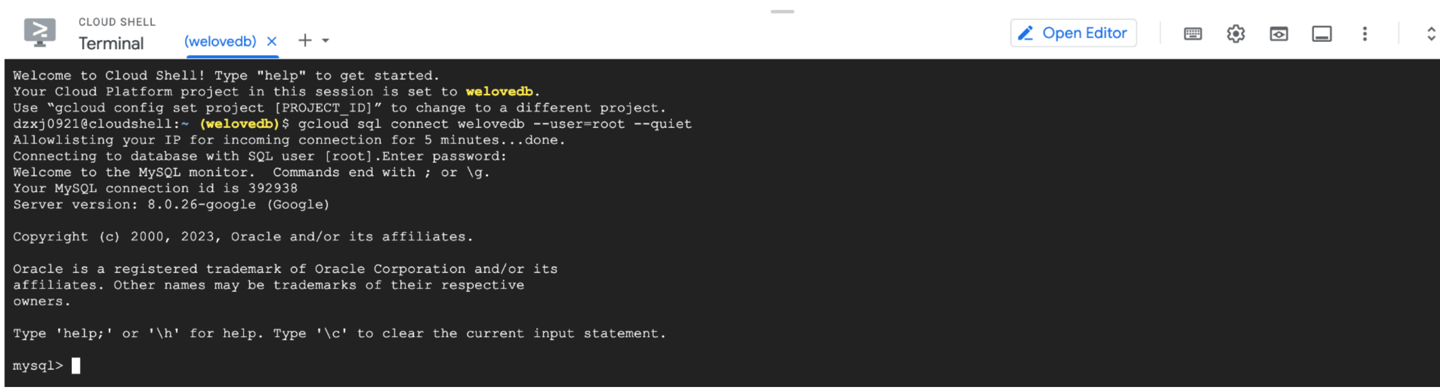
CS 411 Project Track 1 – Stage 3 Report

1) Implementation of MySQL database on Google Cloud Platform



2) DDL Commands to create the relations

```
CREATE TABLE Users (
     user_id INT NOT NULL,
     user_name VARCHAR(255) NOT NULL,
     user_email VARCHAR(320) NOT NULL,
     user_password VARCHAR(100) NOT NULL,
     PRIMARY KEY (user_id)
);

CREATE TABLE Tags (
     tag_id INT NOT NULL,
     tag_description VARCHAR(255),
     PRIMARY KEY (tag_id)
);

CREATE TABLE Categories (
     category_id INT NOT NULL,
     category_description VARCHAR(255),
     PRIMARY KEY (category_id)
);

CREATE TABLE Channels (
     channel_id VARCHAR(63) NOT NULL,
     channel_title VARCHAR(255),
     PRIMARY KEY (channel_id)
);
```

```
CREATE TABLE Favorite_Videos (
     user_id INT,
     video_id VARCHAR(255),
     favorite_date DATE,
     PRIMARY KEY(user_id, video_id),
     FOREIGN KEY (user_id) REFERENCES Users(user_id),
     FOREIGN KEY (video_id) REFERENCES Videos(video_id)
);

CREATE TABLE Favorite_Tags (
     user_id INT,
     tag_id INT,
     favorite_date DATE,
     PRIMARY KEY(user_id, tag_id),
     FOREIGN KEY (user_id) REFERENCES Users(user_id),
     FOREIGN KEY (tag_id) REFERENCES Tags(tag_id)
);

CREATE TABLE Video_Tags (
     video_id VARCHAR(255),
     tag_id INT,
     PRIMARY KEY(video_id, tag_id),
     FOREIGN KEY (video_id) REFERENCES Videos(video_id),
     FOREIGN KEY (tag_id) REFERENCES Tags(tag_id)
);

CREATE TABLE Videos (
  video_id VARCHAR(255) NOT NULL,
  video_title VARCHAR(255),
  uploaded_date DATETIME,
  channel_id VARCHAR(63),
  channel_title VARCHAR(255),
  category_id INT,
  trending_date DATETIME,
  view_count INT,
  like_count INT,
  dislike_count INT,
  comment_count INT,
  thumbnail_link VARCHAR(512),
  comments_disabled BOOLEAN,
```

```
  ratings_disabled BOOLEAN,
  PRIMARY KEY (video_id),
  FOREIGN KEY (category_id) REFERENCES Categories(category_id),
  FOREIGN KEY (channel_id) REFERENCES Channels(channel_id)
);
```

As per comments from Stage 2, we altered Videos to be a weak entity set of Channels.

