Course Schedule Reuse at NUM

Content

Introduction

Project goal: build an Integrated Knowledge Graph (KG)
Context: Academic operations at the National University of Mongolia
Focus: Course scheduling and curriculum alignment
Methodology: iTelos Knowledge Graph Engineering (KGE)
Scope: 10 selected academic programs

Integration of:

- Existing KGs: Courses, Course–Curriculum, Course Schedule
- New KGs: Student, Planned Course, Curriculum–Student

Outcome:

- Detect schedule conflicts
- Identify curriculum overlaps
- Reveal academic inconsistencies

Team Roles and Contributions

Team Workflow and Responsibilities

- Each member documented their own contributions
- Domain Expert submitted each phase to the instructor
- Project Manager coordinated the process and communication
- Continuous collaboration across phases

DE – Myagmarsuren
DS – Baigali
KE – Oyu-Erdene

Knowledge Engineer (KE)

- Language Definition phase
- Concept identification and UKC alignment

Data Scientist (DS)

- Initial Resources
- Purpose Formalization
- Information Gathering
- Knowledge Definition

Domain Expert (DE)

- Information Gathering
- Entity Definition
- Evaluation phase

Domain of Interest

Domain: Academic operations at NUM
Objective: Support detection of conflicts and overlaps
Target programs: 10 selected academic programs
Semester: Fall 2025

Focus areas:

- Courses
- Course schedules
- Curriculum structures
- Student course planning

Boundaries

Geographical Boundaries

- **Limited to:** National University of Mongolia (NUM)
- **Includes:** Internal academic structures only
- **Excludes:**
  - Other universities
  - External institutions

Temporal Boundaries

- **Time scope:** Fall 2025 semester
- **Data includes:**
  - Course schedules
  - Curriculum requirements
  - Student course plans

Domain Boundaries

- **Included:**
  - Planned courses
  - Selected (enrolled) courses
  - Curriculum-required courses
- **Focus:**
  - Scheduling conflicts
  - Curriculum alignment
- **Excluded:**
  - Administrative processes
  - Non-academic domains
  - Programs outside the selected ten

Initial Resources

Knowledge Resources

- Courses Knowledge Graph
- Curriculum–Course Knowledge Graph
- Course Schedule Knowledge Graph

Data Sources

- Student Dataset
- Planned Course Dataset
- Selected Course Dataset
- Courses Knowledge Dataset
- Curriculum–Course Dataset
- Course Schedule Dataset

Based on data from LiveData NUM

Purpose Formalization

Purpose Definition

- Build a unified Knowledge Graph for courses, curriculum, course schedules
- Support students and academic staff in detecting timetable overlaps, identifying prerequisite violations, validating curriculum requirements

Purpose Formalization

Persona 1 Freshman Od

- First-year student planning courses for the next semester
- Needs to avoid:
  - Time overlaps
  - Prerequisite violations

Persona 2 Senior Student Bilguun

- Senior student with an existing course schedule
- Focus: courses that compatible his selected (enrolled) courses
- Needs to quickly detect timetable conflicts

Purpose Formalization

Persona 3 Naraa

- Naraa wants to check courses in her curriculum that she has not selected before and that are currently available, with the additional constraint that these courses are scheduled only on Tuesdays, Wednesdays, and Thursdays.

Persona 4 Staff Sky

- Administrative staff member
- Needs to identify:
  - Overlapping schedules of major courses within a program

Competency Questions (CQs)

CQ1:
What time conflicts exist between the courses that Od plans to take for the next semester?

CQ2:
Which timetable overlaps occur among the courses that Bilguun has already enrolled in?

CQ3:
Which available courses in Naraa's curriculum that she has not previously selected are scheduled only on Tuesdays, Wednesdays, and Thursdays?

CQ4:
Which major courses within the same academic program have overlapping schedules?

