CS411_Team072_Stage3 Submission

Our database implements eight main tables: Professors, Departments, Users, GeneralCourse, SectionAttributes, GPAHistory, Teaches, and UserFeedback. Five of these tables contain more than 1000 rows: Professors, GeneralCourse, SectionAttributes, GPAHistory, and Teaches. The DDL commands for making and linking these tables are included in the repository in the src/db_setup.ddl file. All of the tables, excluding Users and UserFeedback, use real data. One thing we would like to note is that Departments was not included in our previous documents or submissions, but we added this table because our data didn't have a standard format for the department. We standardized the format by using DepartmentCode for everything and have this table to get the department name from the code easily.

Data sources

Professors: Come from a page with most of the faculty

Departments: Comes from GeneralCourse

Users: Generated by us

GeneralCourse: Scraped all the courses starting from here for Fall 2023. Example page we scrape GeneralCourse info from

SectionAttributes: Scraped from the "sections" portion of a GeneralCourse .xml page. Example page, we scrape the SectionAttributes info from

To clarify further on *GeneralCourse* and *SectionAttributes*, we basically follow the chain of .xml files that, starting from Semester, give you all departments, courses, sections, etc. See the create_course_csv.py file in the data_parsing folder in the github to see how we did this.

GPAHistory: Comes from some of the raw data in Wade's dataset

Teaches: Generated with the Professors and SectionAttributes .csv files

UserFeedback: Generated by us

See the screenshots below for statistics on our tables and some example entries (hot off the GCP console).

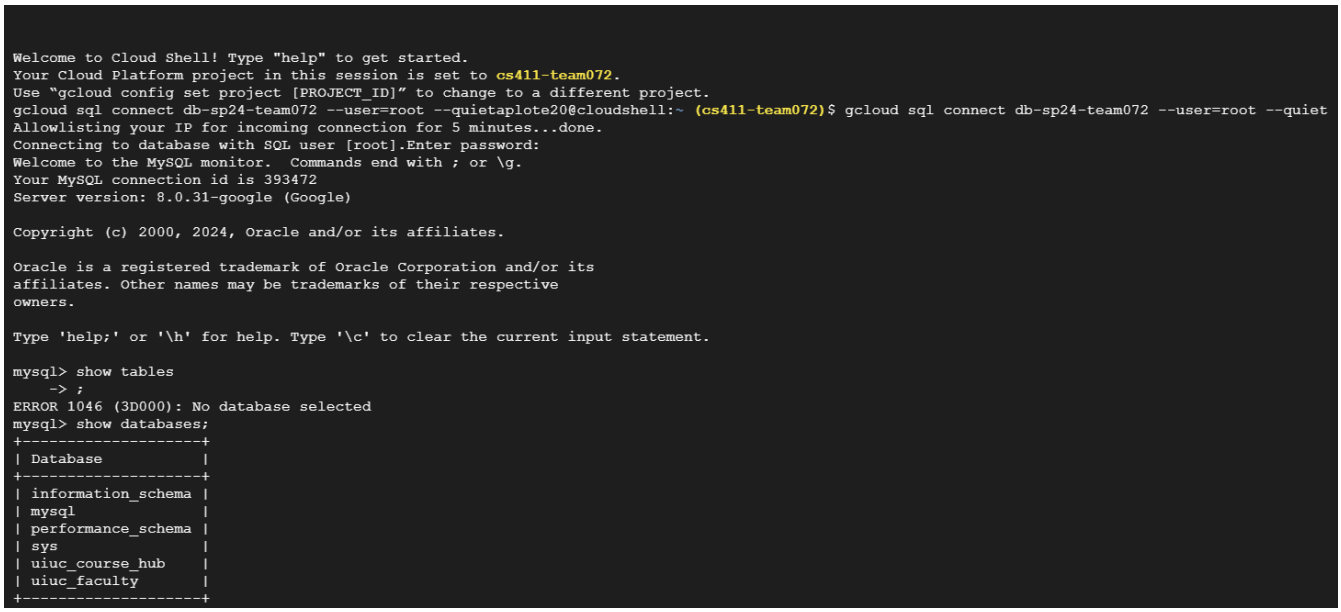


Figure 1: GCP Connection and databases. Our database is uiuc_course_hub

DDL Statements for our Tables (Figure 2-5)

```
# DDL for team072 database for CS 411 SP24

CREATE TABLE IF NOT EXISTS Professors(
    NetId                   VARCHAR(255) PRIMARY KEY,
    LastName                VARCHAR(255),
    FirstName               VARCHAR(255),
    LastNameFirstIni        VARCHAR(255),
    DepartmentCode          VARCHAR(10)
);

CREATE TABLE IF NOT EXISTS Departments(
    DepartmentCode          VARCHAR(10) PRIMARY KEY,
    Department              VARCHAR(255)
);

CREATE TABLE IF NOT EXISTS Users(
    Email                   VARCHAR(255) PRIMARY KEY,
    Password                VARCHAR(255),
    LastName                VARCHAR(255),
    FirstName               VARCHAR(255)
);
```

Figure 2 : DDL Commands

```sql
CREATE TABLE IF NOT EXISTS GeneralCourse(
    CourseNum               INT,
    CourseName              VARCHAR(255),
    CreditHours             VARCHAR(255),
    Description             VARCHAR(16384),
    GenEdAtrrib             VARCHAR(255),
    DepartmentCode          VARCHAR(10),
    Department              VARCHAR(255),
    PRIMARY KEY (CourseNum, DepartmentCode)
);

CREATE TABLE IF NOT EXISTS SectionAttributes(
    CourseNum               INT,
    CRN                     INT,
    Section                 VARCHAR(10),
    SectionType             VARCHAR(255),
    Professors              VARCHAR(1024),
    DepartmentCode          VARCHAR(10),
    Department              VARCHAR(255),
    Year                    INT,
    Semester                VARCHAR(16),
    FOREIGN KEY (CourseNum, DepartmentCode) REFERENCES GeneralCourse(CourseNum, DepartmentCode) ON DELETE CASCADE ON UPDATE CASCADE,
    PRIMARY KEY (CRN, Semester, Year)
);
```