3) Insertion of more than 1000 records in `Tags`, `Videos` and `Video_Tags`

```
mysql> SELECT COUNT(*) FROM Tags;
+----------+
| COUNT(*) |
+----------+
|   192970 |
+----------+
1 row in set (0.06 sec)
```

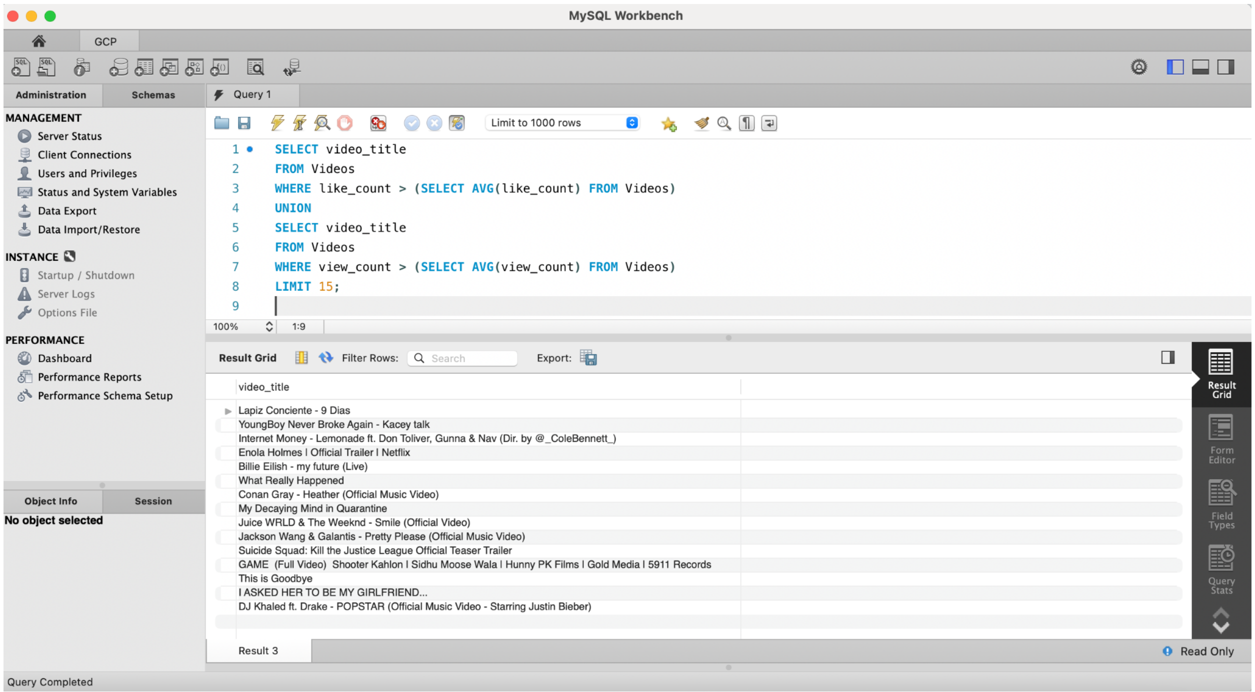
```
mysql> SELECT COUNT(*) FROM Videos;
+----------+
| COUNT(*) |
+----------+
|     1049 |
+----------+
1 row in set (0.00 sec)
```

```
mysql> SELECT COUNT(*) FROM Video_Tags;
+----------+
| COUNT(*) |
+----------+
|    21041 |
+----------+
1 row in set (0.00 sec)
```

4) Two advanced queries with querying results

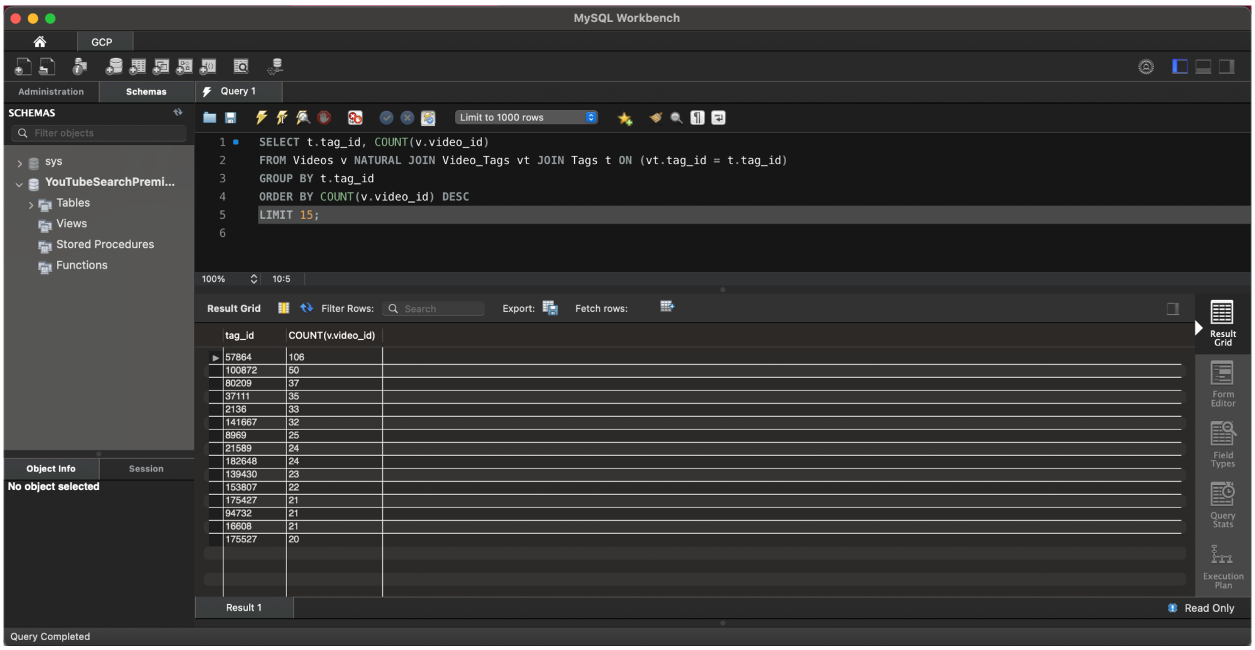
Query 1 – finding videos which either have more likes than the average number of likes or more views than the average number of views.

```
SELECT video_title
FROM Videos
WHERE like_count > (SELECT AVG(like_count) FROM Videos)
UNION
SELECT video_title
FROM Videos
WHERE view_count > (SELECT AVG(view_count) FROM Videos)
LIMIT 15;
```