Phase 2: Information Gathering

Goal

- Identify, collect, clean, and standardize datasets
- Prepare initial resources for the Knowledge GraphData Sources

Data Sources

1. LiveDataNUM (Reuse datasets – JSON)
    - Course, Curriculum–Course relations, Course schedules
2. NUM Internal Systems (CSV)
    - Student, Curriculum, Planned course, Selected course

Data Preparation, Issues

Data Preparation

- Field naming standardization - *snake_case*
- Structural alignment between reuse and internal datasets

Key Challenge

No shared identifier

- Reuse data: UUID / hashed IDs
- Internal data: integer IDs

Data Preparation, Issues

Solution

Multi-attribute matching using:

- Course title, index, school / department
- Instructor, schedule (day/time)
- Program name, school / department, first year, academic level

Outcomes

Results

- 13,117 reuse courses → 230 relevant NUM courses
- 6,742 schedules → 2,616 aligned schedules
- 84,444 curriculum-course relation → 515 aligned records
- Duplicates removed, curriculum validation applied

Summary

Phase 2 produced a clean, standardized, and aligned dataset collection by integrating reuse data with internal NUM data, providing a solid foundation for Knowledge Graph development.

Phase 3: Language Definition

Goal: define a purpose-specific semantic language

Describe:

- Concepts
- Relationships
- Properties

Based on:

- Previous phases' outputs
- Team collaboration

Main activities:

- Concept Identification
- UKC Alignment
- Dataset Filtering

3.1 Concept Identification

Identified concepts from:

- Purpose
- ER model
- Dataset

Grouped concepts into:

- Core
- Linking / Activity
- Data properties

Issues

- Ambiguous distinctions between:
  - Course vs Course_schedule
  - Time_slot vs Moment

Solution

- Used reasoning requirements
- Chose concepts that support conflict detection

3.2 UKC Alignment

Checked each concept against UKC

Reused:

- Student, Course, Curriculum, Program

Created new concepts:

- Course_schedule
- Planned_course
- Selected_course

Issues

- Partial matches in UKC

Solution

- Avoided forced mappings
- Defined project-specific concepts with GIDs

3.3 Dataset Filtering

Removed:

- Unused attributes
- Redundant entities
- Isolated identifiers

Issues

- Too many attributes with no reasoning role

Solution

- Applied filtering rules:
  - Support reasoning
  - Avoid redundancy
  - Reduce complexity

Knowledge Definition

Goal

- Transform concepts and datasets into a formal OWL ontology

Based on

- Phase 2: Standardized datasets
- Phase 3: Language Definition

Output:

- Unified and consistent OWL-based ontology

Knowledge Definition

Knowledge Teleontology

- Concepts from Language Definition phase used as primary input
- iTelos methodology applied
- kTelos process
  - Entity types
  - Object properties
  - Data properties
- All encoded as OWL classes and properties

Ensures traceability from language definition to ontology

Knowledge Definition

Ontology Design Choices

Core Domain Classes

- Represent fundamental academic entities

Project Specific Classes

- Represent planning, selection, and scheduling semantics
- Capture planning, enrollment, and scheduling semantics

Core Classes	Project-specific Classes
Student	Course_schedule
Program	Curriculum_course
Curriculum	Planned_course
Course	Selected_course
Time_slot	Prerequisite

Knowledge Definition

Action Classes

- Planned_course
- Selected_course

Represent student decisions and intentions, not time-bound events

Event Classes

- Course_schedule
- Time_slot

Represent time-specific academic events

Design Rationale

Separates student actions from scheduled occurrences
Enables clearer semantic modeling and conflict detection,
Separates student behavior from temporal events

Knowledge Definition

Data Properties

- Course:
  - course_id, course_index, course_name
- Course_schedule:
  - schedule_id, schedule_start, schedule_end, type, frequency, cycle
- Time_slot:
  - day_of_week, start_time, end_time
- Program / Curriculum / Student:
  - program_id, program_name, academic_level first_year student_id, enrollment_year