Figure 3 : DDL Commands

```sql
CREATE TABLE IF NOT EXISTS GPAHistory(
    DepartmentCode          VARCHAR(10),
    CourseNum               INT,
    CRN                     INT,
    CourseName              VARCHAR(255),
    Sched_Type              VARCHAR(10),
    A_plus                  INT,
    A_stan                  INT,
    A_minus                 INT,
    B_plus                  INT,
    B_stan                  INT,
    B_minus                 INT,
    C_plus                  INT,
    C_stan                  INT,
    C_minus                 INT,
    D_plus                  INT,
    D_stan                  INT,
    D_minus                 INT,
    F_stan                  INT,
    Avg_Grade               DECIMAL(10,2),
    Instructor              VARCHAR(255),
    Semester                VARCHAR(16),
    Year                    INT,
    FOREIGN KEY (CourseNum, DepartmentCode) REFERENCES GeneralCourse(CourseNum, DepartmentCode) ON DELETE CASCADE ON UPDATE CASCADE,
    PRIMARY KEY (CRN, Semester, Year)
);

CREATE TABLE IF NOT EXISTS Teaches(
    CRN                     INT,
    Semester                VARCHAR(16),
    Year                    INT,
    NetId                   VARCHAR(255),
    FOREIGN KEY (CRN, Semester, Year) REFERENCES SectionAttributes(CRN, Semester, Year) ON DELETE CASCADE ON UPDATE CASCADE,
    FOREIGN KEY (NetId) REFERENCES Professors(NetId) ON DELETE CASCADE ON UPDATE CASCADE,
    PRIMARY KEY (CRN, Semester, Year, NetId)
);
```

Figure 4: DDL Commands

```
CREATE TABLE IF NOT EXISTS UserFeedback(
    FeedbackId              VARCHAR(255) PRIMARY KEY,
    Email                   VARCHAR(255),
    Year                    INT,
    CRN                     INT,
    Semester                VARCHAR(16),
    Testimony               VARCHAR(16384),
    Rating                  DECIMAL(10,2),
    Difficulty              DECIMAL(10,2),
    TimeCommit              DECIMAL(10,2),
    Time_stamp              TIMESTAMP,
    FOREIGN KEY (Email) REFERENCES Users(Email) ON DELETE CASCADE ON UPDATE CASCADE,
    FOREIGN KEY (CRN, Semester, Year) REFERENCES SectionAttributes(CRN, Semester, Year) ON DELETE CASCADE ON UPDATE CASCADE
);
```

Figure 5 : DDL Commands

```
mysql> SELECT COUNT(*) FROM GPAHistory;
+----------+
| COUNT(*) |
+----------+
|    17294 |
+----------+
1 row in set (0.10 sec)

mysql> SELECT COUNT(*) FROM GeneralCourse;
+----------+
| COUNT(*) |
+----------+
|     4497 |
+----------+
1 row in set (0.46 sec)

mysql> SELECT COUNT(*) FROM Professors;
+----------+
| COUNT(*) |
+----------+
|     1643 |
+----------+
1 row in set (0.16 sec)

mysql> SELECT COUNT(*) FROM SectionAttributes;
+----------+
| COUNT(*) |
+----------+
|    12040 |
+----------+
1 row in set (0.11 sec)

mysql> SELECT COUNT(*) FROM Teaches
    -> ;
+----------+
| COUNT(*) |
+----------+
|     2979 |
```

Figure 6: Tables with more than 1000 rows

Queries

1. List of professors who teach 400 and 500 level courses with avg_grade greater than 3.5, group by department name

```
Select p.FirstName, p.LastName, p.Netid, g.CourseNum, d.Department, g.CourseName, g.Avg_grade
from Professors p join Teaches t on t.NetId=p.NetId
Join GPAHistory g on g.CRN=t.CRN
Join Departments d on d.DepartmentCode=g.DepartmentCode
Where g.CourseNum like "4%" or g.CourseNum like "5%"
Group by d.Department, p.FirstName, p.LastName, p.Netid, g.CourseNum, g.CourseName, g.Avg_grade
Having avg(g.avg_grade) >3.5
Order by g.avg_grade desc, d.department asc
limit 15;
```

Output:

```
Database changed
mysql> Select p.FirstName, p.LastName, p.Netid, g.CourseNum, d.Department, g.CourseName, g.Avg_grade from Professors p join Teaches t on t.NetId=p.NetId  Join GPAHistory g on g.CRN=t
s d on d.DepartmentCode=g.DepartmentCode Where g.CourseNum like "4%" or g.CourseNum like "5%" Group by d.Department, p.FirstName, p.LastName, p.Netid, g.CourseNum, g.CourseName, g.Av
.avg_grade) >3.5 Order by g.avg_grade desc, d.department asc limit 15;
+-----------------+-----------------+---------------------+-----------+-----------------------------------------+-------------------------------+-----------+
| FirstName       | LastName        | Netid               | CourseNum | Department                              | CourseName                    | Avg_grade |
+-----------------+-----------------+---------------------+-----------+-----------------------------------------+-------------------------------+-----------+
| Mimi Thi        | Nguyen          | mimin@illinois.edu  |       504 | Accountancy                             | Auditing                      |      3.98 |
| Lena            | Song            | lenasong@illinois.edu |       498 | Bioengineering                          | Immunoengineering             |      3.98 |
| Grace           | Giorgio         | giorgio@illinois.edu  |       432 | Communication                           | Gender Communication          |      3.98 |
| Yuan-Xiang      | Pan             | yxpan@illinois.edu  |       422 | Food Science and Human Nutrition        | Intro Personalized Nutrition  |      3.98 |
| Bo              | Zhang           | bozhang3@illinois.edu |       475 | Psychology                              | Personnel Psych               |      3.98 |
| Hans Friedrich  | Koehn           | hkoehn@illinois.edu |       506 | Psychology                              | Statistical Methods I         |      3.98 |
| Johnell L       | Bentz           | jbentz@illinois.edu |       514 | Special Education                       | Equity Issues in Spec Educ    |      3.98 |
| Armanda         | Formigao Gameiro | armanda@illinois.edu |       518 | Accountancy                             | Financial Statement Fraud     |      3.97 |
| Jamie Lee Berry | Putnam          | jamielb3@illinois.edu |       518 | Accountancy                             | Financial Statement Fraud     |      3.97 |
| John A          | Juvik           | juvik@illinois.edu  |       455 | Biochemistry                            | Technqs Biochem & Biotech     |      3.97 |
| Moonsub         | Shim            | mshim@illinois.edu  |       550 | Business Administration                 | Business Practicum            |      3.97 |
| Tina H          | Huang           | thhuang@illinois.edu |       500 | Education Policy, Organization and Leadership | EdD Essentials Seminar        |      3.97 |
| Laura Jean      | Mattie          | ljhahn@illinois.edu |       515 | Information Sciences                    | Information Modeling          |      3.97 |
| Cheryl          | Light Shriner   | slight@illinois.edu |       470 | Special Education                       | Learning Environments I       |      3.97 |
| Chengxiang      | Zhai            | czhai@illinois.edu  |       410 | Computer Science                        | Text Information Systems      |      3.96 |
+-----------------+-----------------+---------------------+-----------+-----------------------------------------+-------------------------------+-----------+
15 rows in set (0.03 sec)
```