MySQL Workbench
GCP
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
Object Info
Session
No object selected
Limit to 1000 rows
SELECT video_title
FROM Videos
WHERE like_count > (SELECT AVG(like_count) FROM Videos)
UNION
SELECT video_title
FROM Videos
WHERE view_count > (SELECT AVG(view_count) FROM Videos)
LIMIT 15;
100%
1:9
Result Grid
Filter Rows:
Search
Export:
video_title
Lapiz Conciente - 9 Dias
YoungBoy Never Broke Again - Kacey talk
Internet Money - Lemonade ft. Don Toliver, Gunna & Nav (Dir. by @_ColeBennett_)
Enola Holmes | Official Trailer | Netflix
Billie Eilish - my future (Live)
What Really Happened
Conan Gray - Heather (Official Music Video)
My Decaying Mind in Quarantine
Juice WRLD & The Weeknd - Smile (Official Video)
Jackson Wang & Galantis - Pretty Please (Official Music Video)
Suicide Squad: Kill the Justice League Official Teaser Trailer
GAME (Full Video) Shooter Kahlon | Sidhu Moose Wala | Hunny PK Films | Gold Media | 5911 Records
This is Goodbye
I ASKED HER TO BE MY GIRLFRIEND...
DJ Khaled ft. Drake - POPSTAR (Official Music Video - Starring Justin Bieber)
Result Grid
Form Editor
Field Types
Query Stats
Result 3
Read Only
Query Completed

Query 2 – finding most popular tags of trending YouTube videos

```
SELECT t.tag_id, COUNT(v.video_id)
FROM Videos v NATURAL JOIN Video_Tags vt JOIN Tags t ON
(vt.tag_id = t.tag_id)
GROUP BY t.tag_id
ORDER BY COUNT(v.video_id) DESC
LIMIT 15;
```

