

# Temporal Qualification in Topic Maps

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**Abstract.** This paper will introduce a number of predefined elements for the Topic Maps Data Model. It will start with a short introduction of the level and possible context of these elements. Then the problem this paper deals with will be described. This will be the problem of adding temporal qualifications to a topic map. A set of criteria for the quality of a possible solution will be given and possible solutions will be evaluated against these criteria. This will lead to the final proposal for adding temporal qualification to a topic map.

## 1 Introduction

This paper deals with the problem of adding temporal quantifications to Topic Map constructs. This will be referred to as the problem of this paper. We will only deal with the problem of modeling the temporal domain insofar it is necessary for the problem of the paper. In modeling the temporal domain, as it is understood here, one would be concerned with questions like the decision, if a date that already exists in a topic map should be used to model a stretch of time, if there should be a minimal resolution of dates, if temporal entities should all have calendar dates as names or if other names should be allowed (e.g. should it be allowed to create a temporal entity “Renaissance” ?) and so on. The problem of this paper in contrast will be the connection between the domain modeled in this way and Topic Map Constructs in general. These connections are supposed to express temporal aspects of the information given in a Topic Map. This problem will be defined more precisely in section 3 of this paper. Before this is done we will look at a wider project in relation to the Topic Maps Data Model. The problem of this paper and the proposed solution are part of this wider project.

## 2 Predefined Constructions for Topic Maps

The topic of this paper can be associated with the larger goal of giving a set of predefined constructions for Topic Maps. These constructions could be used for modeling tasks that occur repeatedly in creating a Topic Map. With such predefined elements it would be possible to use their predefined semantics in order to allow for automatic reasoning with given Topic Maps. Many other

generic interfaces would possible for Topic Maps with such predefined constructions.

An example for an already existing predefined construction is the supertype-subtype relation. This example also illustrates the relation to the Topic Maps Data Model. The set of predefined constructions should be an additional level using the Topic Maps Data Model. The predefined relations should not add any elements to the model itself. No new elements should be added because the set of predefined constructions could be an open set, where new standard solutions to problems are added as they are agreed upon by the community. Allowing this set of predefined relations to add new constructions would therefore be impractical with respect to establishing all-purpose topic map engines. The domain of predefined constructions will be referred to as *pred* in this paper for lack of an established domain.

Such constructions should be defined by giving the topic map constructs to be used and the PSIs that should identify them. With these elements given it is easy to identify predefined constructs and merge them according to their semantics, when different topic maps are merged.

One possible objection to this idea could be that the semantics of these constructions are fixed. Therefore anyone using those predefined constructions might be forced to give or leave out information that is not available or that is not supposed to be given. When and how predefined relations are used would be standardized and therefore these constructions would have fixed semantics. However it would still be possible for any topic map creator to add any information that would be necessary for computations or other tasks. If information necessary for a certain construction should be left out, another construction might be used. Another objection to a standardization project may be that such constructions may be an overkill for certain tasks. This objection can be defused if interfaces for the automated inclusion of these constructions would be provided. In this case they could be added without much additional work to be done and could be processed efficiently.

In order to create such a set of predefined constructions it will be necessary to identify the problems the Topic Maps community faces repeatedly in modeling domains and create a forum for their discussion. There has to be a common agreement about what is to be achieved by using these predefined constructions and there should be interfaces handling these predefined constructions built on top of popular Topic Map Engines.

This paper will introduce a problem that one often faces in creating a topic map: temporal qualifications for topic map constructs. Discussing this problem will serve as an introduction for predefined constructions and their standards.

### 3 The Problem

It is an recurring task to model temporal relations within a topic map and then to connect the modeling of the temporal domain with other information in that topic map. Throughout this paper the following examples will be used, each

example includes a description of the relevant Topic Maps Constructs in CTM. While discussing different solutions to the problem of temporal qualifications example code for those solutions will be added:

1. Storing the birth and death date of a person represented in a topic map. Let us assume that there is a topic representing John and the topic map is supposed to include the information that John was born on 01.02.1904 and died on 05.06.1977. How is this to be modeled?

```
John;
http://www.foo.bar/John;
- "John Johnson".
```

