

Here are the top 15 rows returned when this query is executed:

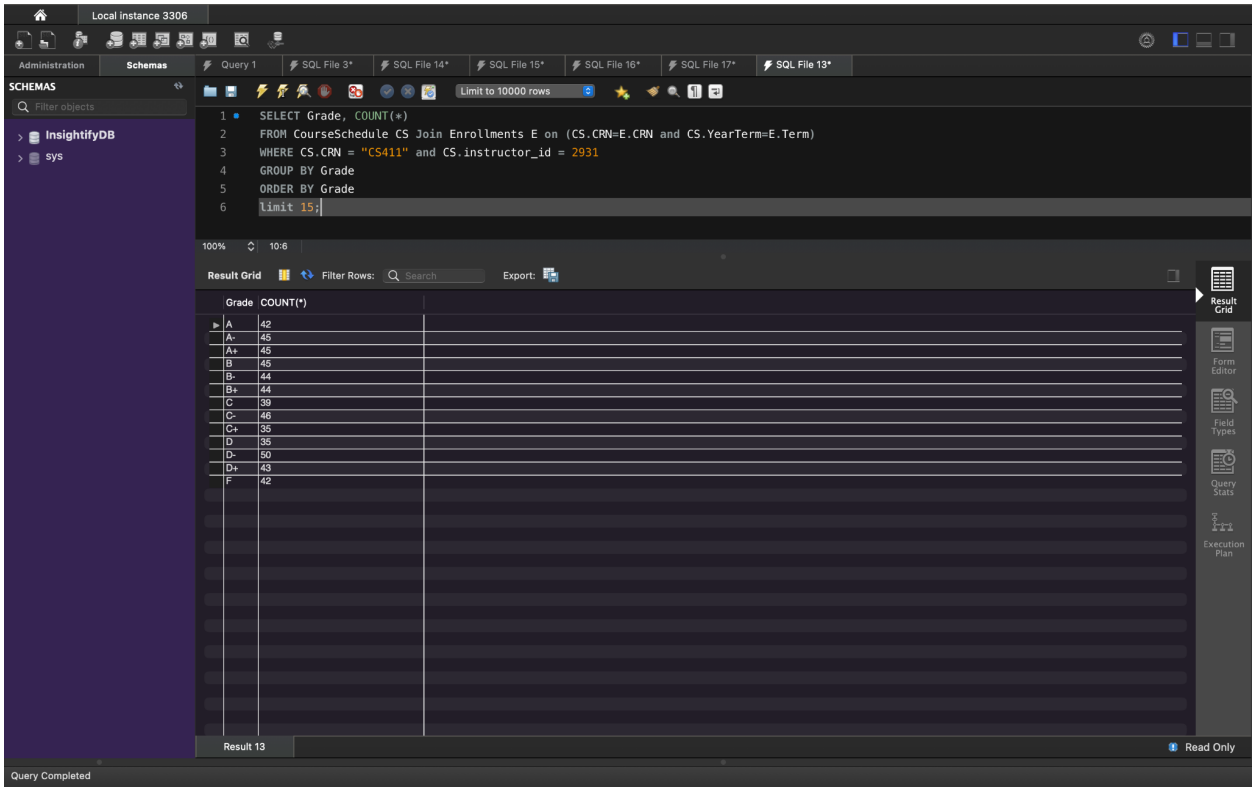


Query 2

```
SELECT Grade, COUNT(*)
FROM CourseSchedule CS Join Enrollments E on (CS.CRN=E.CRN and
CS.YearTerm=E.Term)
WHERE CS.CRN = "CS411" and CS.instructor_id = 2931
GROUP BY Grade
ORDER BY Grade
limit 15;
```

