UNLV

Metadata Repository Design Concepts

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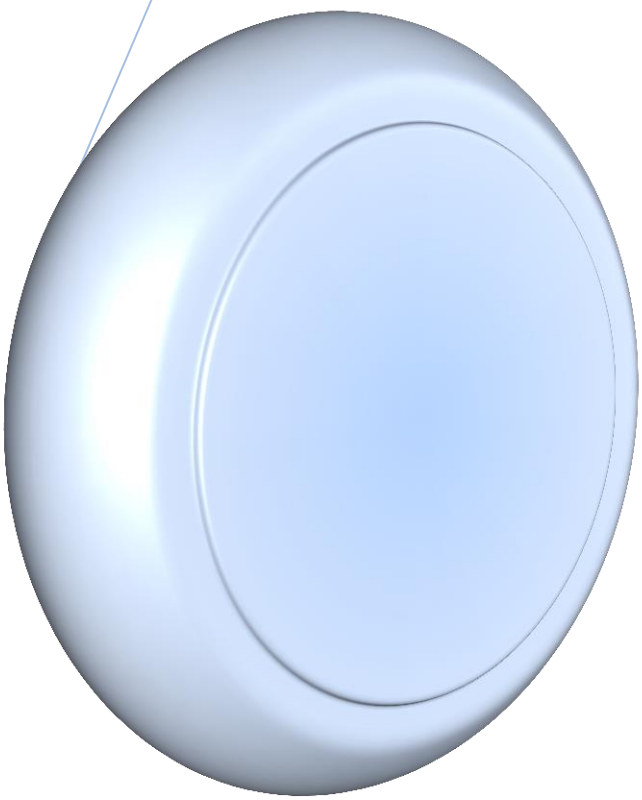

This document describes UNLV's technical approach to the development of an extensible, institutional Metadata Repository. The repository supports the development of multiple subject areas independently, while maintaining the ability to relate any item to any other, including the tracking of lineage relationships.

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5/11/2012

UNLV – Metadata Repository Design Concepts

As a central responsibility in its ongoing efforts to develop an institutional data warehouse and business intelligence initiative, UNLV maintains and develops an institutional Metadata Repository. Subject areas of immediate interest include Data Definitions (elements identified as having strategic value to the institution), Relational Database Metadata (RDBMS systems, tables, and columns), ETL metadata (data warehousing jobs and sequences), and Reporting Elements metadata (OBIEE presentation elements). Additional areas of interest to be developed include Business Process metadata, the tracking of Data Feeds, and the application of Stewardship.

UNLV maintains all subject areas of metadata in a central SQL Server database, designed around a *type/subtype* paradigm borrowed from object-oriented programming. Several key considerations influenced the approach of this design:

1. Ultimately we want multiple subject areas of metadata.
2. Time/resource constraints require us to build this out over time, so we need an approach that allows for expansion.
3. Each subject area of metadata should stand alone, potentially with its own set of applications.
4. We do however want the ability to establish associations among any of the different subject areas.
5. We want the ability to track a complete lineage of relationships across subject areas.
6. Some subject areas may be refreshed or updated via purely automated processes. Some must be manually tracked. We want the ability to work with both.

Type/Subtype Paradigm

To allow for multiple subject areas of metadata to be built independently, but still remain inter-relatable, the metadata repository is designed around a *type/subtype* object concept. One table, *BaseObjects*, serves as a master catalog for all metadata records and contains a few attributes common to all types of metadata:

Column	Description
BaseID	Auto-incrementing identity column.
ObjectType	Up to 8-character text code which identifies the subject area for the given object record
ObjectKey	A key unique within a given subject area; the combination of *ObjectType* and *ObjectKey* is unique across the table.
Name	The title of the object as it appears in the catalog.
Description	A friendly text description of the object.

The *BaseObjects* table serves two purposes. In addition to functioning as the master catalog for all metadata objects, it also, through the *BaseID* field, provides the means for which global ID values are assigned to individual items of metadata. These global ID's are intended to be unique across all subject

areas. In our SQL Server implementation, we use an identity column to auto-increment the values as new items are added to the table. A sequence could be used in an Oracle implementation.