2. When information is added to a topic map, it may be necessary to store additional meta information including when the information was gathered. Consider a costumer service collecting data. After a given amount of time, collected data may have to be deleted. Therefore it should be added to a topic map just when any piece of information was collected. Here a piece of information may be a Name, an Occurrence or an Association. For the example assume we also know bank account number and want to add to our topic map the information, that we collected this data on the 08.09.1967.

```
John;
http://www.foo.bar/John;
- "John Johnson";
AccountNumber:"1234567".
```

3. It may be necessary to include information about the time at which certain information applies. This is similar to the problems addressed by using scope. In our example we might want to add the information that the Johns marriage, which is modeled by an Association, lasted from 05.04.1969 to 03.02.1974.

```
John;
http://www.foo.bar/John;
- "John Johnson";
AccountNumber:"1234567".
Mary;
http://www.foo.bar/Mary;
- "Mary Johnson".
married(husband:John,wife:Mary).
```

We will refer to these examples as “problems” 1,2 and 3 respectively throughout the paper and refer to the whole set of examples as the example problems.

It would be easy to come up with additional problems. The examples given have the benefit of including the most frequently used Topic Maps Constructs. Associations, Topics and Occurrences are to be temporally qualified. There is

no example for Names as these are so similar to Occurrences that any solution for one of these construct types is almost certain to solve the problem for both.

Each of these problems seems to have a natural solution in the topic maps framework and all of them are quite different in terms of the mechanisms used. Still this paper will argue for a general standard for modeling temporal information. This decision will be justified in the following chapters.

As said before this paper will only be concerned with the question of modeling the temporal domain insofar this is necessary for the purpose of using the temporal domain for temporal qualifications. It is assumed that there is some solution for modeling the temporal domain in place.

#### 4 Discussion of the Problems and Arguments for a Standard

Returning to the example problems in the last section it will be helpful to discuss what would be a natural way of solving those problems. This will help in introducing the different types of solutions and it will be a starting point for arguing that a standard for modeling temporal qualification will be useful.

Problem 1 seems to have two natural solutions. The first one would be to give two Occurrences “Birthdate” and “Deathdate” for the topic Representing John and maybe for any topic representing a person. this solution to problem one would look like this:

```
John;
http://www.foo.bar/John;
- "John Johnson";
AccountNumber:"1234567"
Birthdate:"01.02.1904"
Deathdate:"05.06.1977".
Mary;
http://www.foo.bar/Mary;
- "Mary Johnson".
married(husband:John,wife:Mary).
```

Another possible solution is creating topics for both dates and adding an association with appropriate role types. The code for this solution could look like this:

```
John;
http://www.foo.bar/John;
- "John Johnson";
AccountNumber:"1234567".
Mary;
http://www.foo.bar/Mary;
- "Mary Johnson".
```

```

married(husband:John,wife:Mary).
lived(person:John,birth:01.02.1904,death:05.06.1977).
01.02.1904;
"01.02.1904".
05.06.1977;
"05.06.1977".

```

Both solutions include an assumption about the temporal domain insofar as the first assumes dates to be data that is not further structured using the Topic Maps Data Model and the second approach assumes that there are topics to represent the different dates.

The most natural solution to problem 2 (at least in the opinion of the authors) is to make use of Reification to store meta information. This is not fully correct with respect to the semantics of Topic Maps, as Reification means that a topic is used to represent the statement made by the Reified construct. A construction that uses an item identifier of the occurrence as the subject locator of another topic to which the necessary meta information is assigned would be more accurate. However this method seems overly complicated. The Reifier related construction that is chosen will be used with date topics and an association that has an appropriate type to indicate that this association represents meta information. Therefore the following code is the proposed solution:

```

John;
http://www.foo.bar/John;
- "John Johnson";
AccountNumber:"1234567"
Reifier: OccurrenceReifier.
Mary;
http://www.foo.bar/Mary;
- "Mary Johnson".
married(husband:John,wife:Mary).
lived(person:John,birth:01.02.1904,death:05.06.1977).
01.02.1904;
"01.02.1904".
05.06.1977;
"05.06.1977".
08.09.1967;
"08.09.1967".
OccurrenceReifier;
http://www.foo.bar/Reifier.
collected_at(collected:OccurrenceReifier,
collection_time:08.09.1967).

