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Lesson 8
Constraints and Triggers

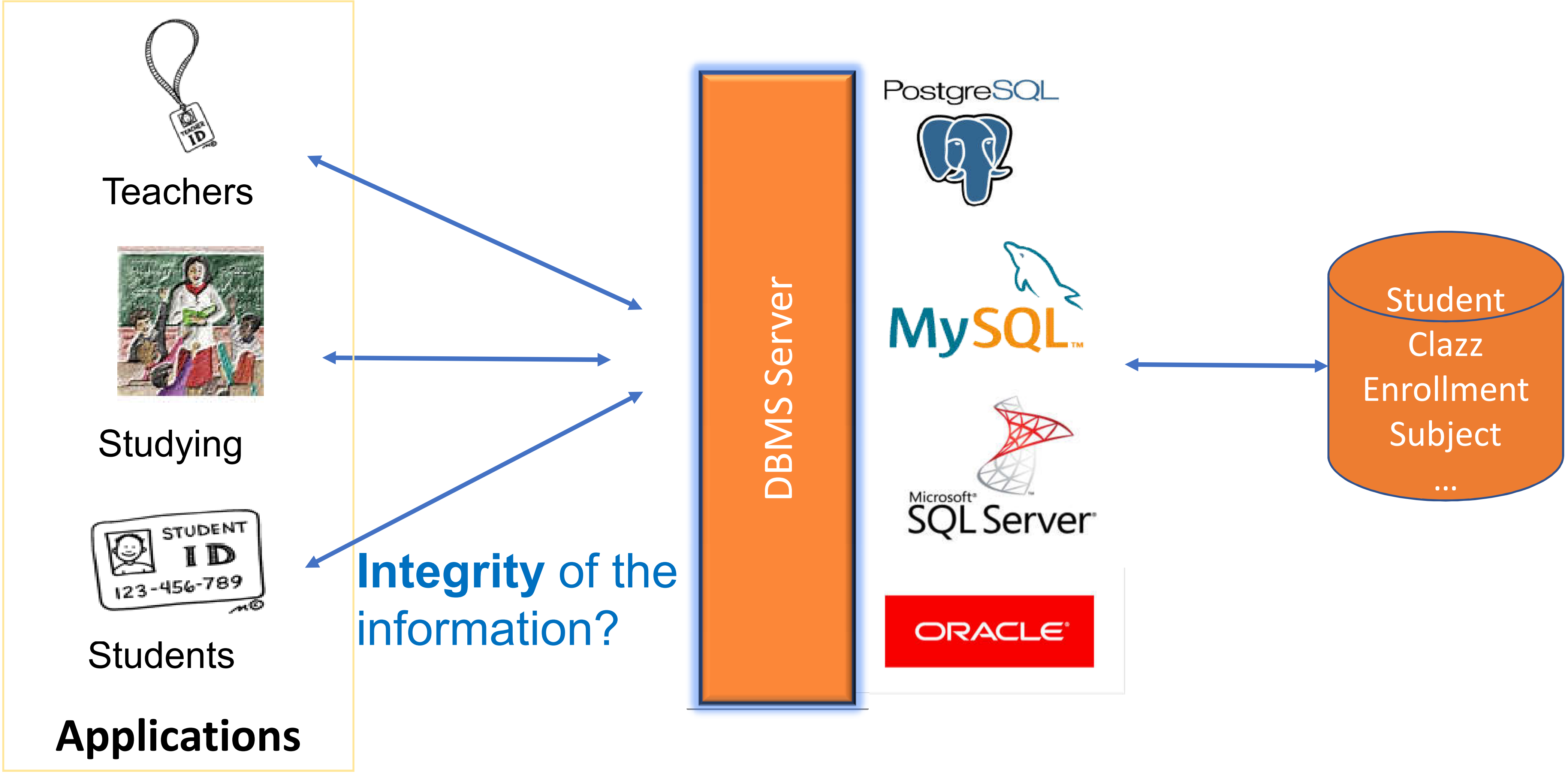
Learning objectives

- ***Upon completion of this lesson, students will be able to:***
  1. Well known about different constraints and define them correctly
  2. Understand triggers: What is a trigger? how it works ? When using?
  3. Define simple triggers

Outline

- Constraints
- Triggers

1. Introduction



Integrity of the information?