For any given subject area of metadata, a second table is used to hold the specific attributes associated with items of that metadata type. For example, to store information about Data Definitions, we create a *subtype* table called *DataDefinitions_Tbl*. The "Tbl" suffix is a convention used throughout the repository to denote a table that relates to *BaseObjects* but holds type-specific attributes. While *Name* and *Description* are maintained in the central *BaseObjects* table, attributes specific to Data Definitions, such as *Interpretation*, *PotentialValues*, and *SourceDescription* are maintained in the *DataDefinitions_Tbl* subtype table. The two are then related through the common *BaseID* field as the primary key in each.

To ensure that as records are added or updated the data attributes are appropriately divided between the two tables, all data entry, manipulation, and selection is handled through a dedicated view. By convention, the view name is the same as the subtype table without the *_Tbl* suffix. For example, there is a view titled *DataDefinitions* which provides the primary interface for selecting and manipulating records in both the *BaseObjects* and *DataDefinitions_Tbl* tables. The tables themselves are intentionally off-limits for direct editing. Instead we use triggers coded on the view to support editing in such a way as to put the right data in the base and subtype tables.

Example – Tracking Widgets

Say we want to track an area of metadata called *widgets*. (Bad name, I know. Pretend it is a very important metadata subject area of interest.) We start by creating the *BaseObjects* table and a couple of related tables for tracking object types and categories. INSERT statements in the example prepare an object type code 'TESTWIDG' to identify the new metadata area.

```
create table ObjectTypeCategories
(
  CategoryCode varchar(8) primary key
, Category varchar(64)
, CategoryDesc varchar(1024)
)
GO

create table ObjectTypes
(
  TypeCode varchar(8) primary key
, CategoryCode varchar(8) foreign key references ObjectTypeCategories(CategoryCode)
, TypeDesc varchar(128)
, TypeDescShort varchar(32)
, DetailsTable varchar(128)
, DetailsView varchar(128)
)
GO

-- test data
insert into ObjectTypeCategories values ('TEST','Test Category', 'This category is for test
objects.')
go

insert into ObjectTypes
  values ('TESTWIDG', 'TEST','Test Widget', 'TestWidgets_Tbl', 'TestWidgets')


create table BaseObjects
```

```
(
  BaseID int primary key identity(1,1)
, ObjectType varchar(8) foreign key references ObjectTypes(TypeCode) on update cascade
, ObjectKey varchar(128)
, Name varchar(128)
, Description varchar(1024)

, CONSTRAINT cnst_baseObjects_objectKey UNIQUE (ObjectType, ObjectKey)
)
GO
```

We also create a table to hold the attributes that would be specific to a *widget*. Note the unique key applied to the *WidgetID* field. It is important that there be a field that can serve as a unique subject area key. While *BaseID* will be the globally unique key across all subject areas, *WidgetID* will be the unique key within the subject area.

```
-- create the table to store detail information about TestWidgets.
-- By convention, end this in _Tbl
create table TestWidgets_Tbl
(
 BaseID int primary key foreign key references BaseObjects(BaseID) on delete
cascade
,WidgetID int
,ManufactureDate datetime
,Manufacturer varchar(32)

,CONSTRAINT cnst_testWidget_WidgetID UNIQUE (WidgetID)
 )
GO
```

Finally, we create the view intended to be the primary interface for adding, modifying, and deleting *widgets*. The view selects columns from both the *BaseObjects* and *TestWidgets_Tbl* tables, ensuring that the full set of editable attributes for the widget is available in one database object.

```
-- create the view to display detail TestWidget data with corresponding
-- base data.  By convention, we won't include a suffix (we want
-- to treat it as though it is a table).
create view TestWidgets
as
select d.BaseID
     , b.Name, b.Description
     , d.WidgetID, d.ManufactureDate, d.Manufacturer
  from TestWidgets_Tbl d inner join BaseObjects b on d.BaseID = b.BaseID
GO
```