```

Problem 3 could be solved by using scope. The only problem with this approach is deciding if one should use just the dates that already exist or to create a new topic to be used as a scope. In this case we decided to just use a topic

representing the stretch of time for which the statement is valid. This leads to the following code:

```
John;
http://www.foo.bar/John;
- "John Johnson";
AccountNumber:"1234567"
Reifier: OccurrenceReifier.
Mary;
http://www.foo.bar/Mary;
- "Mary Johnson".
married(husband:John,wife:Mary) @ 05.04.1969 - 03.02.1974.
lived(person:John,birth:01.02.1904,death:05.06.1977).
01.02.1904;
"01.02.1904".
05.06.1977;
"05.06.1977".
08.09.1967;
"08.09.1967".
05.04.1969 - 03.02.1974;
"05.04.1969 - 03.02.1974".
OccurrenceReifier;
http://www.foo.bar/Reifier.
collected_at(collected:OccurrenceReifier,
collection_time:08.09.1967).
```

So why should one want to introduce a standard for creating temporal qualifications?

The first argument is more or less obvious from the discussion of the examples. The temporal information is stored in many different ways. If one encounters a new topic map that they did not create it may be unclear how to interpret the constructions used to store temporal information. A standard for the introduction of temporal information would counteract this tendency.

The second reason that comes to mind is the use in general interfaces. These could be user interfaces for the generation of Topic Maps that provide predefined elements for topic maps or reasoning tools operating on Topic Maps. A standard way for introducing temporal information would allow such interfaces to automatically find and display temporal information. As introducing temporal qualifications is a recurring problem in creating Topic Maps advanced user interfaces should incorporate a way of easily integrating temporal information into a Topic Map. A predefined standard will help making this integration easier.

## 5 The Types of Problems

In order to define a standard for integrating temporal qualifications it will be useful to identify some general classes of problems that should be solved using

this standard. The first question in identifying these problems is how they should be characterized. In this paper the problems will be described by two different properties. The first property is the type of construct in a Topic Map or domain references which should be qualified with temporal information. Each type of construct allows for different ways of including temporal qualifications. This property of a problem will be referred to as the construct type.

The types of constructs will be separated into the classes *Reifiable*, *Scoped* and *Topics*. These classes are chosen, as all Topic Maps Constructs belong to at least one of these classes. They are also chosen because they are actual classes in the *TMAPI* [1]. At least Reification and scoping are very natural ways to handle temporal information. Topics have to be chosen as a single class because they belong to no other general class in the Topic Maps Data Model. Note that these classes are not mutually exclusive. In fact the set of Scoped Constructs is included in the set of Reifiable Constructs.

The second property that will be used to describe the problems to be solved by this paper is the type of information that is given by way of a temporal qualification. This is important for differentiating between information in a Topic Map. This will be referred to as the information type. This paper will consider three different types of information. The information type exemplified by problem 1 is information about the domain that is to be described. This class will accordingly be called domain information. The second problem is an example of information about the validity of the information given. Here validity is meant to denote a distinction between situations where a piece of information can be used and when it cannot be used. This is obviously the distinction intended to be made by using scope. Therefore this will be called scope information. The last type of information is the information related to the collection and use of information. This will be called meta-information.

It is important to note that it may be necessary to make a distinction between information about a Topic Map construct and information about the statements and referents the Topic Map Constructs refer to. This will be handled in this paper by drawing a differentiation between meta information and other information.

Therefore the following geometry for all problems discussed in this paper will be the following:

	domain information	meta information	validity information
scoped	?	example 2	example 3
Reifiable	?	example 2	example 3
topic	problem 1	?	?

Not all the fields are filled with possible examples. However it should be easy to come up with additional examples based on the ones given so far. When it is necessary we will present additional examples.

The standardization approach proposed here is supposed to give one solution for each of the fields in this table.

## 6 Criteria for a Good Standardization

Before different standardization approaches are discussed it will be necessary to establish a way of deciding what would constitute a good standardization approach as opposed to a bad one. Therefore a list of desirable qualities for a standardization approach will be given and justified. With each criterion we will also mention whether we think this criterion should be necessary or if it is a gradual criterion. Also some criteria will be introduced that are specific to the problem of this paper.