1. Introduction: Database Schema

student(**student_id**, first_name,last_name, dob, gender,
address, note, email, *clazz_id*)

clazz(**clazz_id**, name, *lecturer_id*, *monitor_id,* number_students)

subject(**subject_id**, name, credit, percentage_final_exam)

enrollment(***student_id***, ***subject_id***, **semester**, midterm_score, final_score)

lecturer(**lecturer_id**, first_name, last_name, dob, gender, address, email)

teaching(***subject_id, lecturer_id***)

grade(**code**, from_score, to_score)

1. Introduction: Constraints and Triggers

- A constraint is a relationship among data elements that the DBMS is required to enforce
  - Example: key constraints
- Triggers are only executed when a specified condition occurs, e.g., insertion of a tuple
  - Easier to implement than complex constraints

2. Constraints

2.1. Keys: PRIMARY KEY vs. UNIQUE

2.2. Foreign keys

2.3. Attribute-based checks

2.4. Tuple-based checks

2.5. Assertions

2. Constraints: Kinds of Constraints

- Keys
- Foreign-key, or referential-integrity
- Value-based constraints
  - Constrain values of a particular attribute.
- Tuple-based constraints
  - Relationship among components
- Assertions: any SQL boolean expression

2.1. Keys: PRIMARY KEY vs. UNIQUE

- Declaring: similar syntax as primary key
- Example:

```sql
CREATE TABLE student (
   student_id CHAR(8) NOT NULL,
   first_name VARCHAR(20) NOT NULL,
   last_name VARCHAR(20) NOT NULL,
   ...
   email varchar(50) UNIQUE,
   clazz_id CHAR(8),
   CONSTRAINT student_pk PRIMARY KEY (student_id));
```

2.1. Keys: PRIMARY KEY vs. UNIQUE

	PRIMARY KEY	UNIQUE KEY
Number defined on table	One	Multiple
Null columns allowed	No	Yes
Default index	CLUSTERED	NON-CLUSTERED
Purpose	Enforce Entity Integrity	Enforce Unique Data
Number of columns	One or more columns	One or more columns
Referenced by a Foreign Key Constraint	Yes	Yes

2.2. Expressing Foreign Keys

- Use keyword REFERENCES, either:
  1. After an attribute (for one-attribute keys)
  2. As an element of the schema:

     [CONSTRAINT <name>] FOREIGN KEY (<list of attributes>)
     REFERENCES <relation> (<attributes>)
- Referenced attributes must be declared PRIMARY KEY or UNIQUE

2.2. Foreign keys: Example

```
CREATE TABLE clazz (
   clazz_id CHAR(8) NOT NULL PRIMARY KEY,
   name VARCHAR(20), … );

CREATE TABLE student (
   student_id CHAR(8) NOT NULL,
   ...,
   clazz_id CHAR(8),
   CONSTRAINT student_pk PRIMARY KEY (student_id));

ALTER TABLE student ADD CONSTRAINT student_fk_class
FOREIGN KEY (clazz_id) REFERENCES clazz(clazz_id);
```

2.2. Foreign keys: Enforcing constraint

- An insert or update to student that introduces a non-existent clazz_id (clazz_id value is not found in clazz)

  ➔ **Reject**

- A deletion or update to clazz that removes a clazz_id value found in some tuples of student?
  - Default: reject the modification
  - Cascade: make the same changes in student
  - Set NULL: change clazz_id in student to NULL