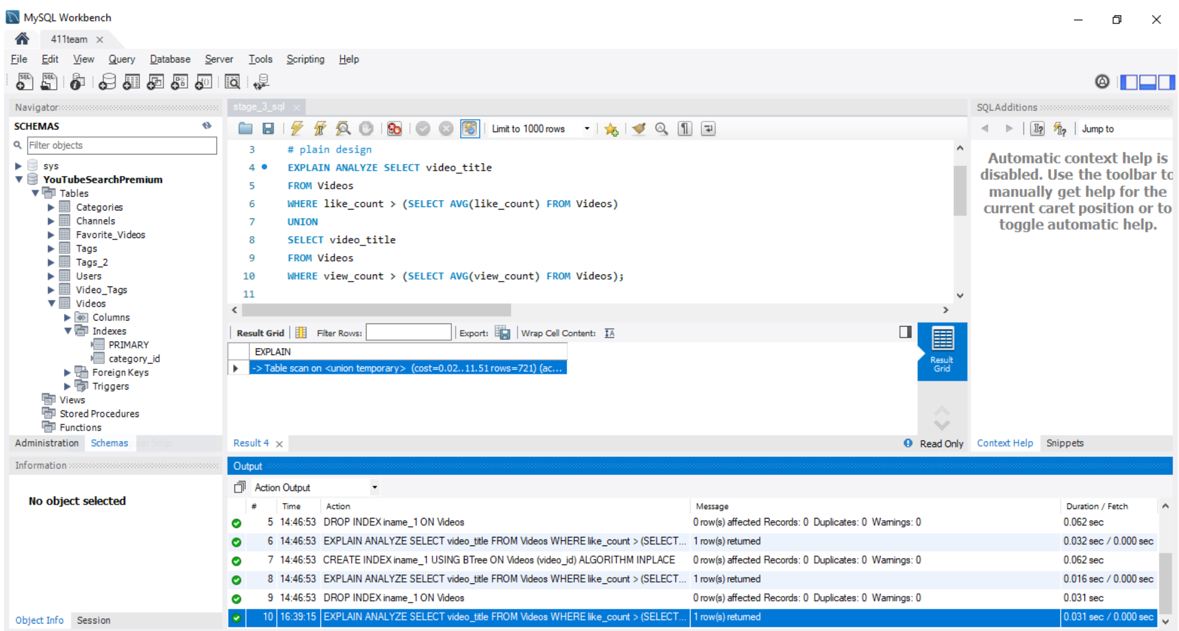


5) Indexing Design and Analysis for the advanced queries

Query 1

```
SELECT video_title
FROM Videos
WHERE like_count > (SELECT AVG(like_count) FROM Videos)
UNION
SELECT video_title
FROM Videos
WHERE view_count > (SELECT AVG(view_count) FROM Videos);
```

Default Indexing:

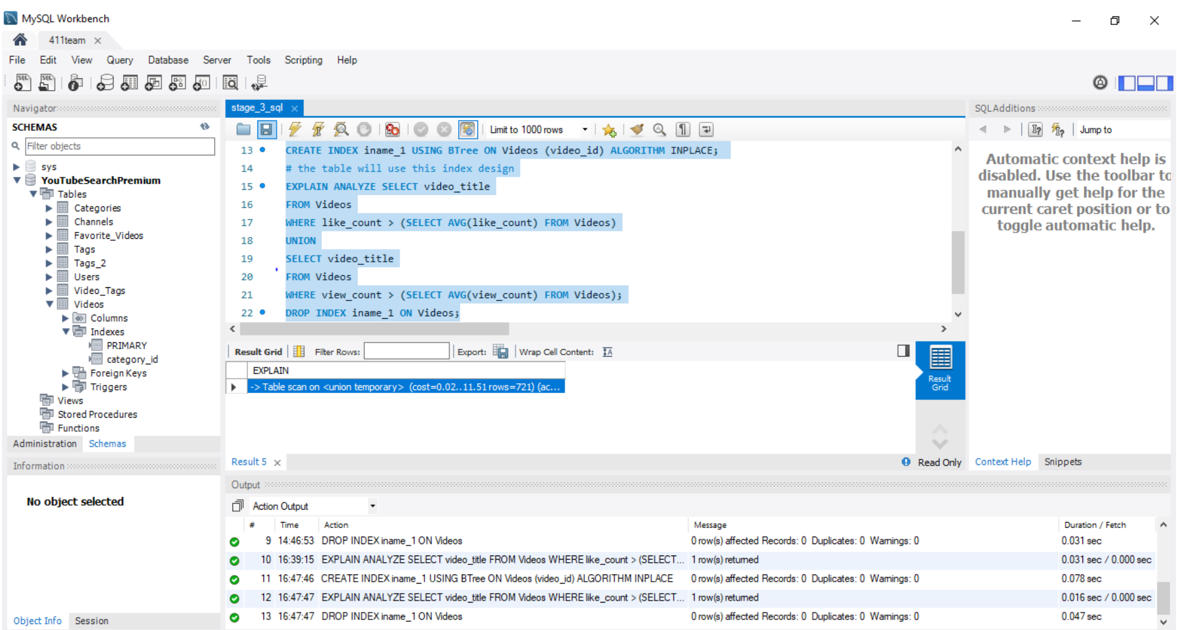



```
# EXPLAIN
-> Table scan on <union temporary>  (cost=0.02..11.51 rows=721) (actual
time=0.001..0.019 rows=268 loops=1)
    -> Union materialize with deduplication  (cost=156.27..167.76 rows=721)
(actual time=4.056..4.089 rows=268 loops=1)
        -> Filter: (Videos.like_count > (select #2))  (cost=42.06 rows=361)
(actual time=2.163..2.612 rows=206 loops=1)
            -> Table scan on Videos  (cost=42.06 rows=1082) (actual
time=0.692..1.021 rows=1049 loops=1)
            -> Select #2 (subquery in condition; run only once)
                -> Aggregate: avg(Videos.like_count)  (cost=222.40
rows=1082) (actual time=1.393..1.393 rows=1 loops=1)
```

```
                    -> Table scan on Videos  (cost=114.20 rows=1082)
(actual time=0.028..1.253 rows=1049 loops=1)
        -> Filter: (Videos.view_count > (select #4))  (cost=42.06 rows=361)
(actual time=0.677..1.101 rows=228 loops=1)
            -> Table scan on Videos  (cost=42.06 rows=1082) (actual
time=0.214..0.520 rows=1049 loops=1)
            -> Select #4 (subquery in condition; run only once)
                -> Aggregate: avg(Videos.view_count)  (cost=222.40
rows=1082) (actual time=0.392..0.392 rows=1 loops=1)
                    -> Table scan on Videos  (cost=114.20 rows=1082)
(actual time=0.023..0.290 rows=1049 loops=1)
```