1. The solution should be minimal with respect to the number of new Locators.
  - This criterion is gradual.
  - The spirit of the Topic Maps Data Model includes the attempt to allow for giving models of a domain with a minimal amount of constructions while still keeping the created model human readable. Introducing a new predefined construction will be done by defining how an instance should be constructed and which Locators should be used.
2. The solution should be minimal with respect to the number of new Topic Map Constructs demanded to create an instance.
  - This criterion is gradual.
  - In order to keep Topic Maps that adhere to the standards introduced by the predefined constructions small this criterion should be observed.
3. The different elements of the temporal domain should be represented as topics and the temporal information should be connected to these topics.
  - This is a necessary condition.
  - It has been proposed to include temporal information in the form of simple time stamps, maybe even introducing a new data type to do this. We think that this approach should not be used. This is the case because of the basic goal of Topic Maps to allow for the simple management of Subject related information. If dates are represented by topics, it is simple to manage all the information related to a date by managing and maybe merging the topics representing the date.  
Note that this criterion forces a certain structure in the modeling of the temporal domain. However we do only demand that there are topics representing elements of the temporal domain.
4. It should be possible to add temporal information to any Topic Map construct.
  - This is a necessary condition.
  - Temporal information may be necessary in all stages of the construction of a Topic Map. From information about the time when a Topic Map was constructed to information about when data of an occurrence came to be defined.
5. It should be possible to add further information to each temporal qualification.
  - This is a necessary condition.

- When a temporal qualification is given it might be necessary to add some information to these qualifications. E. g. when saying when some information was checked it might also be useful to add the information who checked it and how.
6. It should be possible to add multiple temporal qualifications to a construct.
    - This is a necessary condition.
    - It should be obvious that this is necessary if a domain is complicated. There may be information about the birthdate, deathdate and other dates for a person to give an example.
  7. No extension should be required for the Topic Maps data model.
    - This is a necessary condition.
    - It was already mentioned that this criterion should generally be fulfilled by any predefined construction. This way there is no dependence between the set of predefined constructions and generic Topic Maps engines.

This set of criteria will be used in the evaluation of all possible solutions to the problem of this paper which is supposed to be part of a discussion about predefined constructions and temporal qualification. Therefore the criteria proposed here should be subject to a discussion in the Topic Maps community.

## 7 Possible Solutions

This section will introduce four approaches to including temporal information into Topic Maps. All of them represent a very straight forward use of the possibilities of the Topic Maps Data Model. With each possible approach we will revisit the example problems to show how they would be solved using this approach if it is at all possible.

### 7.1 Scope

In order to model temporal information by using scope all that needs to be done is create date topics and use them as scopes. But when only date topics are used, it is not clear what kind of information is given. When it is necessary to add information about the time a name became valid and information about the time when this name information was collected, then simple date topic will not allow to make this distinction. Therefore one would have to use topics that represent all or some of the temporal information given about a Topic Map construct in another way. This is undesirable as it makes the creation of additional Topic Maps constructs necessary. Another disadvantage of the scope approach is its dependency on scope. It can only be applied if the construct in question allows for scoping. Therefore topics and Reifiable constructs that do not allow for scope could not be handled by this approach. In our code example we will just show what we meant with creating special topics for the representation of the temporal information. We assume that this information should be added by making use of one of the methods proposed later in this article.

```

John;
http://www.foo.bar/John;
- "John Johnson";
AccountNumber:"1234567"
@TimeTopic1.
Mary;
http://www.foo.bar/Mary;
- "Mary Johnson".
married(husband:John,wife:Mary) @TimeTopic2.
TimeTopic1;
http://www.foo.bar/TT1.
TimeTopic2;
http://www.foo.bar/TT2.

```

As you can see no code for the dates related to John's life are added. With this example it is possible to solve some of the problems defined by the given geometry.

	domain information	meta information	validity information
scoped	x	x	x
Reifiable	?	example 2	example 3
topic	problem 1	?	?

The "x" marks would give the problems that can be solved if a solution using Scopes is given.

## 7.2 Occurrences

Another way of solving the temporal qualification problem is to introduce occurrences of a special type and let them have the dates as their values. The distinction between domain, scope and meta information could be drawn by using different types of occurrences, which could be added directly to the topics. In case of other constructs one could use topics in the scope to which the occurrences are added or add them to a Reifier. In order to have a homogeneous solution the authors would prefer the Reifier approach.

Additional information could be given by Reification of the occurrences. So it would also be possible to add information about the temporal informations.