2.2. Foreign keys: Choosing policy

```
ALTER TABLE student
   ADD CONSTRAINT student_fk_class FOREIGN KEY
(clazz_id) REFERENCES clazz(clazz_id)
   ON DELETE SET NULL
   ON UPDATE CASCADE;
```

2.3. Attribute-based checks

- ***Declaring***
  - Constraints on the value of a particular attribute
    - Add CHECK(<condition>) to the declaration for the attribute or add as relation-schema element
    - The condition may use the name of the attribute, but any other relation or attribute name must be in a subquery
- Example:

```
CREATE TABLE student (
    student_id CHAR(8) NOT NULL PRIMARY KEY, ...,
    gender CHAR(1),
    clazz_id CHAR(8) CHECK (clazz_id IN (SELECT clazz_id FROM clazz)),
    CONSTRAINT student_chk_gender CHECK (gender = 'F' OR gender = 'M'));
```

2.3. Attribute-based checks

- ***Timing of checks***
  - Only when a value for that attribute is inserted or updated

```
CREATE TABLE student (
    student_id CHAR(8) NOT NULL PRIMARY KEY, ...,
    gender CHAR(1),
    clazz_id CHAR(8) CHECK (clazz_id IN (SELECT
clazz_id FROM clazz)),
    CONSTRAINT student_chk_gender CHECK (gender = 'F'
OR gender = 'M') );
```

Not checked if a class is deleted from **clazz**

2.4. Tuple-based checks

- CHECK (<condition>) may be added as a **relation-schema element**.
- The condition may refer to any attribute of the relation
  - But other attributes or relations require a subquery
- Timing of checks: on insert or update only.

```
CREATE TABLE grade(
   code CHAR(1) NOT NULL,
   from_score DECIMAL(3,1) NOT NULL,
   to_score DECIMAL(3,1) NOT NULL, ...,
   CONSTRAINT grade_chk_toScore CHECK (to_score >
from_score) );
```

2.5. Assertions

- ***Declaring***
  - Database-schema elements, like relations or views
  - Defined by:

```
CREATE ASSERTION <name>
        CHECK (<condition>);
```

  - Condition may refer to any relation or attribute in the database schema
  - Drop an assertion:

```
DROP ASSERTION <assertion name>;
```

2.5. Assertions: Example

```
CREATE ASSERTION teachingSubject CHECK (
   (SELECT COUNT(*) FROM teaching) >=
   (SELECT COUNT(*) FROM subject) );

CREATE ASSERTION numberStdInClass CHECK (
   NOT EXISTS (
     SELECT * FROM clazz c
     WHERE number_students <>
        (SELECT count(*) FROM student
          WHERE clazz_id = c.clazz_id) ) );
```

2.5. Assertions

- ***Timing of Assertion Checks***
  - In principle, we must check every assertion after every modification to any relation of the database
  - A clever system can observe that only certain changes could cause a given assertion to be violated
    - No change to **student** can affect **teaching Subject**
    - Neither can an insertion to **teaching**
  - Very hard to implement assertions efficiently

3. Triggers

3.1. Motivation

3.2. Trigger

3.3. Using trigger

3.4. Examples

3.1. Motivation

- **Assertions**
  - powerful,
  - but the DBMS often can’t tell when they need to be checked
- **Attribute- and tuple-based checks**
  - checked at known times,
  - but are not powerful
- **Triggers** let the **user decide** when to check for any condition