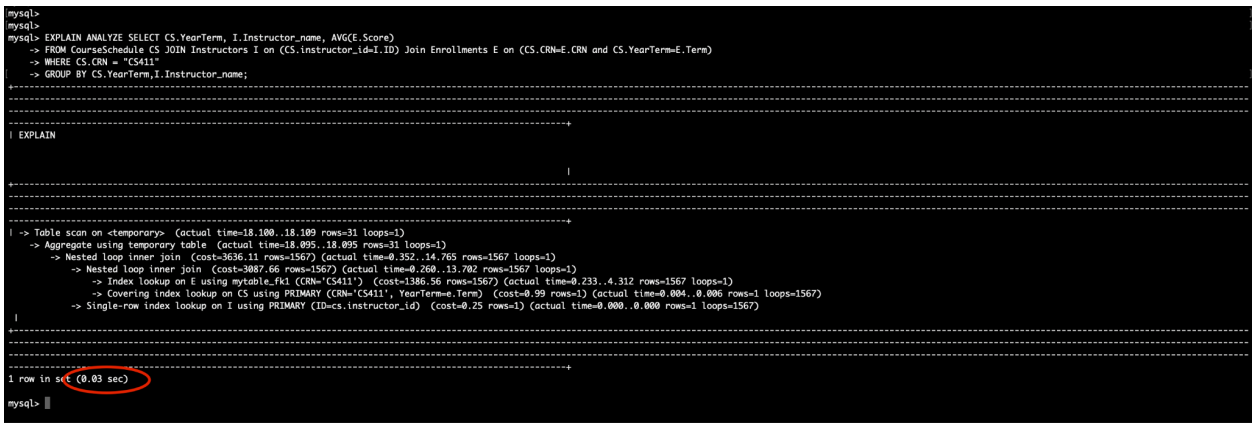
Explanation: This query finds the Grade distribution (Grade and the total number of students who got this grade) for a particular course and particular instructor. In our application, a student will be able to see how a particular instructor grades students for a course. The student will be able to get other metrics and other types of queries as well (like grade distribution for a particular term), but this data (in current query) will be shown at the high level when a student checks for an instructor and course.

Here are the top 15 rows returned when this query is executed:



Indexing on Query 1

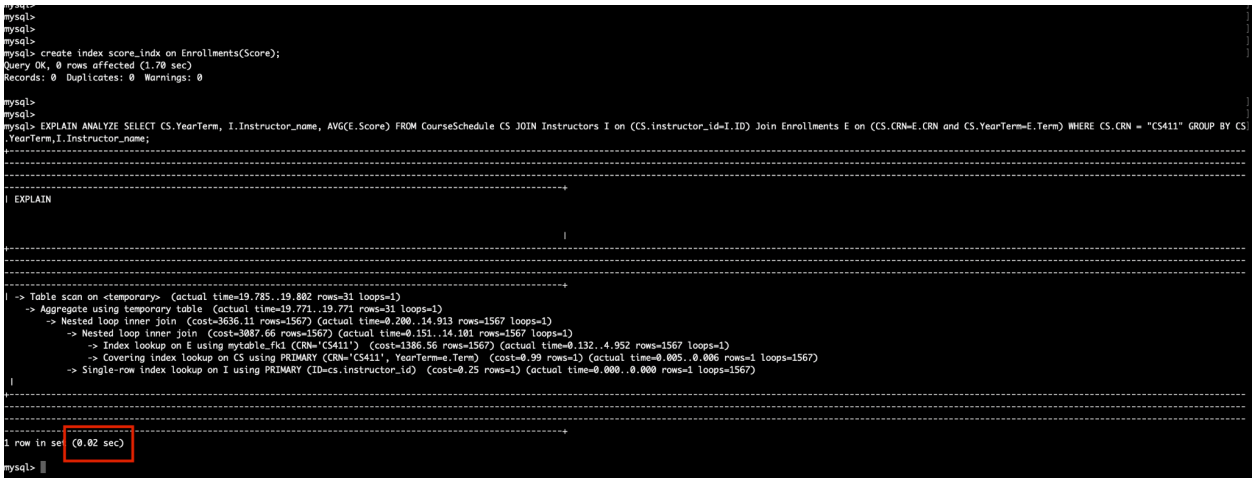
EXPLAIN ANALYZE on Query 1 without adding any new index:



- All the primary keys of all tables will already be indexed by default. So, we tried to index using different combinations of attributes which are not primary keys and not indexed by default.