The main problem with this approach is the question of what to use as the value of the occurrences. It was stipulated that elements of the temporal domain should be given in the form of topics. A connection could be made by using the topics representing the dates as the values of the occurrences. In the current version of the TMAPI this is not a legal data type for this a occurrence. This could be changed and it would not constitute a change to the Topic Maps Data Model. Changing the definitions of the TMAPI should be discouraged in the context of additional constructions. Another possibility for creating a relation to the temporal topics would be adding one of their locators as the value of the

occurrence. This would only be a partial solution. If there is a change to the temporal topics and especially to their locators, this would not automatically be reflected in the relevant occurrences. This may be problematic if there is a need to change the identifiers for a date topic.

To end this discussion the following code gives an example how the occurrences could be used:

```

John;
http://www.foo.bar/John;
- "John Johnson";
AccountNumber:"1234567"
Reifier: OccurrenceReifier
birthdate: 01.02.1904
deathdate: 05.06.1977.
Mary;
http://www.foo.bar/Mary;
- "Mary Johnson".
married(husband:John,wife:Mary);
Reifier: AssociationReifier.
01.02.1904;
"01.02.1904".
05.06.1977;
"05.06.1977".
08.09.1967;
"08.09.1967".
05.04.1969 - 03.02.1974;
"05.04.1969 - 03.02.1974".
OccurrenceReifier;
http://www.foo.bar/Reifier;
collected: 08.09.1967.
AssociationReifier;
http://www.foo.bar/Reifier2;
lasted: 08.09.1967.

```

All problems described by the table earlier could be solved by this approach. However it has already been explained why the authors of this paper do not think that this is the optimal approach.

	domain information	meta information	validity information
scoped	x	x	x
Reifiable	x	x	x
topic	x	x	x

### 7.3 Associations

If it is decided that temporal elements should be represented as topics a natural way to connect them to other topics is by using associations. By using different types of associations it would be possible to represent differences in the type of information.

Additional information can be added by Reification just as it could have been done with occurrences. The use of associations demands that association types and role types will be given for them. This hurts the minimality that was demanded of the solution to the problem of this paper.

The greatest problem with this approach is its inability to handle anything but topics. Therefore this approach alone cannot be the solution to the problem of this paper. The code for this approach is fairly short:

```
John;
http://www.foo.bar/John;
- "John Johnson";
AccountNumber:"1234567"
Reifier: OccurrenceReifier.
Mary;
http://www.foo.bar/Mary;
- "Mary Johnson".
married(husband:John,wife:Mary).
lived(person:John,birth:01.02.1904,death:05.06.1977).
01.02.1904;
"01.02.1904".
05.06.1977;
"05.06.1977".
```

The table is therefore only partially filled:

	domain information	meta information	validity information
scoped	?	example 2	example 3
Reifiable	?	example 2	example 3
topic	x	x	x

### 7.4 Reifier

The association approach had the benefit of a natural connection with the temporal topics. It had the shortcoming of not being applicable for all construct types for the problem described in this paper. The solution can be improved if Reifier are used, if the associations are created between the Reifier of Topic Map constructs and the temporal topics. This combination of mechanisms is the solution advocated by this paper.

The main competition for this approach seems to be the occurrences approach. This approach had the disadvantage of being more or less incompatible

with the requirement that a standard construction should make use of temporal topics. If one does not take this as an requirement then the occurrence approach may be seen as superior, as the approach using Reifier and associations requires more Topic Map items and will need more locators to be defined.

The remaining task is to flesh out the standard proposal, but before this is done, some example code for this approach will be given.

```

John;
http://www.foo.bar/John;
- "John Johnson";
AccountNumber:"1234567"
Reifier: Reifier1.
Mary;
http://www.foo.bar/Mary;
- "Mary Johnson".
married(husband:John,wife:Mary);
Reifier: Reifier2.
lived(person:John,birth:01.02.1904,death:05.06.1977).
01.02.1904;
"01.02.1904".
05.06.1977;
"05.06.1977".
08.09.1967;
"08.09.1967".
05.04.1969 - 03.02.1974;
"05.04.1969 - 03.02.1974".
Reifier1;
http://www.foo.bar/Reifier1.
Reifier2;
http://www.foo.bar/Reifier2.
collected_at(collected:OccurrenceReifier,
collection_time:08.09.1967).
marriage_lasting(marriage:OccurrenceReifier,
duration:05.04.1969 - 03.02.1974).