To make the metadata view fully interfaceable we code INSTEAD OF INSERT, UPDATE, and DELETE triggers on the view. The INSTEAD OF INSERT trigger adds a record for the metadata item to the *BaseObjects* table, generating the new primary key *BaseID* for the item. It then in turn uses this newly generated key to insert a record in the subtype *TestWidgets_Tbl* table. The INSTEAD OF UPDATE and INSTEAD OF DELETE triggers similarly work to affect both tables appropriately. Note the use of the *ObjectKey* field – the field in *BaseObjects* which is intended to be unique within a given *ObjectType* - in each trigger. This key mechanism matched to the subject area key *WidgetID* is used to keep records synchronized across both tables.

```
-- create an INSERT INSTEAD OF trigger on the view, to ensure the right
-- fields are inserted in the base & the detail; also ensure the creation
-- of the BaseID and its proper assignment in the detail table

CREATE TRIGGER TestWidgets_Trigger_Insert_InsteadOf
ON TestWidgets
INSTEAD OF INSERT AS
BEGIN

    declare @typeCode varchar(8)
    set @typeCode = 'TESTWIDG'

        -- insert the base record(s) first so we can generate BaseID's;
        Insert Into BaseObjects (ObjectType, ObjectKey, Name, Description)
     Select @typeCode
           , convert(varchar(64),WidgetID)
           , Name
           , Description
       from inserted

    -- now link the BaseObjects data back to [inserted] to join the new BaseID
    -- and insert the rest of the details in TestObjects_Tbl
        Insert Into TestWidgets_Tbl (BaseID, WidgetID, ManufactureDate, Manufacturer)
     Select b.BaseID
          , i.WidgetID, i.ManufactureDate, i.Manufacturer
       from inserted i inner join BaseObjects b on convert(varchar(64),WidgetID) = b.ObjectKey
      where b.ObjectType = @typeCode


END
GO


-- create an UPDATE INSTEAD OF trigger on the view, to ensure the right
-- fields are updated in the base & the detail;

CREATE TRIGGER TestWidgets_Trigger_Update_InsteadOf
ON TestWidgets
INSTEAD OF UPDATE AS
BEGIN

        -- trying to update BaseID?  Don't allow that
    if (UPDATE(BaseID))
    begin
        raiserror(N'You can not edit the BaseID.', 16, 1)
        return
    end

    -- other base fields are okay
    if (UPDATE(Name)) begin
        Update BaseObjects Set Name = i.Name
          from inserted i inner join BaseObjects b on i.BaseID = b.BaseID
         where i.BaseID = b.BaseID
    end
```

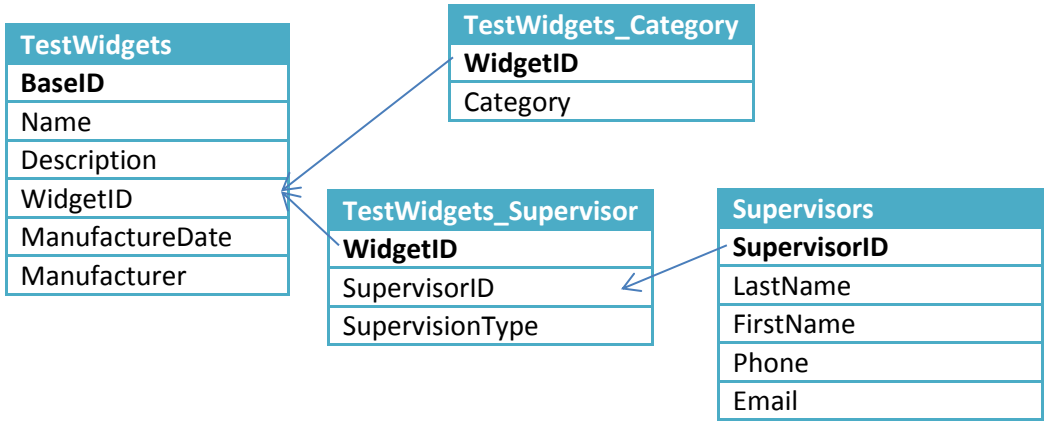
```
    if (UPDATE(Description)) begin
        Update BaseObjects Set Description = i.Description
          from inserted i inner join BaseObjects b on i.BaseID = b.BaseID
         where i.BaseID = b.BaseID
    end


    -- now look to the detail fields
    -- by convention, if the WidgetID changes, update the ObjectKey in the base to keep them in
sync
    if (UPDATE(WidgetID)) begin
        Update TestWidgets_Tbl Set WidgetID = i.WidgetID
          from inserted i inner join TestWidgets_Tbl b on i.BaseID = b.BaseID
         where i.BaseID = b.BaseID

        Update BaseObjects Set ObjectKey = convert(varchar(128),WidgetID)
          from inserted i inner join BaseObjects b on i.BaseID = b.BaseID
         where i.BaseID = b.BaseID
    end

    -- and address the other  detail fields
    if (UPDATE(ManufactureDate)) begin
        Update TestWidgets_Tbl  Set ManufactureDate = i.ManufactureDate
          from inserted i inner join TestWidgets_Tbl b on i.BaseID = b.BaseID
         where i.BaseID = b.BaseID
        end

    if (UPDATE(Manufacturer)) begin
        Update TestWidgets_Tbl Set Manufacturer = i.Manufacturer
          from inserted i inner join TestWidgets_Tbl b on i.BaseID = b.BaseID
         where i.BaseID = b.BaseID
        end


END
GO


-- create a DELETE INSTEAD OF trigger on the view
CREATE TRIGGER TestWidgets_Trigger_Delete_InsteadOf
ON TestWidgets
INSTEAD OF DELETE AS
BEGIN
        -- actually delete from the BaseObjects table.
    -- cascade delete will take care of removing other referenced records
    delete from BaseObjects
     where BaseID in (select BaseID from deleted)
END
GO
```