Knowledge Definition

Object Properties

- Academic structure
  - has_schedule: Course - Course_schedule
  - includes/has_course: Curriculum - Course
  - has_curriculum: Program - Curriculum
  - part_of: structural hierarchy
- Prerequisite relations
  - has_prerequisite: Course - Prerequisite
  - is_prerequisite_of: inverse relation
- Student actions
  - plans: Student - Planned_course
  - selects: Student - Selected_course

Entity Definition

Goal

- Transform conceptual model into instantiable entities
- Ensure consistent identification, matching, and mapping

Inputs

- Aligned datasets (Phase 2)
- Knowledge teleontology and language resource (Phase 3, 4)

Output

- Final KG

Entity Definition

Model Refinements

- Removed degree_program from Course (redundant)
- Converted room_number to string
- Added academic_level to Program

Entity Matching & Identification Strategy

Core Entity Matching

- Stable identifiers:
  - course_id
  - curriculum_id
  - student_id
  - schedule_id

Composite Entities (Time_slot)

- Hash-based identifier:
  - schedule_id, day_of_week, start_time, end_time

KG Instantiation & Summary

Knowledge Graph Instantiation

- Python + rdflib
- Programmatic RDF triple generation
- Serialized as:
  - OWL/XML, Turtle
- Ready for SPARQL querying and validation

Summary

- Abstract concepts → concrete entities
- Reliable foundation for querying and reasoning

Evaluation

Purpose

- Evaluate the final Knowledge Graph produced using iTelos
- Assess:
  - Structure
  - Quality
  - Suitability for project goals

Evaluation Scope

- Knowledge layer
- Data layer
- Competency query execution (SPARQL)

Knowledge Layer Evaluation

Evaluation Criteria

- Correct use of entity types
- Proper object property usage
- Logical relationship modeling

Key Findings

- Ontology correctly reflects academic scheduling domain
- Clear separation of:
  - Course
  - Course_schedule
  - Time_slot
- Supports temporal reasoning and overlap detection
- No structural inconsistencies found

Entity Properties

Core Entities

- Course
- Course_schedule
- Time_slot
- Curriculum
- Program
- Student

Contextual Entities

- Curriculum_course
- Planned_course
- Selected_course
- Prerequisite

Data Properties

- **Course:** course_id, course_index, course_name
- **Schedule:** schedule_id**,** schedule_start, schedule_end, type, frequency, cycle
- **Time Slot:** schedule_id**,** day_of_week, start_time, end_time
- **Location:** building_name, room_name, room_number
- **Program:** program_id, program_name, academic_level
- **Curriculum:** program_id, first_year
- **Student:** student_id, enrollment_year
- **Curriculum course:** curriculum_id, required_course_id, group_name

Object Properties

Academic Relationships

- has_schedule — Course → Course_schedule
- includes / has_course — Curriculum → Course
- has_curriculum — Program → Curriculum
- part_of — Structural hierarchy

Prerequisite Relationships

- has_prerequisite — Course → Prerequisite
- is_prerequisite_of — Inverse prerequisite relation

Student Action Relationships

- plans — Student → Planned_course
- selects — Student → Selected_course

Data layer evalution

IRI

- Based on dataset identifiers
- No duplicate IRIs

Time_slot

- Hash-based identifiers → guaranteed uniqueness

Datatype

- All literal values explicitly typed using XML Schema datatypes

Connectivity

- All entities participate in at least one object property relation
- No disconnected subgraphs observed

Competency query execution (SPARQL)