Figure 7 : Query 1

2. Ranking of departments based on their academic performance, represented by the average GPA of courses offered, and the breadth of their academic offerings, indicated by the number of distinct courses available. Departments with higher average GPAs and more course offerings are considered to be of higher academic standing.

```
With DepartmentGPA AS (
    Select DepartmentCode, AVG(Avg_Grade) AS AverageGPA
    From GPAHistory Group By DepartmentCode
), DepartmentCourses AS (
    Select DepartmentCode, Count(DISTINCT CourseNum) AS CourseCount
    From GeneralCourse Group By DepartmentCode
), DepartmentRanking AS (
    Select
        d.DepartmentCode, d.Department,
        IFNULL(g.AverageGPA, 0) AS AvgGPA,
        IFNULL(c.CourseCount, 0) AS CourseCount,
        (IFNULL(g.AverageGPA, 0) * 0.7 + IFNULL(c.CourseCount, 0) * 0.3) AS CombinedScore
    From Departments d
    LEFT JOIN DepartmentGPA g ON d.DepartmentCode = g.DepartmentCode
    LEFT JOIN DepartmentCourses c ON d.DepartmentCode = c.DepartmentCode
)
Select DepartmentCode,Department,AvgGPA,CourseCount,CombinedScore,
RANK() OVER (ORDER BY CombinedScore DESC) AS Ranking
From DepartmentRanking
Order By CombinedScore DESC, DepartmentCode
LIMIT 15;
```

Metrics:

Average GPA: Calculated from the GPAHistory table, representing the academic quality.
Course Offerings: The count of distinct courses in the GeneralCourse table, representing the breadth of the department's offerings.
Combined Score: A weighted score that considers both the average GPA and the number of courses to rank departments.

Output:

```
    -> LIMIT 15;
+----------------+-------------------------------------+----------+-------------+---------------+---------+
| DepartmentCode | Department                          | AvgGPA   | CourseCount | CombinedScore | Ranking |
+----------------+-------------------------------------+----------+-------------+---------------+---------+
| MUSC           | Music Lessons and Ensembles         | 3.902500 |         142 |    45.3317500 |       1 |
| MUS            | Music                               | 3.597831 |         108 |    34.9184817 |       2 |
| IS             | Information Sciences                | 3.761738 |         103 |    33.5332166 |       3 |
| ECE            | Electrical and Computer Engineering | 3.240278 |         101 |    32.5681946 |       4 |
| CS             | Computer Science                    | 3.512753 |          89 |    29.1589271 |       5 |
| THEA           | Theatre                             | 3.543867 |          84 |    27.6807069 |       6 |
| CLE            | Clinical Sciences and Engineering   | 0.000000 |          89 |    26.7000000 |       7 |
| BADM           | Business Administration             | 3.689046 |          77 |    25.6823322 |       8 |
| MATH           | Mathematics                         | 3.114456 |          76 |    24.9801192 |       9 |
| PSYC           | Psychology                          | 3.251376 |          67 |    22.3759632 |      10 |
| FIN            | Finance                             | 3.492004 |          65 |    21.9444028 |      11 |
| CEE            | Civil and Environmental Engineering | 3.380821 |          61 |    20.6665747 |      12 |
| ENGL           | English                             | 3.547385 |          60 |    20.4831695 |      13 |
| CHEM           | Chemistry                           | 3.063567 |          58 |    19.5444969 |      14 |
| FSHN           | Food Science and Human Nutrition    | 3.644809 |          56 |    19.3513663 |      15 |
+----------------+-------------------------------------+----------+-------------+---------------+---------+
15 rows in set (0.17 sec)
```

Figure 8 : Query 2

3. List of 1 Credit course offered by the CS department having avg_grade > 3.9

```
Select distinct c.CourseNum, c.CourseName, c.CreditHours, g.Semester, g.Year, g. Avg_grade
from GeneralCourse c join GPAHistory g on g.CourseNum=c.CourseNum
Where c.CreditHours='1 hours.' and g.Year in (2022,2023) AND g.Semester LIKE 'Sp%'
Group by c.CourseNum, c.CourseName, c.CreditHours, g.Semester, g.Year, g. Avg_grade
Having g.Avg_grade >=3.9
Order by g.CourseNum desc Limit 15;
```

Output:

```
    -> LIMIT 15;
+-----------+-----------------------------------------------------+-------------+----------+------+-----------+
| CourseNum | CourseName                                          | CreditHours | Semester | Year | Avg_grade |
+-----------+-----------------------------------------------------+-------------+----------+------+-----------+
|       598 | Seminar                                             | 1 hours.    | Spring   | 2022 |      3.90 |
|       598 | Seminar                                             | 1 hours.    | Spring   | 2022 |      3.91 |
|       598 | Seminar                                             | 1 hours.    | Spring   | 2022 |      3.98 |
|       598 | Seminar                                             | 1 hours.    | Spring   | 2023 |      3.91 |
|       598 | Seminar                                             | 1 hours.    | Spring   | 2023 |      3.94 |
|       592 | Preparing Graduate Fellowships                      | 1 hours.    | Spring   | 2023 |      3.93 |
|       591 | Current Research in Geoscience                      | 1 hours.    | Spring   | 2023 |      3.95 |
|       591 | Engineering Advanced Seminar                        | 1 hours.    | Spring   | 2023 |      3.95 |
|       591 | Introductory Professional Development for Chemists  | 1 hours.    | Spring   | 2023 |      3.95 |
|       591 | Seminar                                             | 1 hours.    | Spring   | 2023 |      3.95 |
|       590 | Doctoral Research Seminar and Colloquium            | 1 hours.    | Spring   | 2022 |      3.92 |
|       590 | Doctoral Research Seminar and Colloquium            | 1 hours.    | Spring   | 2022 |      3.95 |
|       590 | Doctoral Research Seminar and Colloquium            | 1 hours.    | Spring   | 2022 |      3.97 |
|       590 | Doctoral Research Seminar and Colloquium            | 1 hours.    | Spring   | 2023 |      3.92 |
|       590 | Seminar                                             | 1 hours.    | Spring   | 2022 |      3.92 |
+-----------+-----------------------------------------------------+-------------+----------+------+-----------+
15 rows in set (0.06 sec)
```