3.1. Motivation: ECA Rules

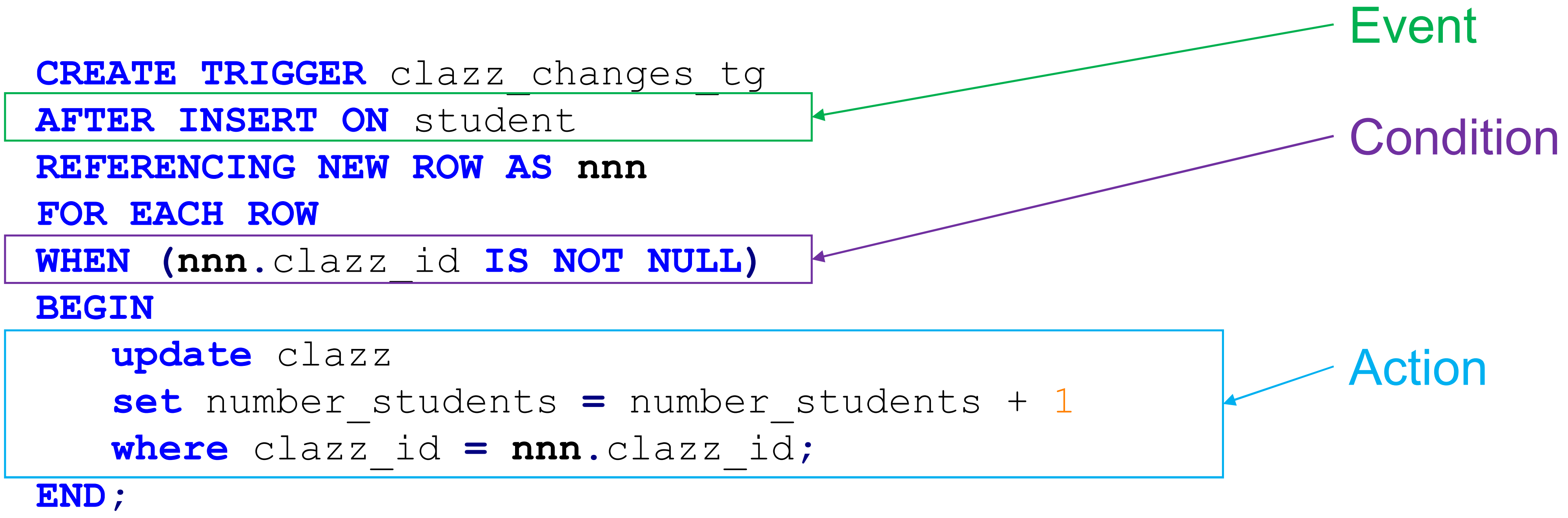
- A trigger defines an operation that is performed when a specific event occurs on a relation:
  - inserts a new record / updates an existing record / deletes a record
- Trigger functions have access to special variables from the database engine
- Called also ECA rules **(Event-Condition-Action)**
  - Event: type of database modification
  - Condition: Any SQL Boolean-valued expression
  - Action: Any SQL statements

3.1. Motivation: Example

- **Constraint:** when a new student is inserted into student relation, the number of students in his class must be increased

student(**student_id**, first_name,last_name, dob, gender, address, note, email, *clazz_id*)

clazz(**clazz_id**, name, *lecturer_id*, *monitor_id,* number_students)



```
CREATE TRIGGER clazz_changes_tg
AFTER INSERT ON student
REFERENCING NEW ROW AS nnn
FOR EACH ROW
WHEN (nnn.clazz_id IS NOT NULL)
BEGIN
    update clazz
    set number_students = number_students + 1
    where clazz_id = nnn.clazz_id;
END;
```

Event

Condition

Action

3.2. Trigger: Definition syntax

- Creating a trigger:

```
CREATE [OR REPLACE] TRIGGER <trigger_name>
   {BEFORE | AFTER | INSTEAD OF }
   {INSERT | DELETE | UPDATE [OF <attribute_name>]}
   ON <table_name>
   REFERENCING {NEW | OLD} {ROW | TABLE} AS <name>
   [FOR EACH ROW ]
   [WHEN (<condition>) ]
   BEGIN
       <trigger body goes here >
   END;
```