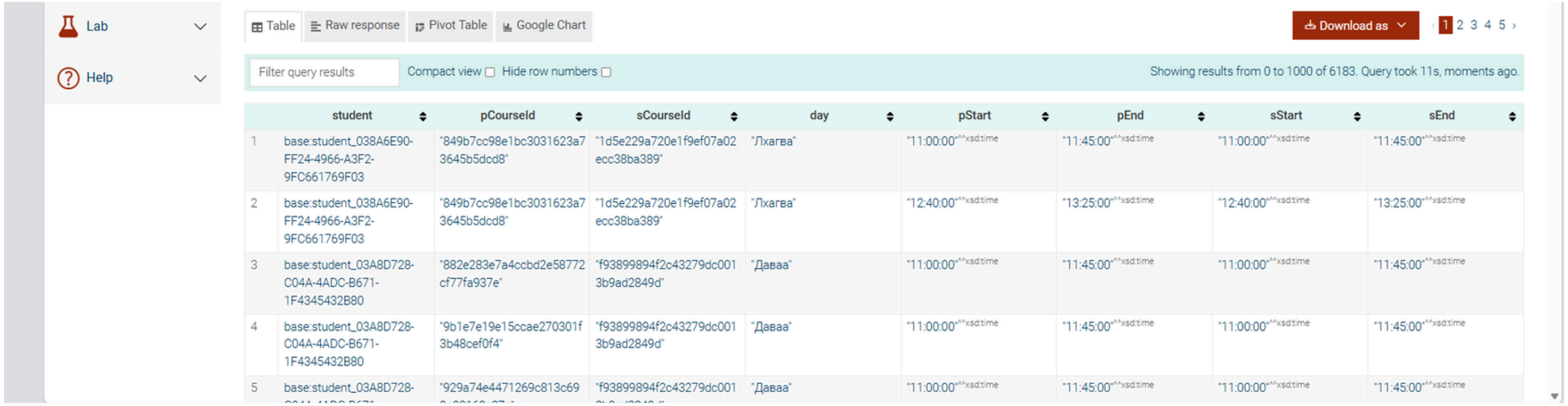
SPARQL queries executed:

- planned course conflicts
- selected and planned course overlaps
- curriculum-required conflicts
- selected and curriculum-required conflicts
- time/day-based schedule queries

Conclusion:

- KG satisfies project purpose
- Supports academic scheduling and validation
- Ready for exploitation and reuse

Plan and select course conflict



	student	pCourseId	sCourseId	day	pStart	pEnd	sStart	sEnd
1	base:student_038A6E90-FF24-4966-A3F2-9FC661769F03	"849b7cc98e1bc3031623a73645b5dcd8"	"1d5e229a720e1f9ef07a02ecc38ba389"	"Лхагва"	"11:00:00"^^xsd:time	"11:45:00"^^xsd:time	"11:00:00"^^xsd:time	"11:45:00"^^xsd:time
2	base:student_038A6E90-FF24-4966-A3F2-9FC661769F03	"849b7cc98e1bc3031623a73645b5dcd8"	"1d5e229a720e1f9ef07a02ecc38ba389"	"Лхагва"	"12:40:00"^^xsd:time	"13:25:00"^^xsd:time	"12:40:00"^^xsd:time	"13:25:00"^^xsd:time
3	base:student_03A8D728-C04A-4ADC-B671-1F4345432B80	"882e283e7a4ccbd2e58772cf77fa937e"	"f93899894f2c43279dc0013b9ad2849d"	"Даваа"	"11:00:00"^^xsd:time	"11:45:00"^^xsd:time	"11:00:00"^^xsd:time	"11:45:00"^^xsd:time
4	base:student_03A8D728-C04A-4ADC-B671-1F4345432B80	"9b1e7e19e15ccae270301f3b48cef0f4"	"f93899894f2c43279dc0013b9ad2849d"	"Даваа"	"11:00:00"^^xsd:time	"11:45:00"^^xsd:time	"11:00:00"^^xsd:time	"11:45:00"^^xsd:time
5	base:student_03A8D728-	"929a74e4471269c813c69	"f93899894f2c43279dc001	"Даваа"	"11:00:00"^^xsd:time	"11:45:00"^^xsd:time	"11:00:00"^^xsd:time	"11:45:00"^^xsd:time

```
PREFIX ont: <http://num.edu.mn/ontology#>
PREFIX tel:  <http://www.semanticweb.org/num/ontologies/2025/academic-scheduling-teleology#>
SELECT DISTINCT       ?student  ?pCourseId ?sCourseId
WHERE {
  ?student a tel:Student ;
           tel:plans   ?planned ;
           tel:selects ?selected .
  ?planned ont:has_course ?pCourse .
  ?pCourse tel:course_id ?pCourseId ;
           tel:has_schedule ?pSchedule .
  ?pSchedule tel:includes ?pSlot .
  ?sSchedule tel:selected ?selected ;
            tel:includes ?sSlot .
  ?sCourse tel:has_schedule ?sSchedule ;
           tel:course_id ?sCourseId .
  FILTER (?pCourseId != ?sCourseId)
}
```