Figure 9 : Query 3

4. List the Number of Courses offered by the CS and ECE departments with an avg_grade greater than or equal to 3.5 using Union.

```
SELECT g.DepartmentCode, c.CourseNum, c.CourseName, c.CreditHours, g.Semester, g.Avg_grade
FROM GeneralCourse c
JOIN GPAHistory g ON g.CourseNum = c.CourseNum
WHERE g.DepartmentCode = 'CS' AND g.CourseNum LIKE '5%' AND g.Avg_grade >= 3.5
GROUP BY g.DepartmentCode, c.CourseNum, c.CourseName, c.CreditHours, g.Semester, g.Avg_grade

UNION

SELECT g.DepartmentCode, c.CourseNum, c.CourseName, c.CreditHours, g.Semester, g.Avg_grade
FROM GeneralCourse c
JOIN GPAHistory g ON g.CourseNum = c.CourseNum
WHERE g.DepartmentCode = 'ECE' AND g.CourseNum LIKE '5%' AND g.Avg_grade >= 3.5
GROUP BY g.DepartmentCode, c.CourseNum, c.CourseName, c.CreditHours, g.Semester, g.Avg_grade

ORDER BY Semester
LIMIT 15;
```

Output:

DepartmentCode	CourseNum	CourseName	CreditHours	Semester	Avg_grade
CS	527	Advanced Vitamins and Minerals: Regulations of Metabolism	3 hours.	Fall	3.83
CS	527	Advanced Price Analysis	4 hours.	Fall	3.74
CS	527	Graduate Level Trombone	2 TO 5 hours.	Fall	3.83
CS	527	Geospatial Artificial Intelligence & Machine Learning	4 hours.	Fall	3.83
CS	527	Seminar in 18th C Literature	4 hours.	Fall	3.74
CS	527	Topics in Software Engineering	4 hours.	Fall	3.74
CS	527	Seminar in 18th C Literature	4 hours.	Fall	3.83
CS	527	Plasma Technology of Gaseous Electronics	4 hours.	Fall	3.83
CS	527	MSFE Professional Development	0 hours.	Fall	3.83
CS	527	System-On-Chip Design	4 hours.	Fall	3.83
CS	527	Advanced Regression Analysis	4 hours.	Fall	3.83
ECE	549	Asymptotic Methods	4 hours.	Fall	3.52
CS	527	System-On-Chip Design	4 hours.	Fall	3.74
CS	527	Parasitology/Epidemiology Sem	1 hours.	Fall	3.83
CS	527	Topics in Software Engineering	4 hours.	Fall	3.83

15 rows in set (0.03 sec)

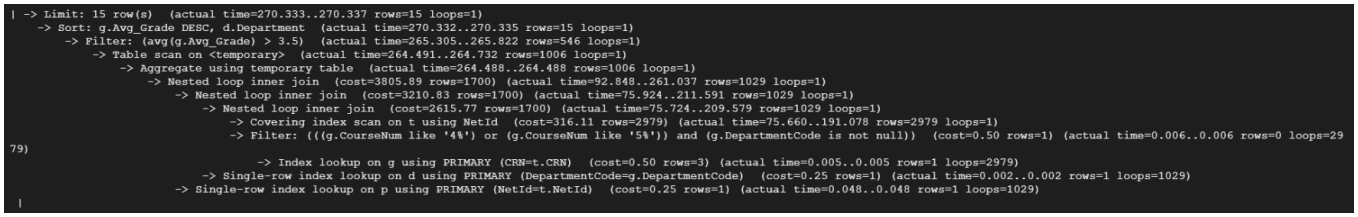
Figure 10 : Query 4

Indexing Analysis

Query 1

Indexing Analysis Report:
The initial query aims to identify professors who have taught courses with an average GPA greater than 3.5. These courses belong to departments and have course numbers starting with either '4' or '5'
(helping in assessing the performance of professors in teaching higher-level courses and their impact on students' academic performance)

On Running EXPLAIN ANALYZE on the first query following output was obtained:



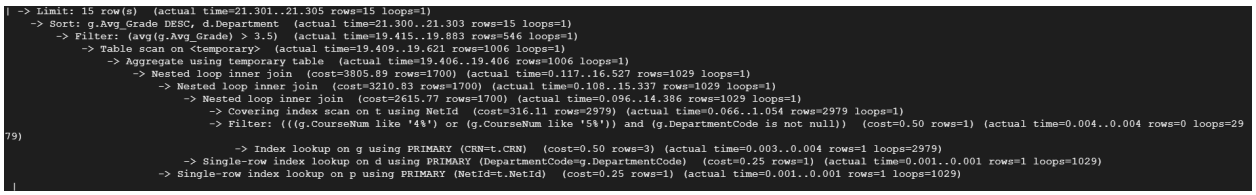
Nested loop inner join cost: 3805.89

<u>Indexing Design 1</u>

Indexing GPAHistory(Avg_grade) for this query:

```
CREATE INDEX idx_gpa_history_avg_grade ON GPAHistory(Avg_grade);
```

After running for GPAHistory(Avg_grade)



Observations / Analysis:

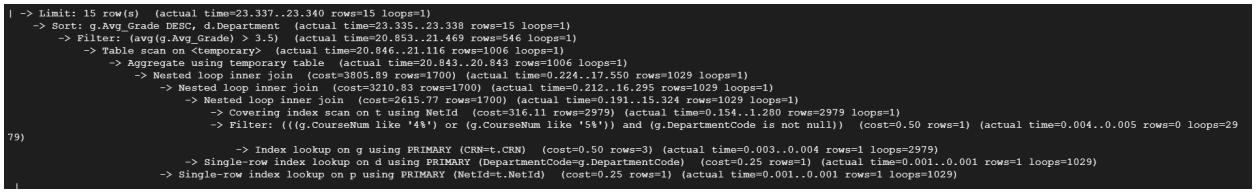
- Nested loop inner join cost: 3805.89
- The cost did not change for this indexing, likely because most of the cost comes from the joins on attributes that are already indexed as primary keys.

<u>Indexing Design 2</u>

Indexing GPAHistory(CourseNum) for this query

```
CREATE INDEX idx_gpa_history_course_num ON GPAHistory(CourseNum)
```

After running for GPAHistory(CourseNum)



Observations / Analysis:

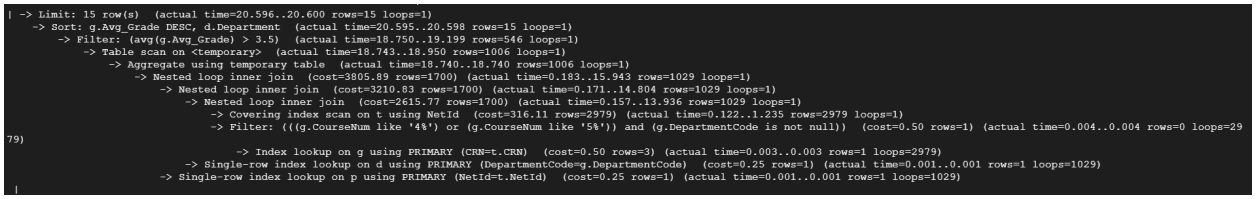
- Nested loop inner join cost: 3805.89
- The cost did not change for this indexing, likely because most of the cost comes from the joins on attributes that are already indexed as primary keys.