Duration: 0.031 sec / Fetch: 0.000 sec

Design 1: B+ Tree Index of `Videos.video_id` with in-place algorithm

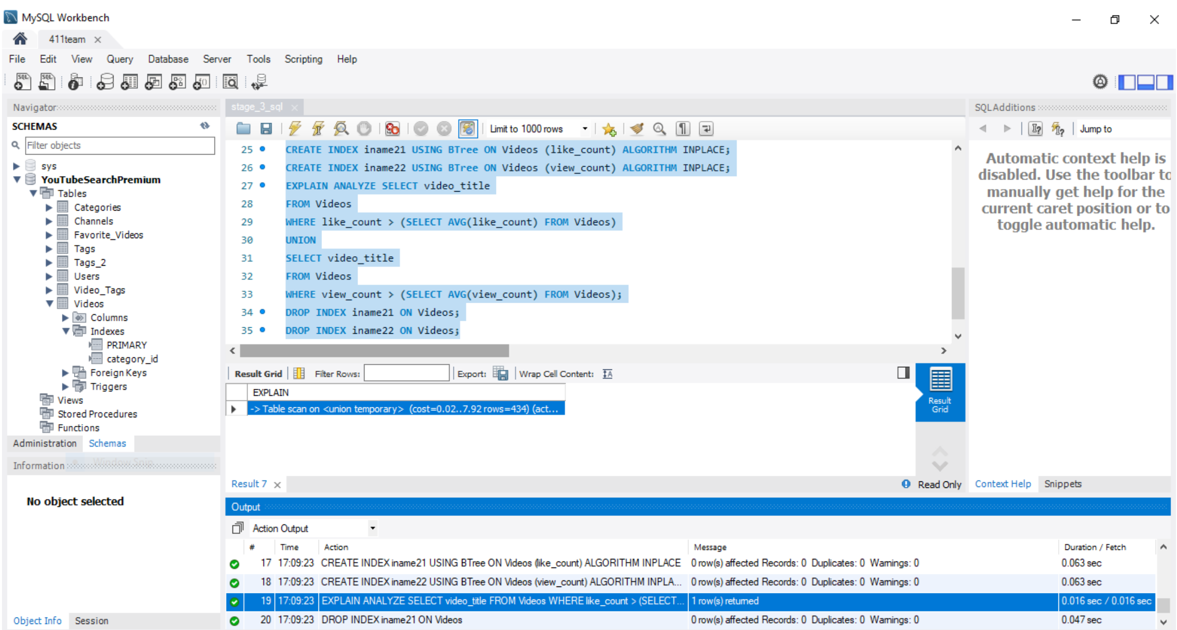



```
# EXPLAIN
-> Table scan on <union temporary>  (cost=0.02..11.51 rows=721) (actual
time=0.001..0.021 rows=268 loops=1)
    -> Union materialize with deduplication  (cost=156.27..167.76 rows=721)
(actual time=2.840..2.875 rows=268 loops=1)
        -> Filter: (Videos.like_count > (select #2))  (cost=42.06 rows=361)
(actual time=1.238..1.679 rows=206 loops=1)
            -> Table scan on Videos  (cost=42.06 rows=1082) (actual
time=0.122..0.455 rows=1049 loops=1)
            -> Select #2 (subquery in condition; run only once)
                -> Aggregate: avg(Videos.like_count)  (cost=222.40
rows=1082) (actual time=1.095..1.096 rows=1 loops=1)
                    -> Table scan on Videos  (cost=114.20 rows=1082)
```

```
(actual time=0.634..0.979 rows=1049 loops=1)
        -> Filter: (Videos.view_count > (select #4))  (cost=42.06 rows=361)
(actual time=0.449..0.867 rows=228 loops=1)
            -> Table scan on Videos  (cost=42.06 rows=1082) (actual
time=0.032..0.350 rows=1049 loops=1)
            -> Select #4 (subquery in condition; run only once)
                -> Aggregate: avg(Videos.view_count)  (cost=222.40
rows=1082) (actual time=0.408..0.408 rows=1 loops=1)
                    -> Table scan on Videos  (cost=114.20 rows=1082)
(actual time=0.022..0.296 rows=1049 loops=1)
```

