Advanced Databases

1. **Course number and name:** 020BDAES3/020ADDES3 Advanced Databases

2. **Credits and contact hours:** 4 ECTS credits, 2x1:15 contact hours

3. **Name of course coordinator:** Dany Mezher

4. **Instructional materials:** Slides; course handouts in-class problems

   References:

5. **Specific course information**
   a. **Catalog description:**
      This course explores advanced concepts and techniques in database systems, building on foundational knowledge of relational databases. Students will gain in-depth understanding and practical skills in database design, optimization, transaction management, and security. Emphasis is placed on enhancing the performance, integrity, and reliability of database systems through advanced methodologies and tools.

   b. **Prerequisites:** Relational Databases (020BDRES2/020RDBES2)

   c. **Selected Elective** for CCE students

6. **Educational objectives for the course**
   a. **Specific outcomes of instruction:**
      - Analyze and apply advanced database design principles, including normalization techniques up to 5NF, to create efficient and scalable database schemas.
      - Implement and manage advanced referential integrity constraints, including composite foreign keys, circular relationships, and deferred foreign keys, to ensure data consistency in complex systems.
      - Evaluate and enhance database performance using views, materialized views, indexes, and query execution plans.
      - Demonstrate a deep understanding of ACID properties and manage transaction lifecycles effectively.
      - Identify and mitigate concurrency issues using appropriate isolation levels and control mechanisms.
      - Differentiate between optimistic and pessimistic locking strategies and apply the appropriate approach for specific use cases to balance performance and consistency.
      - Develop and implement advanced database design patterns, including normalized (EAV) and denormalized (JSON) structures, to meet specific application requirements.
      - Apply database security best practices to protect sensitive data and ensure compliance with security standards.

- Design and implement effective backup and recovery strategies to minimize data loss.
- Configure and manage replication techniques to enhance database reliability and availability.
- Analyze complex database scenarios, identify potential challenges, and propose robust solutions that address performance, integrity, and scalability requirements.

b. PI addressed by the course:

PI	1.1	1.2	1.3	6.3	6.4
Covered	x	x	x	x	x
Assessed		x	x	x	x

7. Topics

- **Introduction and Database Normalization**
  - Overview of relational database principles and design.
  - Exploration of database normalization, including an overview of normal forms (1NF, 2NF, 3NF, BCNF, 4NF, 5NF).
- **Referential Integrity**
  - Advanced referential integrity concepts, including composite foreign keys and circular referential integrity.
  - Deferred foreign keys and their applications in complex database structures.
- **Performance Tuning**
  - Techniques to optimize database performance, including the use of views, materialized views, and indexes.
  - Performance considerations in query execution and the use of tools such as query execution plans and the `ANALYZE` command.
- **Transaction Management**
  - Comprehensive coverage of ACID properties and transaction lifecycles.
  - Examination of concurrency control mechanisms and read phenomena (dirty reads, non-repeatable reads, phantom reads).
  - Understanding and implementing isolation levels (Read Uncommitted, Read Committed, Repeatable Read, Serializable) in SQL.
- **Optimistic vs. Pessimistic Locking**
  - Exploration of locking mechanisms, their concepts, and real-world use cases.
  - Implementation strategies in SQL and performance trade-offs of each approach.
- **Database Design Patterns**
  - Investigation of item-specific design patterns and dynamic attributes.
  - Comparison of normalized (EAV model) and denormalized (JSON) database designs.
- **Security, Backup, and Replication**
  - Database security best practices and strategies for protecting data integrity.
  - Backup and recovery methodologies to ensure data availability.
  - Overview of replication techniques for enhancing system reliability and scalability.