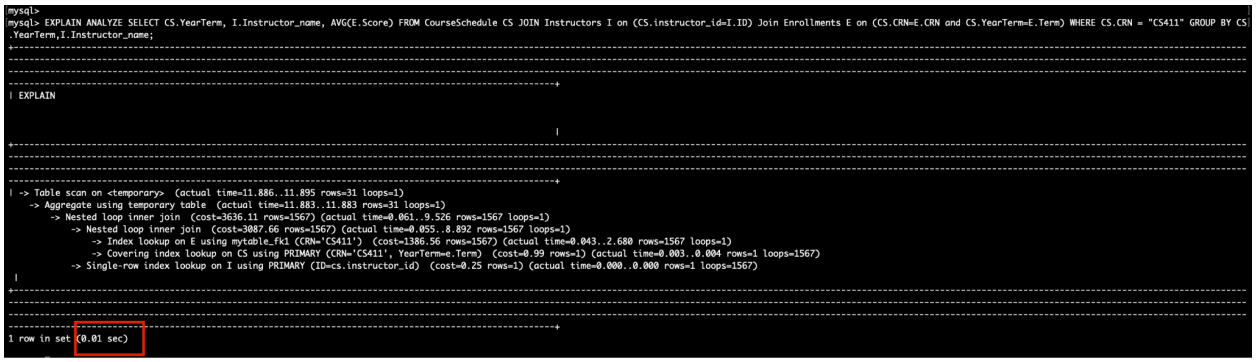
- We can see above that the execution time is 0.03 seconds when we did not add any new index.

Adding Index on Score attribute of Enrollments table:



- As we can see above, when we added index on Score attribute and ran EXPLAIN ANALYZE, we got the execution time as 0.02 which is marginally less than the time taken before without adding any index (0.03)
- We indexed on this attribute to experiment indexing on a new attribute part of aggregation.
- We saw a very marginal improvement probably because of the very low size of data. The execution time without new indexes itself is very low at 0.03 seconds.

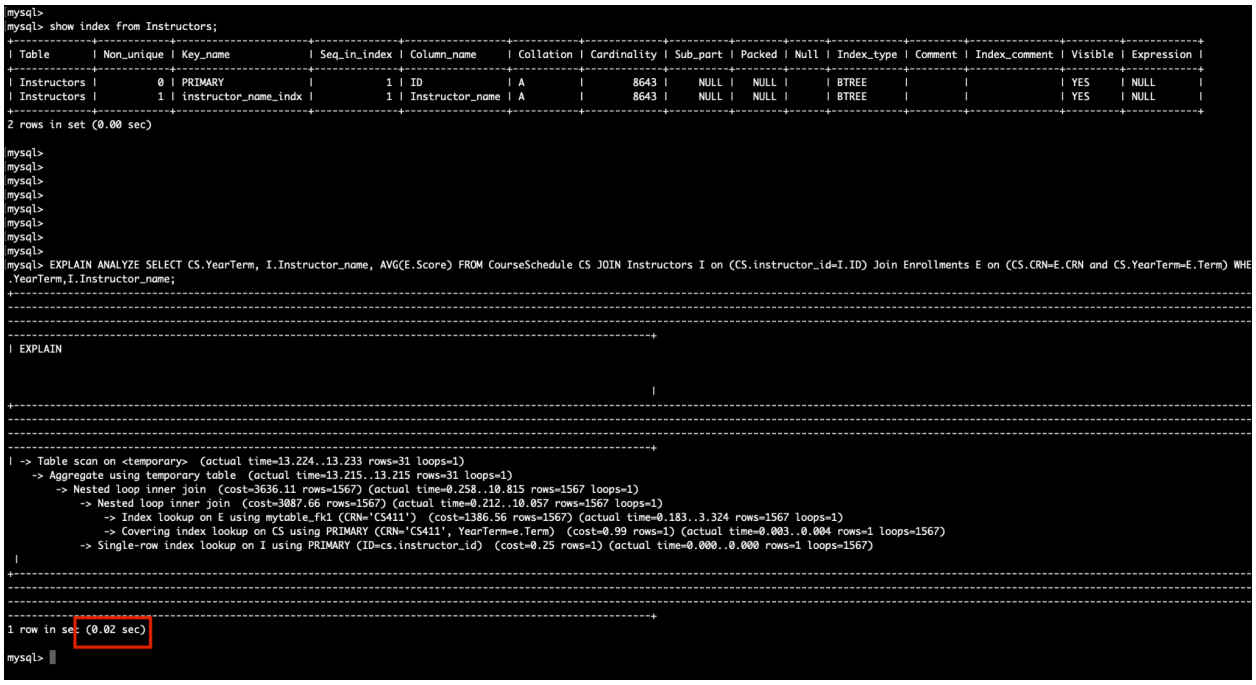
Adding Index on Instructor_name attribute of Instructors table (after adding index on Score):