Duration: 0.016 sec / Fetch: 0.000 sec

Design 2: B+ Trees Index of `Videos.view_count` and `Videos.like_count`, both with in-place algorithms

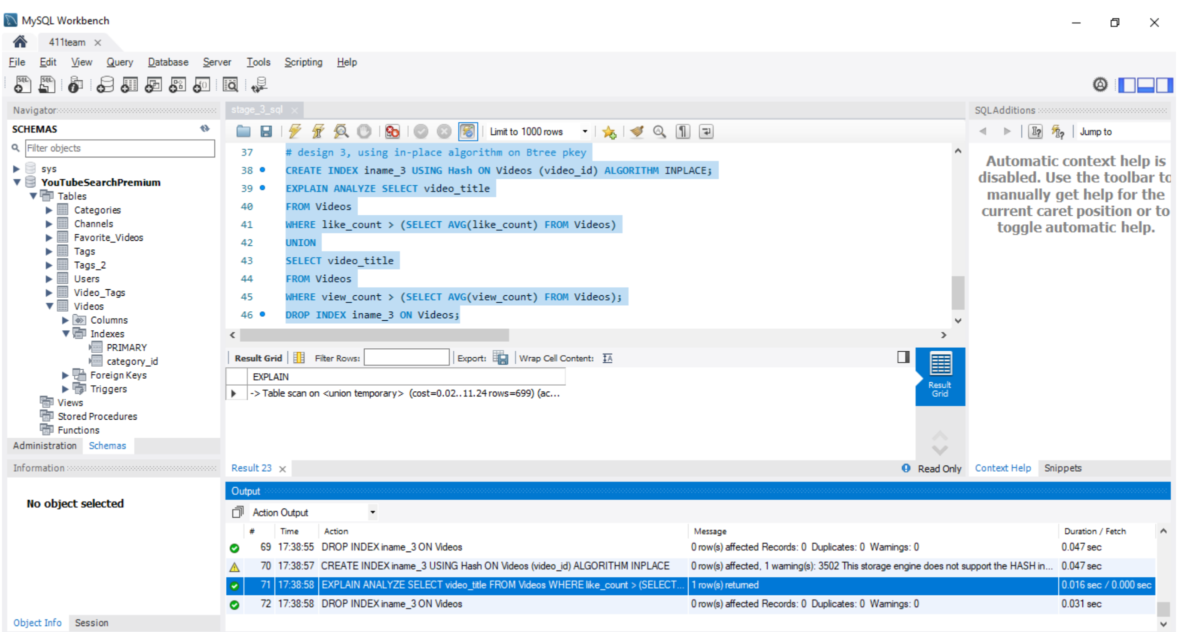



```
# EXPLAIN
-> Table scan on <union temporary>  (cost=0.02..7.92 rows=434) (actual
time=0.002..0.019 rows=268 loops=1)
    -> Union materialize with deduplication  (cost=239.24..247.15 rows=434)
(actual time=6.396..6.429 rows=268 loops=1)
        -> Filter: (Videos.like_count > (select #2))  (cost=92.96 rows=206)
(actual time=0.764..3.461 rows=206 loops=1)
            -> Index range scan on Videos using iname21  (cost=92.96
rows=206) (actual time=0.759..3.425 rows=206 loops=1)
            -> Select #2 (subquery in condition; run only once)
                -> Aggregate: avg(Videos.like_count)  (cost=222.40
rows=1082) (actual time=0.346..0.346 rows=1 loops=1)
```

```
                    -> Index scan on Videos using iname21  (cost=114.20
rows=1082) (actual time=0.041..0.246 rows=1049 loops=1)
        -> Filter: (Videos.view_count > (select #4))  (cost=102.86
rows=228) (actual time=2.254..2.586 rows=228 loops=1)
            -> Index range scan on Videos using iname22  (cost=102.86
rows=228) (actual time=2.250..2.550 rows=228 loops=1)
            -> Select #4 (subquery in condition; run only once)
                -> Aggregate: avg(Videos.view_count)  (cost=222.40
rows=1082) (actual time=0.322..0.322 rows=1 loops=1)
                    -> Index scan on Videos using iname22  (cost=114.20
rows=1082) (actual time=0.029..0.213 rows=1049 loops=1)
```