There may be significant work to establish the subtype table, view, and triggers, but once that work is complete, the following benefits are gained:

1. All items of metadata are centrally cataloged in the *BaseObjects* table and given a *BaseID* value that will be unique across all metadata subject areas. This is important to build inter-relationships among different subject areas and establish flexible lineage relationships.
2. The *TestWidgets* view may now be treated exactly like a table. One may use plain SQL to insert, update, or delete from it, and the *BaseObjects* data remain in sync.

3. The *TestWidgets* view may also be exposed to any application development context. One could create an application that manages *TestWidgets* data independently of other metadata. One could also use an ODBC connection to *TestWidgets* for editing or reporting contexts.
4. The *TestWidget* coding serves as a template for other subject areas. After building one, the others are easier.

It is also useful to know that, for the *TestWidget* subject area, only the main *TestWidgets* table (view) requires this level of attention as the only object data that will be maintained in the master catalog. Other tables that would provide related data to *TestWidgets* may be built as normal tables and related to *TestWidgets* on the subject area key *WidgetID*. For example, consider the following schema that links a widget category and a widget supervisor to the main *TestWidget* table:



All tables within the subject area relate on the subject area key *WidgetID*. The only table with the *BaseID* identifier, and a record in the main catalog *BaseObjects*, is the main *TestWidgets* table itself. In this way, a complete metadata subject area may be easily developed independently of others, while preserving its place in the master catalog.

Metadata that can be Automatically Refreshed

The following are metadata areas that can be refreshed (kept up-to-date) through at least somewhat automated strategies:

Metadata Area	General Strategy for Source
Relational Databases, Tables, and Columns	Execute queries against INFORMATION_SCHEMA views to retrieve database, table, and column metadata
PeopleSoft Metadata	Query PS metadata tables such as PSRECDEFN, PSDBFIELD, PSPNLFIELD to retrieve record, field, and page information.

DataStage ETLs	Use the Export XML utility in the DataStage Manager application to generate xml representations of desired ETL's; write scripts to parse the resulting XML to extract ETL metadata, including source and target database tables
OBIEE Repository Layers (Physical, Logical, Presentation)	Use the Generate Metadata Dictionary utility in the OBIEE Administrator application to generate xml representations of desired repository layers; write scripts to parse the resulting XML to extract OBIEE metadata, including relationships of objects among layers.

For any metadata that can be automatically refreshed, we build staging tables in the metadata repository to correspond to the type/subtype metadata views holding the active data. These staging tables are periodically truncated and loaded with up-to-date metadata through whatever automated strategy makes sense. A stored procedure is then run to compare the existing active metadata to the newly staged set based on the subject area key. The stored procedure updates or adds any changed metadata records (without disturbing the *BaseID* global key in the case of updates).

Metadata that is Manually Tracked

Data definitions, business processes, data feeds, and stewardship are examples of metadata which must be manually cataloged and updated over time. Rather than using staging tables, we build applications to manage the live data for these subject areas. Applications may be specifically targeted to a given subject area, and may be used to manage relationships among subject areas.

Designing for Associations among Metadata Areas

Regardless of whether metadata is automatically refreshed or manually tracked, the application of the globally unique *BaseID* allows any item to relate to any other.