<u>Indexing Design 3</u>

Indexing GPAHistory(DepartmentCode) for this query:

```
CREATE INDEX idx_gpa_history_department_code ON GPAHistory(DepartmentCode);
```

After indexing GPAHistory(DepartmentCode)



Observations / Analysis:

- Nested loop inner join cost: 3805.89
- The cost did not change for this indexing, likely because most of the cost comes from the joins on attributes that are already indexed as primary keys.

Query 1 Final Analysis:

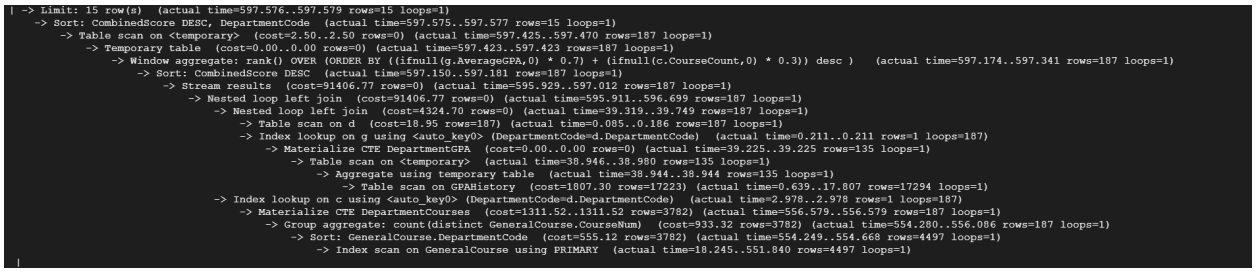
- None of our other indexing schemes helped decrease the cost
- We chose items that were in the GROUP BY portion of this query since the joins were on primary keys, but it did not seem to affect the performance in this case, likely because the GROUP BY didn't seem to have an affect on the cost with the primary keys also being included and used for the index lookups (seen in the screenshots).
- For simplicity, we will consider the original indexing the best.

<u>Query 2:</u>

Indexing Analysis Report:

Initially the query aims to rank departments based on their academic performance (average GPA of courses) and breadth of academic offerings (number of distinct courses), reflecting departmental academic standing.

On Running EXPLAIN ANALYZE on the second query following output was obtained:



Stream results cost = 91,406.77

<u>Indexing Design 1</u>

Indexing CourseNum in the GeneralCourse table::

```
CREATE INDEX idx_general_course_course_num ON GeneralCourse(CourseNum);
```

After indexing CourseNum

```
| -> Limit: 15 row(s)  (actual time=24.881..24.883 rows=15 loops=1)
    -> Sort: CombinedScore DESC, DepartmentCode  (actual time=24.880..24.881 rows=15 loops=1)
        -> Table scan on <temporary>  (cost=2.50..2.50 rows=0) (actual time=24.773..24.804 rows=187 loops=1)
            -> Temporary table  (cost=0.00..0.00 rows=0) (actual time=24.772..24.772 rows=187 loops=1)
                -> Window aggregate: rank() OVER (ORDER BY ((ifnull(g.AverageGPA,0) * 0.7) + (ifnull(c.CourseCount,0) * 0.3)) desc )  (actual time=24.611..24.717 rows=187 loops=1)
                    -> Sort: CombinedScore DESC  (actual time=24.602..24.621 rows=187 loops=1)
                        -> Stream results  (cost=91406.77 rows=0) (actual time=23.805..24.513 rows=187 loops=1)
                            -> Nested loop left join  (cost=91406.77 rows=0) (actual time=23.784..24.287 rows=187 loops=1)
                                -> Nested loop left join  (cost=4324.70 rows=0) (actual time=19.930..20.216 rows=187 loops=1)
                                    -> Table scan on d  (cost=18.95 rows=187) (actual time=0.055..0.131 rows=187 loops=1)
                                    -> Index lookup on g using <auto_key0> (DepartmentCode=d.DepartmentCode)  (actual time=0.107..0.107 rows=1 loops=187)
                                        -> Materialize CTE DepartmentGPA  (cost=0.00..0.00 rows=0) (actual time=19.864..19.864 rows=135 loops=1)
                                            -> Table scan on <temporary>  (actual time=19.701..19.725 rows=135 loops=1)
                                                -> Aggregate using temporary table  (actual time=19.699..19.699 rows=135 loops=1)
                                                    -> Table scan on GPAHistory  (cost=1807.30 rows=17223) (actual time=0.081..8.972 rows=17294 loops=1)
                                -> Index lookup on c using <auto_key0> (DepartmentCode=d.DepartmentCode)  (actual time=0.021..0.022 rows=1 loops=187)
                                    -> Materialize CTE DepartmentCourses  (cost=1206.85..1206.85 rows=3782) (actual time=3.844..3.844 rows=187 loops=1)
                                        -> Group aggregate: count(distinct GeneralCourse.CourseNum)  (cost=828.65 rows=3782) (actual time=2.613..3.665 rows=187 loops=1)
                                            -> Sort: GeneralCourse.DepartmentCode  (cost=450.45 rows=3782) (actual time=2.595..2.829 rows=4497 loops=1)
                                                -> Index scan on GeneralCourse using idx_general_course_course_num  (actual time=0.025..1.417 rows=4497 loops=1)
|
```

Observations / Analysis

- Stream results cost = 91406.77
- This indexing scheme was the same as the original, and that is a bit surprising since the index we made is actually used (where the primary key is used in the original). This may be because the number of unique course numbers at the time of indexing was the same as the number of entries (corresponding to the same number of primary key values), but more in depth analysis is needed.

<u>Indexing Design 2</u>

Indexing DepartmentCode in the GPAHistory:

```
CREATE INDEX idx_gpa_history_department_code ON GPAHistory(DepartmentCode);
```