- We added an index on Instructor_name as it is part of “Group by”. We think adding index on this attribute will help as “GROUP BY” internally may require table scan on this attribute.

- As we can see above, when we added index on Score attribute and ran EXPLAIN ANALYZE, we got the execution time as 0.01 which is marginally less than the time taken before (0.02)
- We saw a very marginal improvement probably because of the very low size of data. The execution time without new indexes itself is very low at 0.03 seconds.

Index with Instructor_name alone:



- As we can see above, when we added an index on Instructor_name attribute (without adding index on Score) and ran EXPLAIN ANALYZE, we got the execution time as 0.02 which is exactly the same as the time taken when we had only the Score index.
- This is probably because of the very low size of data. The execution time without new indexes itself is very low at 0.03 seconds.

Index selection:

- As per the metrics we saw in the above three experiments, the best design would be to add index on both Score and Instructor_name attributes
- But, these new index bring down the execution time only marginally down
- This is probably because of the very low size of data. The execution time without new indexes itself is very low at 0.03 seconds.
- Ideally, for such low volume databases, it would be wiser to not add new indexes as they may take up more memory with only very marginal improvements in execution time which in any case does not impact the calling application

Indexing on Query 2

EXPLAIN ANALYZE on Query 2 without adding any new index:

```
mysql>
mysql>
mysql>
mysql> EXPLAIN ANALYZE SELECT Grade, COUNT(*)
    -> FROM CourseSchedule CS Join Enrollments E on (CS.CRN=E.CRN and CS.YearTerm=E.Term)
    -> WHERE CS.CRN = "CS411" and CS.instructor_id = 2931
    -> GROUP BY Grade
    -> ORDER BY Grade;
| EXPLAIN
| -> Sort: e.Grade  (actual time=4.357..4.358 rows=13 loops=1)
    -> Table scan on <temporary>  (actual time=3.903..3.905 rows=13 loops=1)
        -> Aggregate using temporary table  (actual time=3.896..3.896 rows=13 loops=1)
            -> Nested loop inner join  (cost=3087.66 rows=1567) (actual time=2.103..3.500 rows=555 loops=1)
                -> Index lookup on E using mytable_fk1 (CRN='CS411')  (cost=1386.56 rows=1567) (actual time=0.092..2.675 rows=1567 loops=1)
                -> Single-row covering index lookup on CS using PRIMARY (CRN='CS411', YearTerm=e.Term, instructor_id=2931)  (cost=0.99 rows=1) (actual time=0.000..0.000 rows=0 loops=1567)
 |
1 row in set (0.02 sec)
```

- We can see above that the execution time is 0.03 seconds when we did not add any new index.