Consider the example of a Data Definition, which records a strategically-valuable informational element and instructions on how to derive the element from transactional sources. Though the Definition is conceptual, it is ultimately implemented in the data warehouse, with logic in an ETL writing a derived result to its own database column. It is desirable to relate the Data Definition item with the ETL and the Database Column items.

As we determine specific areas where such associations make sense, we build those in as their own detail tables in a subject area schema. For example: *DataDefinitions* (the metadata view for DataDefintions_Tbl) has a related table *DataDefinitions_Implementations*, with two columns: *DefinitionID* and *ImplementationID*. Each column is a foreign key to the *BaseID* column in the *BaseObjects* table. *DefinitionID* holds the *BaseID* for a specific Data Definition record, and *ImplementationID* holds the *BaseID* value for a related Database Column, OBIEE Presentation Element, or ETL job. In this way we can track implementations related to a given Data Definition, regardless of the implementation's type.

Stewardship provides another metadata area which may be associated to any of a number of other metadata items. An Operational Steward may be associated to a Business Process or a Data Definition. A Technical Steward may be associated to a Data Feed, or a Data System. Tables holding information about individuals and their roles in the institution may be maintained in the central Stewardship subject area, while specific associations to other metadata items may then be recorded in a *Stewardship_Responsibilities* table, using the *BaseID* of objects to make the relationship.

Lineage

Lineage is a series of associations across different subject areas, with each association in the chain implying a specific atomic relationship between two items of metadata. The goal is to track how a given metadata item (like a database table) may be a source to another (like an ETL job) which itself may be a source to another (like a target database table) and so on (the target table is a source to a reporting application, etc.) We define lineage as a series of *ancestor-descendant* relationships, with one item clearly defined as the ancestor (source to) and the other its descendant (target of) at any stage in a lineage chain.

Our data lineage flows in this general format:

- PeopleSoft Pages host PeopleSoft Records (Pages are ancestors, Records are descendants)
- PeopleSoft Records are instantiated as Database Tables (Records are sources - ancestors - for Tables, their descendants)
- Database Tables are sources for ETL jobs (Tables are ancestors to ETL jobs)
- ETL jobs then write to different Database Tables (ETL jobs are ancestors to additional Tables)
- Those Database Tables are then sources to an OBIEE repository Physical Layer (Table is the ancestor; a Physical Layer is the descendant). Those Database Tables may also be sources to additional ETL jobs that provide additional data processing and restructuring.
- An OBIEE Physical Layer is a source to a Logical (Business Model) Layer (Physical is the ancestor, Logical is the descendant)
- That Logical Layer is a source to a Presentation Layer (Logical is the ancestor to its descendant Presentation)
- That OBIEE Presentation Layer may then be a source to specific institutional reports or dashboards (the Presentation Layer is an ancestor, with specific Reports/Dashboards as descendants)

We maintain these relationships in a single table called *Lineage*. This table has two columns, simply *Ancestor* and *Descendant*, each a foreign key to the *BaseID* column of the *BaseObjects* table. This gives the most flexibility to allow any metadata item desired to participate in a lineage chain. The following table shows an example of how these lineage relationships are represented in the *Lineage* table:

Ancestor	Descendant
101	207
207	305
207	309
305	415
312	415
404	592
406	593
415	594

As an example, take item 594, the descendant in the last row and trace its ancestry up the table. Its immediate parent is item 415, which itself is derived from items 305 and 312. Item 312 has no additional ancestors, but item 305 does with its immediate parent 207. Item 207 is then a child of item 101. The full lineage from item 101 to item 594 then looks like this:

101 → 207 → 305 → 415 → 594.

Item 101 may be a PeopleSoft Record, 207 a Database Table, 305 an ETL job, 415 a target Database Table, and 594 a reporting application leveraging that table. This example illustrates two very powerful benefits of maintaining lineage:

- We can trace back any reporting element not just to its source database tables, but beyond that right to the PeopleSoft editing interfaces. This provides a quick way to identify the sources for reporting elements.
- We can trace items forward in the lineage as well. If, for example, modifications were made to a given PeopleSoft page or record, it would be a simple query to determine what Database Tables, ETL jobs, and Reporting elements could be affected by the modifications.