- Dropping a trigger:

```
DROP TRIGGER <trigger_name>;
```

3.2. Trigger: Event

- AFTER, BEFORE, INSTEAD OF:
  - AFTER, BEFORE: used for tables / views
  - INSTEAD OF: used only for views
    - A way to execute view modifications: triggers translate them to
    - appropriate modifications on the base tables
- INSERT, DELETE, UPDATE , UPDATE OF
  - UPDATE OF <colums>: update on a particular column

3.2. Trigger: Level

- Row-level trigger:
  - Indicated by option FOR EACH ROW
  - Trigger executes once for each modified tuple
- Statement-level trigger:
  - Without option FOR EACH ROW or with FOR EACH STATEMENT
  - Trigger execute once for a SQL statement, regardless how many

    tuples are modified

3.2. Trigger: Referencing

- **INSERT** statements imply a new tuple (for row-level) or new table (for statement-level)
  - The table is the set of inserted tuples
- **DELETE** implies an old tuple or table
- **UPDATE** implies both
- Refer to these by :

  REFERENCING [NEW | OLD] [TUPLE | TABLE] AS <name>

- Each DBMS has its own implementation, REFERENCING may not used:
  - Access directly to special variables from the database engine: NEW, OLD,…

3.2. Trigger: Condition

- Any boolean-valued condition
- Evaluated on the database as it would exist before or after the triggering event, depending on whether BEFORE or AFTER is used.
  - But always before the changes take effect.
- Access the new/old tuple/table through the names in the REFERENCING clause

3.2. Trigger: Action

- Can be more than one SQL statement:
  - Surrounded by BEGIN .. END
- Language:
  - Simple SQL statements
  - Extention of SQL: procedural languages, depends on each DBMD
    - PL/SQL (Oracle), PL/pgSQL (PostgreSQL), T-SQL(SQL Server) ,..

3.3. Using triggers

- Auditing data modification (keeping history of data), providing transparent
  event logging
- Validation and business security checking if so is desired
  - Eg. column formatting before and after inserts into database
- Enforcing complex integrity constraints
- Enforcing complex business rules
- Maintaining replicate tables
- Building complex views that are updatable
- …

3.3. Using triggers: Guidelines for designing triggers

- Do not define triggers that duplicate database features
  - do not define triggers to reject bad data if you can do the same checking through constraints
- Use triggers only for centralized, global operations that must fire for the triggering statement, regardless of which user or database application issues the statement
- Do not create recursive triggers
- Use triggers on DATABASE judiciously (server error, logon, logoff,…):
  - they are executed for every user every time the event occurs on which the trigger is created.

3.4. Examples: Oracle

- Add a new column in **clazz** relation

```
alter table clazz
add column number_students integer not null default 0;
```

- Create a trigger on **student** relation

```
CREATE TRIGGER clazz_changes_tg
AFTER UPDATE ON student
FOR EACH ROW
WHEN (:NEW.clazz_id <> :OLD.clazz_id)
BEGIN
    update clazz set number_students= number_students+1
    where clazz_id = :NEW.clazz_id;
    update clazz set number_students = number_students-1
    where clazz_id = :OLD.clazz_id;
END;
```

3.4. Examples: PostgreSQL

```
CREATE FUNCTION public.tg_fnc_change_clazz()
    RETURNS trigger LANGUAGE 'plpgsql' AS $$
BEGIN
   update clazz set number_students = number_students+1
   where clazz_id = NEW.clazz_id;
   update clazz set number_students = number_students-1
   where clazz_id = OLD.clazz_id;
   return NEW;
END; $$

CREATE TRIGGER tg_af_update_clazz
    AFTER UPDATE OF clazz_id
    ON student
    FOR EACH ROW
    EXECUTE PROCEDURE public.tg_fnc_change_clazz();
```

Summary

- Constraints, Assertions, Triggers:
  - How to declare
  - Timing of checks
  - Differences
- Only use them if you really need to, especially triggers
- Each DBMS has its own variation in implementation:
  - Options
  - Syntax: triggers as an example
  - → Reading documentation for each DBMS installed

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Thank you for your attention!

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