Plan course conflict

Table | Raw response | Pivot Table | Google Chart

Download as

‹ 1 2 3 4 5 ›

Filter query results | Compact view ☐ | Hide row numbers ☐

⚠ Showing results from 0 to 1000 of 51378. Query took 19s, on 2025-12-21 at 16:34.

	student	courseId1	courseId2	day	start1	end1	start2	end2
1	base:student_0023A959-6EAB-427E-A1B3-525231FA452D	"48d094492976621465 72c38c68b7eb5e"	"22108ebbb5f822d6d0f 8dde501523911"	"Лхагва"	"07:40:00"^^xsd:time	"08:25:00"^^xsd:time	"07:40:00"^^xsd:time	"08:25:00"^^xsd:time
2	base:student_0023A959-6EAB-427E-A1B3-525231FA452D	"22108ebbb5f822d6d0f 8dde501523911"	"48d094492976621465 72c38c68b7eb5e"	"Лхагва"	"07:40:00"^^xsd:time	"08:25:00"^^xsd:time	"07:40:00"^^xsd:time	"08:25:00"^^xsd:time
3	base:student_038A6E90-FF24-4966-A3F2-9FC661769F03	"1d5e229a720e1f9ef07 a02ecc38ba389"	"849b7cc98e1bc30316 23a73645b5dcd8"	"Лхагва"	"11:00:00"^^xsd:time	"11:45:00"^^xsd:time	"11:00:00"^^xsd:time	"11:45:00"^^xsd:time
4	base:student_038A6E90-FF24-4966-A3F2-9FC661769F03	"849b7cc98e1bc30316 23a73645b5dcd8"	"1d5e229a720e1f9ef07 a02ecc38ba389"	"Лхагва"	"11:00:00"^^xsd:time	"11:45:00"^^xsd:time	"11:00:00"^^xsd:time	"11:45:00"^^xsd:time

```
PREFIX ont: <http://num.edu.mn/ontology#>
PREFIX tel:  <http://www.semanticweb.org/num/ontologies/2025/academic-scheduling-teleology#>
SELECT DISTINCT ?student ?courseId1 ?courseId2 ?day ?start1 ?end1 ?start2 ?end2
WHERE {
  ?student a tel:Student ;  tel:plans ?p1 , ?p2 .  FILTER (?p1 != ?p2)  ?p1 ont:has_course ?c1 .
  ?c1 tel:course_id ?courseId1 ;  tel:has_schedule ?sch1 .  ?sch1 tel:includes ?slot1 .  ?slot1 tel:day_of_week ?day ;
       tel:start_time ?start1 ;
       tel:end_time  ?end1 .
  ?p2 ont:has_course ?c2 .  ?c2 tel:course_id ?courseId2 ;  tel:has_schedule ?sch2 .
  ?sch2 tel:includes ?slot2 .  ?slot2 tel:day_of_week ?day ;  tel:start_time ?start2 ;  tel:end_time  ?end2 .

  FILTER (?courseId1 != ?courseId2)
  FILTER ( ?start1 < ?end2 &&  ?start2 < ?end1 )
}
ORDER BY ?student ?day ?start1
```