Duration: 0.016 sec / Fetch: 0.016 sec

Design 3: Hash Table Index of `Videos.video_id` with in-place algorithm




```
# EXPLAIN
-> Table scan on <union temporary>  (cost=0.02..11.24 rows=699) (actual
time=0.001..0.019 rows=268 loops=1)
    -> Union materialize with deduplication  (cost=149.37..160.59 rows=699)
(actual time=2.091..2.124 rows=268 loops=1)
        -> Filter: (Videos.like_count > (select #2))  (cost=39.71 rows=350)
(actual time=0.444..0.963 rows=206 loops=1)
            -> Table scan on Videos  (cost=39.71 rows=1049) (actual
time=0.046..0.453 rows=1049 loops=1)
            -> Select #2 (subquery in condition; run only once)
                -> Aggregate: avg(Videos.like_count)  (cost=214.55
rows=1049) (actual time=0.385..0.385 rows=1 loops=1)
```

```
                    -> Table scan on Videos  (cost=109.65 rows=1049)
(actual time=0.018..0.289 rows=1049 loops=1)
        -> Filter: (Videos.view_count > (select #4))  (cost=39.71 rows=350)
(actual time=0.408..0.827 rows=228 loops=1)
            -> Table scan on Videos  (cost=39.71 rows=1049) (actual
time=0.025..0.339 rows=1049 loops=1)
            -> Select #4 (subquery in condition; run only once)
                -> Aggregate: avg(Videos.view_count)  (cost=214.55
rows=1049) (actual time=0.376..0.376 rows=1 loops=1)
                    -> Table scan on Videos  (cost=109.65 rows=1049)
(actual time=0.018..0.273 rows=1049 loops=1)
```

Duration: 0.016 sec / Fetch: 0.000 sec

Analysis: The default indexing executes the query around 31 milliseconds. When using the in-place algorithm option, the execution time is halved to 16 milliseconds, regardless of using B+ Tree or hashing as the indexing implementation.

One reason to explain this in-place advantage is our query objective is that COPY algorithm would generate overhead undo/redo logging statements for the query, and not having pre-sorted secondary indices (according to MySQL documentation https://dev.mysql.com/doc/refman/8.0/en/innodb-online-ddl-operations.html), Even though the `INPLACE` algorithm still requires copying to a clustered indexing structure, not having these extra tasks resulted in a faster query.

Also, one key difference between indexing on primary key (Design 1) and indexing on the direct searching criteria (Design 2) is that primary key is unique and naturally clustered, but other columns such as `view_count` or `like_count` do not have these properties. Even though Design 2 indexed `view_count` and `like_count` directly, the unclustered nature hindered the advantage of direct access, resulting in on par querying efficiency as compared to Design 1.

Lastly, the hashing attempt. Google Cloud Platform uses InnoDB to support MySQL queries, and the hashing implementation of indexing is not possible by design. The remedy is to use the `storage engine default` which uses clustered primary key and the design of adaptive hashing, which has similar performance to a B+ tree indexing design.

Our group will choose Design 1 for its simplicity (no overhead computations) and straightforwardness directly from the primary keys. The drawbacks of Design 2 is that the trick of indexing the selection criteria does not improve as much as we would expect. The folly of design #3 is that the default engine on GCP is not really using a hash table at all, due to systematic memory optimization issues.

Query 2:

```
SELECT t.tag_id, COUNT(v.video_id)
FROM Videos v NATURAL JOIN Video_Tags vt JOIN Tags t ON
(vt.tag_id = t.tag_id)
GROUP BY t.tag_id
ORDER BY COUNT(v.video_id) DESC;
```

Default:

```
-> Sort: `COUNT(v.video_id)` DESC  (actual time=60.924..61.788 rows=14562
loops=1)
    -> Table scan on <temporary>  (actual time=0.001..0.671 rows=14562
loops=1)
        -> Aggregate using temporary table  (actual time=53.108..54.641
rows=14562 loops=1)
            -> Nested loop inner join  (cost=9236.50 rows=18095) (actual
time=0.071..42.589 rows=21041 loops=1)
                -> Nested loop inner join  (cost=2903.12 rows=18095)
(actual time=0.062..12.527 rows=21041 loops=1)
                    -> Index scan on v using category_id  (cost=114.20
rows=1082) (actual time=0.040..0.340 rows=1049 loops=1)
                    -> Index lookup on vt using PRIMARY
(video_id=v.video_id)  (cost=0.91 rows=17) (actual time=0.005..0.010
rows=20 loops=1049)
                -> Single-row index lookup on t using PRIMARY
(tag_id=vt.tag_id)  (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1
loops=21041)
```