To achieve a hierarchical result set that spans the full lineage tree, we query the *Lineage* table using recursive *common table expressions* in SQL. The following SQL shows a query to display all ancestors for a given metadata item:

```
-- @baseID is a parameter established elsewhere
-- which represents the metadata item for which we wish to
-- see its ancestry.

        with Ancestors as
        (
                -- anchor
                select r.Ancestor, r.Descendant, -1 as Level, r.Ancestor as BaseID
                                , b.Name, b.Description, b.ObjectType, b.ObjectKey
                        from Lineage r inner join BaseObjects b on r.Ancestor = b.BaseID
                        where r.Descendant = @baseID

                -- recurse
                union all
                select r.Ancestor, r.Descendant, Level - 1 as Level, r.Ancestor as BaseID
                                , b.Name, b.Description, b.ObjectType, b.ObjectKey
                        from Lineage r inner join BaseObjects b on r.Ancestor = b.BaseID
                                        inner join Ancestors a on r.Descendant = a.Ancestor
```

```
        )
        select distinct Level, BaseID, Name, Description, ObjectType, ObjectKey
                from Ancestors
                order by Level
        ;
```

Likewise, we use the following to query for an item's descendants:

```
-- @baseID is a parameter established elsewhere
-- which represents the metadata item for which we wish to
-- see its descendants.

        with Descendants
        as
        (
                -- anchor
                select r.Ancestor, r.Descendant, 1 as Level, r.Descendant as BaseID
                                , b.Name, b.Description, b.ObjectType, b.ObjectKey
                        from Lineage r inner join BaseObjects b on r.Descendant = b.BaseID
                        where Ancestor = @baseID

                -- recurse
                union all
                select r.Ancestor, r.Descendant, Level + 1, r.Descendant as BaseID
                                , b.Name, b.Description, b.ObjectType, b.ObjectKey
                        from Lineage r inner join BaseObjects b on r.Descendant = b.BaseID
                                        inner join Descendants a on r.Ancestor = a.Descendant
        )
        select distinct Level, BaseID, Name, Description, ObjectType, ObjectKey
                from Descendants
                order by Level
        ;
```

Because *BaseID* values are global across the entire metadata repository, any metadata item may serve in an ancestor-descendant relationship with any other. This is very flexible, but does introduce some considerations:

- If not careful, it is possible to introduce circular relationships in the *Lineage* table. Having the same item recorded as both the ancestor and descendent in the same lineage record is an obvious example. A less obvious, but more likely example could be an ETL job that sources from and writes to the same table. Or this example: table A is a source to an ETL which writes to table B… table B is the source to another ETL which writes to table A. It is important to ensure that processes which populate the *Lineage* table account for these potential circular relationships.
- It is possible to record lineage relationships that skip intervening levels. Borrowing from the above example, one could write a lineage row with PeopleSoft Record 101 as the ancestor and Report 594 as the descendant. If the intervening levels of metadata have not been developed out, this might even be desirable -- a short-term solution until the rest of the metadata is fleshed out. But as additional metadata areas come online, it is preferable that the ancestor-descendant records reflect immediate, atomic relationships to the extent possible.

To help address these concerns, we populate our *Lineage* table exclusively through a stored procedure. This stored procedure truncates the table and repopulates it according to current metadata entries and relationships, with logic that imposes rules designed to prevent circular references. We intend to update this procedure as new metadata areas are developed, to position them correctly in the full lineage tree.

Summary

UNLV's approach to the design of its Metadata Repository reflects the desire to build out additional subject areas over time, while allowing for associations among items in different metadata areas. Attributes that are common to all metadata items, such as *Name* and *Description* are maintained in a central *BaseObjects* table. This table also maintains the *BaseID* field, a primary key that is globally unique across all metadata areas. The *BaseObjects* table also serves as a master catalog of all metadata items in the system.

For each metadata type, a second *subtype* table holds the attributes appropriate for it, and is named with a *_Tbl* prefix by convention. A *metadata view* then combines the base attributes with the subtype attributes into a single object, with triggers coded to make it fully interfaceable. Subject areas may be developed independently and make use of a subject-area key for relating data within the metadata area. The *BaseID* global key may then be used to create relationships across subject areas. This is particularly useful for establishing lineage relationships with as much flexibility as possible.