Course schedule

	course	courseId	schedule	start	end
1	base:Course_0806a60e2e5466094ab2652bef28a251	"0806a60e2e5466094ab2652bef28a251"	base:Schedule_253f4d3876291c81fd3d750749e6a0b0	"11:00:00"^^xsd:time	"11:45:00"^^xsd:time
2	base:Course_0806a60e2e5466094ab2652bef28a251	"0806a60e2e5466094ab2652bef28a251"	base:Schedule_fac463decfffbeba7b1403bc8ea95fe7	"11:00:00"^^xsd:time	"11:45:00"^^xsd:time
3	base:Course_088a5f37b756a42a21cc98eaf804ad02	"088a5f37b756a42a21cc98eaf804ad02"	base:Schedule_5e2e894b1d5e003933664988f8f18016	"11:00:00"^^xsd:time	"11:45:00"^^xsd:time
4	base:Course_0a11fb1ef9c2d18f62b0e07d66466447	"0a11fb1ef9c2d18f62b0e07d66466447"	base:Schedule_a4bc793eaaf92f62994484b6868ddc20	"11:00:00"^^xsd:time	"11:45:00"^^xsd:time
5	base:Course_0a2a51dac6138826127f093500461d91	"0a2a51dac6138826127f093500461d91"	base:Schedule_53dd007392fb99c0a08819c66dbf01da	"11:00:00"^^xsd:time	"11:45:00"^^xsd:time
6	base:Course_0a2a51dac6138826127f093500461d91	"0a2a51dac6138826127f093500461d91"	base:Schedule_e00146591f2c03c61dfad23ce2e77362	"11:00:00"^^xsd:time	"11:45:00"^^xsd:time

```
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX tel: <http://www.semanticweb.org/num/ontologies/2025/academic-scheduling-teleology#>
SELECT DISTINCT
      ?course
      ?courseId
      ?schedule
      ?start
      ?end
WHERE {
  ?course tel:has_schedule ?schedule ;
          tel:course_id ?courseId .
  ?schedule tel:includes ?slot .
  ?slot tel:day_of_week "Мягмар" ;
        tel:start_time "11:00:00"^^xsd:time ;
        tel:end_time ?end .
  BIND("11:00:00"^^xsd:time AS ?start)
}
ORDER BY ?courseId
```

Curriculum-course conflict

```
PREFIX ont: <http://num.edu.mn/ontology#>
PREFIX tel: <http://www.semanticweb.org/num/ontologies/2025/academic-scheduling-teleology#>

SELECT DISTINCT
      ?curriculum
      ?courseId1
      ?courseId2
      ?day
      ?start1 ?end1
      ?start2 ?end2
WHERE {
  ?curriculum a tel:Curriculum ;
            ont:has_course ?course1 , ?course2 .
  FILTER (?course1 != ?course2)
  ?course1 tel:part_of ?cc1 .
  ?cc1 tel:group_name "Мэргэших хичээл" .
  ?course2 tel:part_of ?cc2 .
  ?cc2 tel:group_name "Мэргэших хичээл" .
  ?course1 tel:course_id ?courseId1 ;
          tel:has_schedule ?sch1 .
  ?sch1 tel:includes ?slot1 .
  ?slot1 tel:day_of_week ?day ;
        tel:start_time ?start1 ;
        tel:end_time   ?end1 .
  ?course2 tel:course_id ?courseId2 ;
          tel:has_schedule ?sch2 .
  ?sch2 tel:includes ?slot2 .
  ?slot2 tel:day_of_week ?day ;
        tel:start_time ?start2 ;
        tel:end_time   ?end2 .

  FILTER (?start1 < ?end2 && ?start2 < ?end1 )
}
ORDER BY ?curriculum ?day ?start1
```

Filter query results | Compact view ☐ | Hide row numbers ☐ | ⚠ Showing results from 0 to 580 of 580. Query took 0.6s, on 2025-12-21 at 16:41.