After indexing CourseNum

```
| -> Limit: 15 row(s)  (actual time=273.917..273.919 rows=15 loops=1)
    -> Sort: CombinedScore DESC, DepartmentCode  (actual time=273.916..273.918 rows=15 loops=1)
        -> Table scan on <temporary>  (cost=2.50..2.50 rows=0) (actual time=273.822..273.852 rows=187 loops=1)
            -> Temporary table  (cost=0.00..0.00 rows=0) (actual time=273.821..273.821 rows=187 loops=1)
                -> Window aggregate: rank() OVER (ORDER BY ((ifnull(g.AverageGPA,0) * 0.7) + (ifnull(c.CourseCount,0) * 0.3)) desc )  (actual time=273.679..273.784 rows=187 loops=1)
                    -> Sort: CombinedScore DESC  (actual time=273.670..273.690 rows=187 loops=1)
                        -> Stream results  (cost=1218482595.07 rows=12180691182) (actual time=272.858..273.579 rows=187 loops=1)
                            -> Nested loop left join  (cost=1218482595.07 rows=12180691182) (actual time=272.842..273.359 rows=187 loops=1)
                                -> Nested loop left join  (cost=326394.80 rows=3220701) (actual time=37.354..37.636 rows=187 loops=1)
                                    -> Table scan on d  (cost=18.95 rows=187) (actual time=0.059..0.123 rows=187 loops=1)
                                    -> Index lookup on g using <auto_key0> (DepartmentCode=d.DepartmentCode)  (actual time=0.200..0.200 rows=1 loops=187)
                                        -> Materialize CTE DepartmentGPA  (cost=5251.90..5251.90 rows=17223) (actual time=37.282..37.282 rows=135 loops=1)
                                            -> Group aggregate: avg(GPAHistory.Avg_Grade)  (cost=3529.60 rows=17223) (actual time=2.280..37.022 rows=135 loops=1)
                                                -> Index scan on GPAHistory using idx_gpa_history_department_code  (cost=1807.30 rows=17223) (actual time=1.702..33.967 rows=17294 loops=1)
                                -> Index lookup on c using <auto_key0> (DepartmentCode=d.DepartmentCode)  (actual time=1.260..1.260 rows=1 loops=187)
                                    -> Materialize CTE DepartmentCourses  (cost=1206.85..1206.85 rows=3782) (actual time=235.478..235.478 rows=187 loops=1)
                                        -> Group aggregate: count(distinct GeneralCourse.CourseNum)  (cost=828.65 rows=3782) (actual time=234.149..235.302 rows=187 loops=1)
                                            -> Sort: GeneralCourse.DepartmentCode  (cost=450.45 rows=3782) (actual time=234.130..234.387 rows=4497 loops=1)
                                                -> Index scan on GeneralCourse using PRIMARY  (actual time=0.022..232.466 rows=4497 loops=1)
|
```

Observations / Analysis

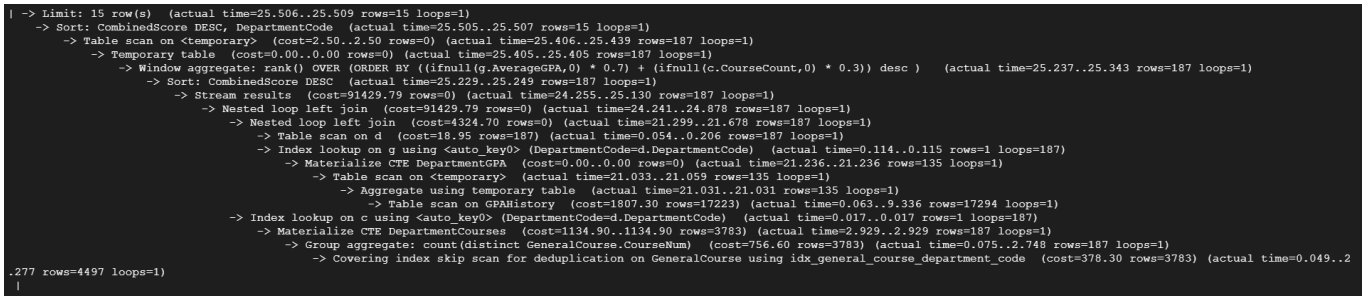
- Stream results cost = 1,218,482,595.07
- We are surprised by these results because the output is very similar. The materialize CTE step is where the issues lie in this one because the costs on the others for this step are 0, but they are very high for this query, so indexing GPAHistory with the DepartmentCode increased the overhead needed for that step significantly somehow.

<u>Indexing Design 3</u>

Indexing DepartmentCode in the General Course:

```
CREATE INDEX idx_general_course_department_code ON
GeneralCourse(DepartmentCode);
```

After Indexing DepartmentCode in the General Course:



Observations / Analysis

- Stream results cost = 91429.79
- This indexing scheme resulted in slightly worse results than the original, and this is a bit strange because certain parts of the query are better than the original, but it seems to be made up in some of the stranger index lookups.

Query 2 Final Analysis:

- None of our other indexing schemes helped decrease the cost, but some increased the cost
- This query likely didn't go down because most of the work was done with the primary keys, but we are still a little perplexed by the significantly increased cost for the 2nd indexing because that is something used in the joins in this query, so that is something that needs further analysis.
- For simplicity, we will consider the original indexing the best.

<u>Query 3:</u>

Indexing Analysis Report:

The query aims to List the number of 1 Credit courses offered by the CS department having avg_grade > 3.9.

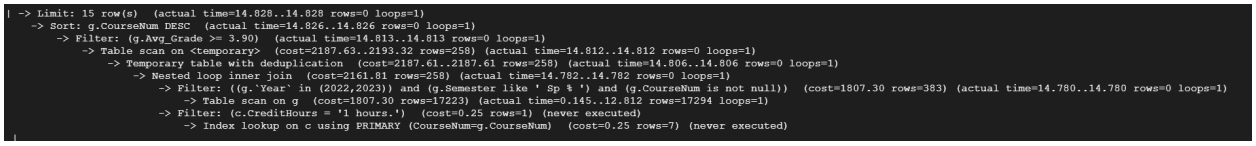


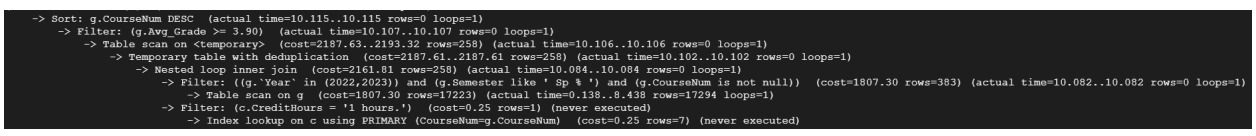
Table scan cost: 2193.32

<u>Indexing Design 1</u>

Indexing GPAHistory(Avg_grade) for this query:

```
CREATE INDEX idx_GPAHistory_Avg_Grade ON GPAHistory(Avg_Grade);
```

After running for GPAHistory(Avg_grade)



Observations / Analysis

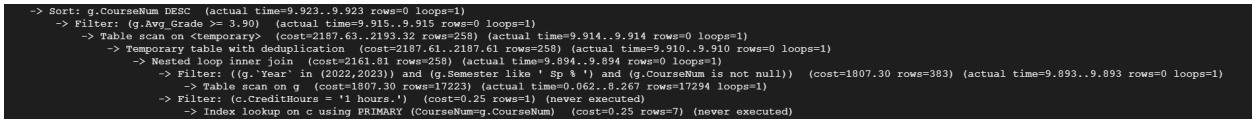
- Table scan cost: 2193.32
- The cost did not change for this indexing, likely because most of the cost comes from the joins on attributes that are already indexed as primary keys. The new index we chose did not have an effect on which indices were used for lookup in this case (the primary keys were still used).