Index on CRN:

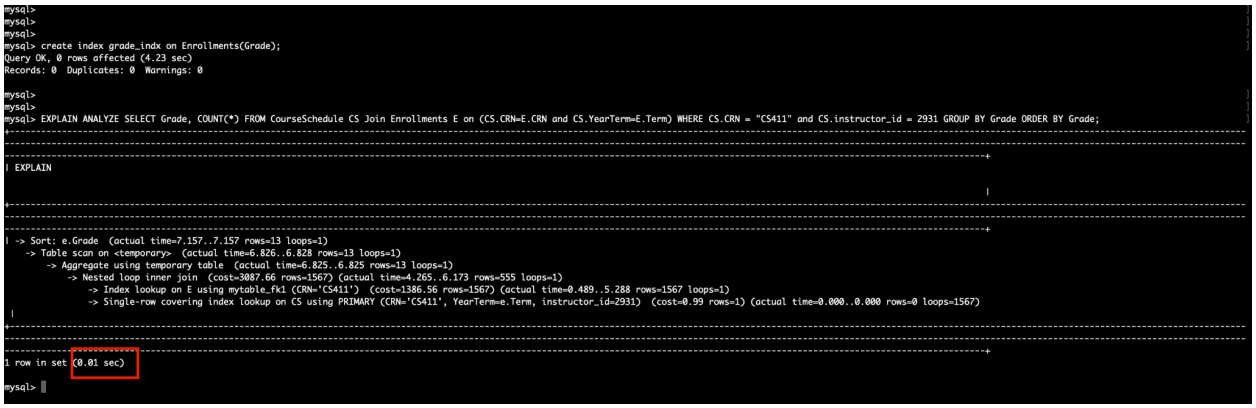
```
mysql> EXPLAIN ANALYZE SELECT Grade, COUNT(*) FROM CourseSchedule CS Join Enrollments E on (CS.CRN=E.CRN and CS.YearTerm=E.Term) WHERE CS.CRN = "CS411" and CS.instructor_id = 2931 GROUP BY Grade ORDER BY Grade;
| EXPLAIN
| -> Sort: e.Grade  (actual time=6.117..6.118 rows=13 loops=1)
    -> Table scan on <temporary>  (actual time=6.074..6.077 rows=13 loops=1)
        -> Aggregate using temporary table  (actual time=6.073..6.073 rows=13 loops=1)
            -> Nested loop inner join  (cost=1935.01 rows=1567) (actual time=3.457..5.490 rows=555 loops=1)
                -> Index lookup on E using mytable_fk1 (CRN='CS411')  (cost=1386.56 rows=1567) (actual time=0.077..4.096 rows=1567 loops=1)
                -> Single-row covering index lookup on CS using PRIMARY (CRN='CS411', YearTerm=e.Term, instructor_id=2931)  (cost=0.25 rows=1) (actual time=0.001..0.001 rows=0 loops=1567)
 |
1 row in set (0.02 sec)

mysql> show index from CourseSchedule;
+----------------+------------+--------------------+--------------+---------------+-----------+-------------+----------+--------+------+------------+---------+---------------+---------+------------+
| Table          | Non_unique | Key_name           | Seq_in_index | Column_name   | Collation | Cardinality | Sub_part | Packed | Null | Index_type | Comment | Index_comment | Visible | Expression |
+----------------+------------+--------------------+--------------+---------------+-----------+-------------+----------+--------+------+------------+---------+---------------+---------+------------+
| CourseSchedule |          0 | PRIMARY            |            1 | CRN           | A         |        3315 |     NULL |   NULL |      | BTREE      |         |               | YES     | NULL       |
| CourseSchedule |          0 | PRIMARY            |            2 | YearTerm      | A         |       24492 |     NULL |   NULL |      | BTREE      |         |               | YES     | NULL       |
| CourseSchedule |          0 | PRIMARY            |            3 | instructor_id | A         |       24492 |     NULL |   NULL |      | BTREE      |         |               | YES     | NULL       |
| CourseSchedule |          1 | CourseSchedule_fk1 |            1 | instructor_id | A         |        6321 |     NULL |   NULL |      | BTREE      |         |               | YES     | NULL       |
| CourseSchedule |          1 | crn_indx           |            1 | CRN           | A         |        3575 |     NULL |   NULL |      | BTREE      |         |               | YES     | NULL       |
+----------------+------------+--------------------+--------------+---------------+-----------+-------------+----------+--------+------+------------+---------+---------------+---------+------------+
5 rows in set (0.03 sec)

mysql>
```