	curriculum	courseId1	courseId2	day	start1	end1	start2	end2
1	base:Curriculum_04da4aea8e38ac933ab23cb2389dddef	"0bdfa70fd4894b47e136ae023e2db7c2"	"90a01a8dc851635ad70876baf3b2d216"	"Баасан"	"07:40:00"^^xsd:time	"08:25:00"^^xsd:time	"07:40:00"^^xsd:time	"08:25:00"^^xsd:time
2	base:Curriculum_04da4aea8e38ac933ab23cb2389dddef	"0bdfa70fd4894b47e136ae023e2db7c2"	"dcd688a2201680e19cf948b319505882"	"Баасан"	"07:40:00"^^xsd:time	"08:25:00"^^xsd:time	"07:40:00"^^xsd:time	"08:25:00"^^xsd:time
3	base:Curriculum_04da4aea8e38ac933ab23cb2389dddef	"0bdfa70fd4894b47e136ae023e2db7c2"	"61cfeaeeca00302aed604bef641447a5"	"Баасан"	"07:40:00"^^xsd:time	"08:25:00"^^xsd:time	"07:40:00"^^xsd:time	"08:25:00"^^xsd:time
4	base:Curriculum_04da4aea8e38ac933ab23cb2389dddef	"61cfeaeeca00302aed604bef641447a5"	"90a01a8dc851635ad70876baf3b2d216"	"Баасан"	"07:40:00"^^xsd:time	"08:25:00"^^xsd:time	"07:40:00"^^xsd:time	"08:25:00"^^xsd:time
5	base:Curriculum_04da4aea8e38ac933ab23cb2389dddef	"61cfeaeeca00302aed604bef641447a5"	"dcd688a2201680e19cf948b319505882"	"Баасан"	"07:40:00"^^xsd:time	"08:25:00"^^xsd:time	"07:40:00"^^xsd:time	"08:25:00"^^xsd:time
6	base:Curriculum_04da4aea8e38ac933ab23cb2389dddef	"61cfeaeeca00302aed604bef641447a5"	"0bdfa70fd4894b47e136ae023e2db7c2"	"Баасан"	"07:40:00"^^xsd:time	"08:25:00"^^xsd:time	"07:40:00"^^xsd:time	"08:25:00"^^xsd:time
7	base:Curriculum_04da4aea8e38ac933ab23cb2389dddef	"90a01a8dc851635ad70876baf3b2d216"	"dcd688a2201680e19cf948b319505882"	"Баасан"	"07:40:00"^^xsd:time	"08:25:00"^^xsd:time	"07:40:00"^^xsd:time	"08:25:00"^^xsd:time

Selected and Curriculum-course conflict

```
PREFIX ont: <http://num.edu.mn/ontology#>
PREFIX tel: <http://www.semanticweb.org/num/ontologies/2025/academic-scheduling-teleology#>

SELECT DISTINCT      ?student      ?majorCourseId      ?selectedCourseId      ?day
     ?mStart ?mEnd      ?sStart ?sEnd
WHERE {
 ?student a tel:Student ;
         tel:selects ?selected ;
         tel:has_curriculum ?curriculum .
 ?curriculum tel:includes ?cc .
 ?cc tel:group_name "Мэргэших хичээл" ;
    tel:has_course ?majorCourse .

 ?majorCourse tel:course_id ?majorCourseId ;
           tel:has_schedule ?mSchedule .

 ?mSchedule tel:includes ?mSlot .
 ?mSlot tel:day_of_week ?day ;
       tel:start_time ?mStart ;
       tel:end_time   ?mEnd .

 ?sSchedule tel:selected ?selected ;
          tel:includes ?sSlot .

 ?sCourse tel:has_schedule ?sSchedule ;
         tel:course_id ?selectedCourseId .

 ?sSlot tel:day_of_week ?day ;
       tel:start_time ?sStart ;
       tel:end_time   ?sEnd .

 FILTER (?mStart < ?sEnd && ?sStart < ?mEnd )

 FILTER (?majorCourseId != ?selectedCourseId)
}
ORDER BY ?student ?day ?mStart
```