Indexing Design 2

Indexing GeneralCourse(CourseName) for this query:

```
CREATE INDEX idx_GeneralCourse_CourseName1 ON
GeneralCourse(CourseName);
```

After running for GeneralCourse(CourseName)



Observations / Analysis

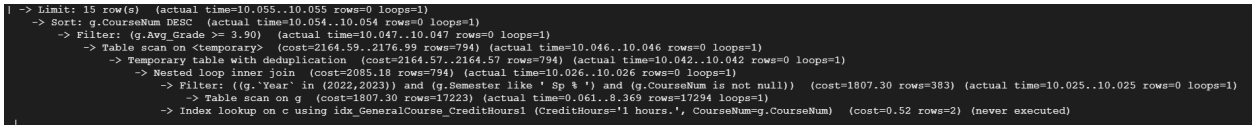
- Table scan cost: 2193.32
- The cost did not change for this indexing, likely because most of the cost comes from the joins on attributes that are already indexed as primary keys. The new index we chose did not have an effect on which indices were used for lookup in this case (the primary keys were still used).

Indexing Design 3

Indexing GeneralCourse(CreditHours) for this query:

```
CREATE INDEX idx_GeneralCourse_CreditHours1 ON
GeneralCourse(CreditHours);
```

After running for GeneralCourse(CreditHours)



Observations / Analysis

- Table scan cost: 2176.99
- This index results in a slightly lower cost than the original.
- One can see that unlike the other results, the index we created was actually used in place of the primary key for the index lookup, which is where we get our slightly lower cost.

Query 3 Final Analysis:

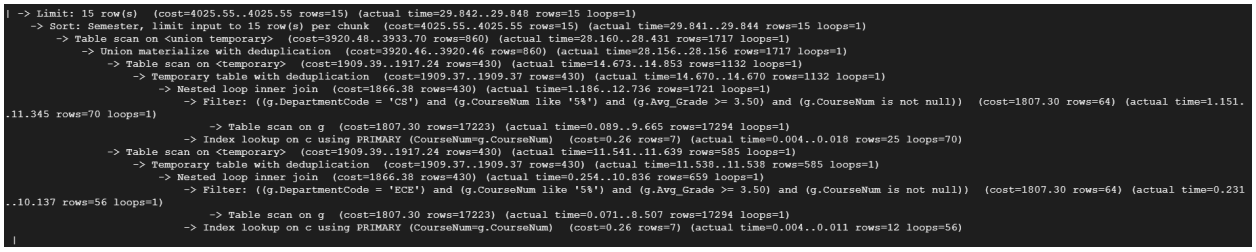
- Only the third indexing scheme reduced the cost
- Similar to Query 1, the first two indexing schemes used attributes that were in the GROUP BY portion of the query, which had no effect on the output. However, since CreditHours was also included in the WHERE clause, we think that is why the third indexing scheme was slightly improved from the original.

- The third indexing is the best for this query.

Query 4:

Indexing analysis report:

The Query aims to List the Number of Courses offered by the CS and ECE departments with an avg_grade greater than or equal to 3.5 using Union operator.



```
| -> Limit: 15 row(s)  (cost=4025.55..4025.55 rows=15) (actual time=29.842..29.848 rows=15 loops=1)
    -> Sort: Semester, limit input to 15 row(s) per chunk  (cost=4025.55..4025.55 rows=15) (actual time=29.841..29.844 rows=15 loops=1)
        -> Table scan on <union temporary>  (cost=3920.48..3933.70 rows=860) (actual time=28.160..28.431 rows=1717 loops=1)
            -> Union materialize with deduplication  (cost=3920.46..3920.46 rows=860) (actual time=28.156..28.156 rows=1717 loops=1)
                -> Table scan on <temporary>  (cost=1909.39..1917.24 rows=430) (actual time=14.673..14.853 rows=1132 loops=1)
                    -> Temporary table with deduplication  (cost=1909.37..1909.37 rows=430) (actual time=14.670..14.670 rows=1132 loops=1)
                        -> Nested loop inner join  (cost=1866.38 rows=430) (actual time=1.186..12.736 rows=1721 loops=1)
                            -> Filter: ((g.DepartmentCode = 'CS') and (g.CourseNum like '5%') and (g.Avg_Grade >= 3.50) and (g.CourseNum is not null))  (cost=1807.30 rows=64) (actual time=1.151.
.11.345 rows=70 loops=1)
                                -> Table scan on g  (cost=1807.30 rows=17223) (actual time=0.089..9.665 rows=17294 loops=1)
                            -> Index lookup on c using PRIMARY (CourseNum=g.CourseNum)  (cost=0.26 rows=7) (actual time=0.004..0.018 rows=25 loops=70)
                -> Table scan on <temporary>  (cost=1909.39..1917.24 rows=430) (actual time=11.541..11.639 rows=585 loops=1)
                    -> Temporary table with deduplication  (cost=1909.37..1909.37 rows=430) (actual time=11.538..11.538 rows=585 loops=1)
                        -> Nested loop inner join  (cost=1866.38 rows=430) (actual time=0.254..10.836 rows=659 loops=1)
                            -> Filter: ((g.DepartmentCode = 'ECE') and (g.CourseNum like '5%') and (g.Avg_Grade >= 3.50) and (g.CourseNum is not null))  (cost=1807.30 rows=64) (actual time=0.231
..10.137 rows=56 loops=1)
                                -> Table scan on g  (cost=1807.30 rows=17223) (actual time=0.071..8.507 rows=17294 loops=1)
                            -> Index lookup on c using PRIMARY (CourseNum=g.CourseNum)  (cost=0.26 rows=7) (actual time=0.004..0.011 rows=12 loops=56)
 |
```

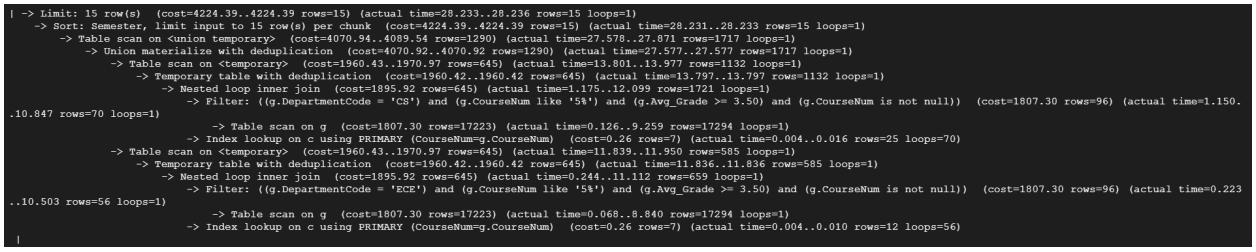
Limit cost: 4025.55

Indexing Design 1

Indexing GPAHistory(Avg_grade) for this query:

```
CREATE INDEX idx_GPAHistory_Avg_Grade ON GPAHistory(Avg_Grade);
```