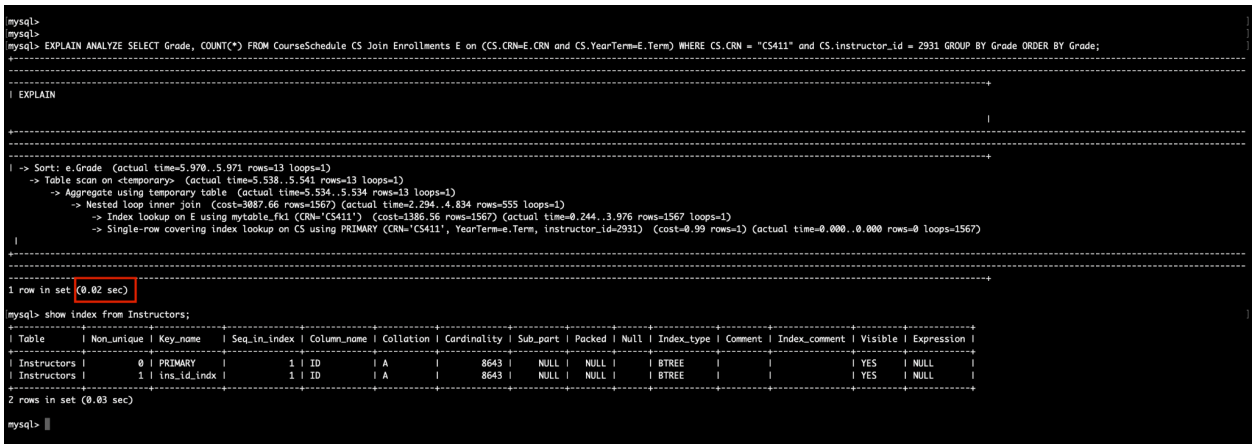
- As we can see above, when we added an index on CRN attribute and ran EXPLAIN ANALYZE, we got the execution time as 0.02 which is exactly the same as the time taken when we had no additional index.
- This is probably because of the very low size of data and already insignificant execution time.

Index on grade:



- We added an index on Grade as it is part of “Group by”. We think adding index on this attribute will help as “GROUP BY” internally may require table scan on this attribute.
- As we can see above, when we added index on Score attribute and ran EXPLAIN ANALYZE, we got the execution time as 0.01 which is marginally less than the time taken before (0.02)
- We saw a very marginal improvement probably because of the very low volume of data.

Index on instructor ID:



- As we can see above, when we added an index on ID attribute and ran EXPLAIN ANALYZE, we got the execution time as 0.02 which is exactly the same as the time taken when we had no additional index.
- This is probably because of the very low size of data and already insignificant execution time.

Index selection:

- As per the metrics we saw in the above three experiments, the best design would be to add an index on the Grade attribute.
- But, this new index bring down the execution time only marginally down
- This is probably because of the very low size of data. The execution time without new indexes itself is very low at 0.02 seconds.
- Ideally, for such low volume databases, it would be wiser to not add new indexes as they may take up more memory with only very marginal improvements in execution time which in any case does not impact the calling application.