Duration: 0.078 s

Design 1: Index on `Videos.video_id`, `Video_Tags.tag_id`, `Tags.tag_id`

```
USE YouTubeSearchPremium;

CREATE INDEX idx_video_tags_tag_id ON Video_Tags(tag_id);
CREATE INDEX idx_videos_video_id ON Videos(video_id);
CREATE INDEX idx_tags_tag_id ON Tags(tag_id);

EXPLAIN ANALYZE SELECT t.tag_id, COUNT(v.video_id)
FROM Videos v NATURAL JOIN Video_Tags vt JOIN Tags t ON (vt.tag_id = t.tag_id)
GROUP BY t.tag_id
ORDER BY COUNT(v.video_id) DESC;
```

```
-> Sort: `COUNT(v.video_id)` DESC  (actual time=63.321..64.139 rows=14562
loops=1)
    -> Table scan on <temporary>  (actual time=0.002..0.668 rows=14562
loops=1)
        -> Aggregate using temporary table  (actual time=55.550..57.089
rows=14562 loops=1)
            -> Nested loop inner join  (cost=9236.50 rows=18095) (actual
time=0.088..43.390 rows=21041 loops=1)
                -> Nested loop inner join  (cost=2903.12 rows=18095)
(actual time=0.078..12.748 rows=21041 loops=1)
                    -> Index scan on v using category_id  (cost=114.20
rows=1082) (actual time=0.053..0.393 rows=1049 loops=1)
                    -> Index lookup on vt using PRIMARY
(video_id=v.video_id)  (cost=0.91 rows=17) (actual time=0.005..0.010
rows=20 loops=1049)
                -> Single-row index lookup on t using PRIMARY
(tag_id=vt.tag_id)  (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1
loops=21041)
```

Duration: 0.078 s

Design 2: (Hash Table index on Video_Tags.tag_id and Video_Tags.video_id)

```sql
USE YouTubeSearchPremium;

CREATE INDEX idx_video_tags_tag_id_video_id USING hash ON Video_Tags(tag_id, video_id);

EXPLAIN ANALYZE SELECT t.tag_id, COUNT(v.video_id)
FROM Videos v NATURAL JOIN Video_Tags vt JOIN Tags t ON (vt.tag_id = t.tag_id)
GROUP BY t.tag_id
ORDER BY COUNT(v.video_id) DESC;


```

```
-> Sort: `COUNT(v.video_id)` DESC  (actual time=55.713..56.516 rows=14562
loops=1)
    -> Table scan on <temporary>  (actual time=0.001..0.661 rows=14562
loops=1)
        -> Aggregate using temporary table  (actual time=50.087..51.614
rows=14562 loops=1)
            -> Nested loop inner join  (cost=9236.50 rows=18095) (actual
time=0.083..40.775 rows=21041 loops=1)
                -> Nested loop inner join  (cost=2903.12 rows=18095)
(actual time=0.074..12.048 rows=21041 loops=1)
                    -> Index scan on v using category_id  (cost=114.20
rows=1082) (actual time=0.049..0.323 rows=1049 loops=1)
                    -> Index lookup on vt using PRIMARY
(video_id=v.video_id)  (cost=0.91 rows=17) (actual time=0.005..0.010
rows=20 loops=1049)
                -> Single-row index lookup on t using PRIMARY
(tag_id=vt.tag_id)  (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1
loops=21041)
```

```
Duration: 0.078 s
```

Design 3: Index of `Videos.video_id` and `Video_Tags.video_id`

```
USE YouTubeSearchPremium;

CREATE INDEX idx_videos_video_id ON Videos(video_id);
CREATE INDEX idx_video_tags_video_id ON Video_Tags(video_id);

EXPLAIN ANALYZE SELECT t.tag_id, COUNT(v.video_id)
FROM Videos v NATURAL JOIN Video_Tags vt JOIN Tags t ON (vt.tag_id = t.tag_id)
GROUP BY t.tag_id
ORDER BY COUNT(v.video_id) DESC;
```

```
-> Sort: `COUNT(v.video_id)` DESC  (actual time=55.441..56.235 rows=14562
loops=1)
    -> Table scan on <temporary>  (actual time=0.002..0.642 rows=14562
loops=1)
        -> Aggregate using temporary table  (actual time=49.842..51.324
rows=14562 loops=1)
            -> Nested loop inner join  (cost=8953.72 rows=17543) (actual
time=0.075..40.313 rows=21041 loops=1)
                -> Nested loop inner join  (cost=2813.51 rows=17543)
(actual time=0.065..11.753 rows=21041 loops=1)
                    -> Index scan on v using category_id  (cost=109.65
rows=1049) (actual time=0.040..0.300 rows=1049 loops=1)
                    -> Index lookup on vt using PRIMARY
(video_id=v.video_id)  (cost=0.91 rows=17) (actual time=0.005..0.010
rows=20 loops=1049)
                -> Single-row index lookup on t using PRIMARY
(tag_id=vt.tag_id)  (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1
loops=21041
)
Duration: 0.078 s
```

Analysis: Of the four indexing schemes, the two best were designs 2 and 3. Looking at the output from `EXPLAIN ANALYZE`, we can see that both take around 55-56 milliseconds to complete, while the default indexing and design 1 take around 60-64 milliseconds. I believe that it is improved due to the fact that the fields we created the indexes on are being used during the joins. Design 2 makes the `JOIN` between `Video_Tags` and `Tags` more efficient, while Design 3 makes the `NATURAL JOIN` on `Videos` and `Video_Tags` faster.