After running for GPAHistory(Avg_grade)



```
| -> Limit: 15 row(s)  (cost=4224.39..4224.39 rows=15) (actual time=28.233..28.236 rows=15 loops=1)
    -> Sort: Semester, limit input to 15 row(s) per chunk  (cost=4224.39..4224.39 rows=15) (actual time=28.231..28.233 rows=15 loops=1)
        -> Table scan on <union temporary>  (cost=4070.94..4089.54 rows=1290) (actual time=27.578..27.871 rows=1717 loops=1)
            -> Union materialize with deduplication  (cost=4070.92..4070.92 rows=1290) (actual time=27.577..27.577 rows=1717 loops=1)
                -> Table scan on <temporary>  (cost=1960.43..1970.97 rows=645) (actual time=13.801..13.977 rows=1132 loops=1)
                    -> Temporary table with deduplication  (cost=1960.42..1960.42 rows=645) (actual time=13.797..13.797 rows=1132 loops=1)
                        -> Nested loop inner join  (cost=1895.92 rows=645) (actual time=1.175..12.099 rows=1721 loops=1)
                            -> Filter: ((g.DepartmentCode = 'CS') and (g.CourseNum like '5%') and (g.Avg_Grade >= 3.50) and (g.CourseNum is not null))  (cost=1807.30 rows=96) (actual time=1.150.
.10.847 rows=70 loops=1)
                                -> Table scan on g  (cost=1807.30 rows=17223) (actual time=0.126..9.259 rows=17294 loops=1)
                            -> Index lookup on c using PRIMARY (CourseNum=g.CourseNum)  (cost=0.26 rows=7) (actual time=0.004..0.016 rows=25 loops=70)
                -> Table scan on <temporary>  (cost=1960.43..1970.97 rows=645) (actual time=11.839..11.950 rows=585 loops=1)
                    -> Temporary table with deduplication  (cost=1960.42..1960.42 rows=645) (actual time=11.836..11.836 rows=585 loops=1)
                        -> Nested loop inner join  (cost=1895.92 rows=645) (actual time=0.244..11.112 rows=659 loops=1)
                            -> Filter: ((g.DepartmentCode = 'ECE') and (g.CourseNum like '5%') and (g.Avg_Grade >= 3.50) and (g.CourseNum is not null))  (cost=1807.30 rows=96) (actual time=0.223
..10.503 rows=56 loops=1)
                                -> Table scan on g  (cost=1807.30 rows=17223) (actual time=0.068..8.840 rows=17294 loops=1)
                            -> Index lookup on c using PRIMARY (CourseNum=g.CourseNum)  (cost=0.26 rows=7) (actual time=0.004..0.010 rows=12 loops=56)
 |
```

Observations / Analysis

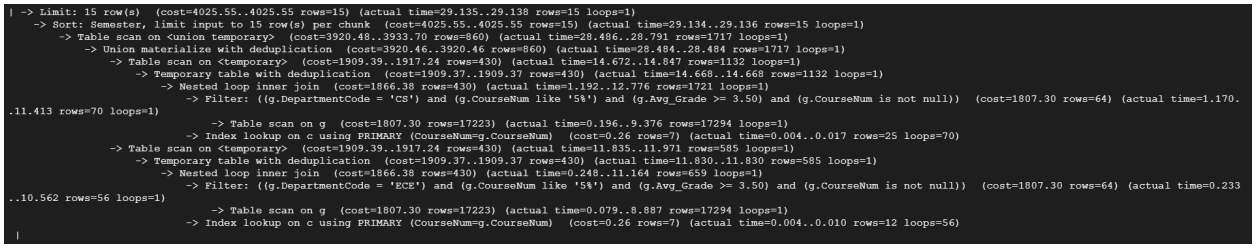
- Limit cost: 4224.39
- This index caused an increase in the cost by about 200.
- Many of the operations within the query increased their cost by a small amount, leading to the overall increase. This may be due to the increased cost of reading the index into memory, which for a relatively small dataset like this, is considerable relative to the overall cost of the query.

Indexing Design 2

Indexing GeneralCourse(CourseName) for this query:

```
CREATE INDEX idx_GeneralCourse_CourseName ON
GeneralCourse(CourseName);
```

After Running for GeneralCourse(CourseName)



Observations / Analysis

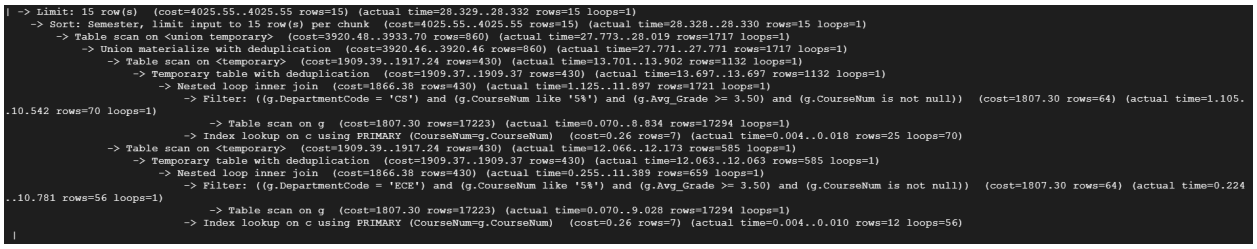
- Limit cost: 4025.55
- This query costs the exact same as the original. Since CourseName is only used in the Group By clause, indexing by it did not induce any effect on the query.

<u>Indexing Design 3</u>

Indexing GeneralCourse(CreditHours) for this query:

```
CREATE INDEX idx_GeneralCourse_CreditHours ON
GeneralCourse(CreditHours);
```

After Running for GeneralCourse(CreditHours)



Observations / Analysis

- Limit cost: 4025.55
- This index did not change the performance of the query at all. Once again, CreditHours is only used in the Group By clause, and we believe that due to this, it did not have an effect on the overall performance of the query.

Query 4 Final Analysis:

None of the proposed indices reduced the cost. Due to this, we would choose not to implement any of these indices. However, as we continue with the project, we can experiment with different indices for our finalized queries used in our application to see if any others could have a positive effect on this query.

Overall Index Design:

Most of our index choices did not improve the cost. However, one index,on GeneralCourse(CreditHours), did improve the cost of Query 3 a bit. Since that was the only index we saw improvement on, and also didn't reduce the performance of other queries, we will use this index going forward in our database. We will continue to evaluate and analyze the performance of different indices as we determine the final structure of the queries we will use in our application.