```

The table can be filled with this approach just as it could have been filled with the occurrences approach.

	domain information	meta information	validity information
scoped	x	x	x
Reifiable	x	x	x
topic	x	x	x

## 8 The Standard Proposal

With the decision on how to model temporal qualifications made this section will focus on how to standardize this approach. To standardize associations the following things need to be defined.

1. the association types
2. the role types
3. the possible players for each role type

There will be no restriction on the number of roles in any of the associations defined here. Therefore it is possible to apply temporal qualifications not only to single constructs but to groups of constructs as well and it will be possible to use multiple temporal roles to signify complex temporal information.

Recall that the domain of predefined constructions is to be referred to as *pred*. As long as no other name for this domain is determined it will be used as a prefix for all the PSIs used in defining topics used as types.

### 8.1 Predefined Association Types

The topic with the subject identifier *pred/temporal-qualification* should be the supertype of all types of associations that represent temporal qualifications. All associations typed by a subtype of this topic should represent temporal qualifications.

In order to discriminate different types of temporal qualifications the following topics are introduced. Each is supposed to be a subtype of the *temporal-qualification* type. This is necessary to create a distinction between different types of information.

1. The subtypes of the topic that has *pred/meta-temporal-qualification* as its subject identifier should be the types of those associations that represent temporal meta information.
2. The subtypes of the topic that has *pred/domain-temporal-qualification* as its subject identifier should be the types of those associations that represent domain related temporal information.
3. The subtypes of the topic that has *pred/validity-temporal-qualification* as its subject identifier should be the types of those associations that represent temporal information about validity.

### 8.2 Predefined Roles

The last element that is needed for a standardization is the definition of the roles of the associations described so far and a restriction on the players of these role.

1. roles of some subtype of the topic that has *pred/Timed* as its subject identifier should be the roles of topics that represent elements to which a temporal qualification should be added. There is no restriction to the type of players for these roles.

2. roles of some subtype of the topic that has *pred/Time* as its subject identifier should be the roles of topics that represent the date which is used in a temporal qualification. These roles should only be played by topics that represent dates.

With this defined we can give a final version of the Topic Map code that was used throughout this paper:

```

John;
http://www.foo.bar/John;
- "John Johnson";
AccountNumber:"1234567" Reifier: Reifier1.
Mary;
http://www.foo.bar/Mary;
- "Mary Johnson".
married(husband:John,wife:Mary);
Reifier: Reifier2.
lived(person:John,birth:01.02.1904,death:05.06.1977).
01.02.1904;
"01.02.1904".
05.06.1977;
"05.06.1977".
08.09.1967;
"08.09.1967".
05.04.1969 - 03.02.1974;
"05.04.1969 - 03.02.1974".
Reifier1;
http://www.foo.bar/Reifier1.
Reifier2;
http://www.foo.bar/Reifier2.
collected_at(collected:OccurrenceReifier,
collection_time:08.09.1967).
marriage_lasting(marriage:OccurrenceReifier,
duration:05.04.1969 - 03.02.1974).
collected_at isa
pred/meta-temporal-qualification.
collection_time isa pred/time.
collected isa pred/timed
marriage_lasting isa
pred/validity-temporal-qualification.
duration isa pred/time.
marriage isa
pred/timed.
lived isa pred/domain-temporal-qualification.
person isa
pred/timed.

```

```
birthdate isa pred/time.  
deathdate isa pred/time.
```

## 9 Conclusion

The idea for a set of predefined constructions for Topic Maps was introduced and justified. Then an example for the kind of problem to be solved by such a construction was introduced.

This paper gave a discussion of different possibilities of introducing temporal information into Topic Maps. One approach was chosen as a candidate for a possible standardization of the handling of temporal qualifications in Topic Maps. Then it was described how this approach could be standardized.

This approach seems to be very versatile and simple. It would even be possible to say that a set of topics shares a certain temporal property by including them all in one association.

Related to this topic is the question of how to represent the domain of time. Further research may include a proposal for a standardization of the representation of the temporal domain. Then tools could be introduced that use standardizations in order to allow for an elegant handling of predefined constructions in Topic Maps.

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