# ENTERPRISE MODELLING FOR AN EDUCATIONAL INFORMATION INFRASTRUCTURE*

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Abstract: This paper reports the modelling exercise of an educational information infrastructure that aims to support the organisation of teaching and learning activities suitable for a wide range of didactic policies. The modelling trajectory focuses on capturing invariant structures of relations between entities in educational organisation into Enterprise object models.
An Educational Model Space has been introduced to define the problem domain context for the modelling. In this space, educational requirements have been elaborated towards the Open Distributed Processing Enterprise Viewpoint object models expressed in terms of the Unified Modelling Language. Recursive structures, which are uniform for the planning, performance and evaluation activities of education, have been used to capture the dynamic needs of education.

## 1. INTRODUCTION

Continuous advances in information and communication technology (ICT) boost the intensive and rapid changes in today's service-oriented society. To cope with such changes, people and organisations must continuously and almost instantaneously learn new and appropriate knowledge and skills. Such 'life-time', 'on-demand', and 'just-in-time' learning intensifies the challenge for tele-education, i.e. education that occurs at any time and any place [1]. ICT offers appropriate support for (tele-)education by its capability to provide dedicated and adaptable environments for (remote) teaching and learning. However, practice proves that accomplishing organisational environments is a sine qua none for (tele-)education.

A challenge is to develop a (distributed) educational information infrastructure that aims to support the organisation of teaching and learning activities in this service-oriented era and which is sufficiently flexible to address a diversity of educational approaches and didactic policies. This paper describes the outcomes of an exercise in the modelling of such infrastructure using an approach of separations of problem domain and enterprise modelling concerns along together with early feedback from developed infrastructure prototypes. This paper emphasises on object models of the infrastructure, dynamic data flow descriptions will not be part of this paper.

Educational literature confirms that effective courses represent a class of complex design problems [2,3,4]. Based on educational objectives, appropriate teaching and learning activities, suitable

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learning materials and instructional media must be selected. Teachers and learners may be required to work plenary, in smaller groups, or even individually within constraining time frames. In addition, proper evaluation procedures must be selected to assess the progress and (intermediate) results of a course. In case of tele-education, the complexity of instructional design is even higher since communication and information processing capabilities, human factors in distributed systems such as 'tele-presence' awareness, as well as distributed course organisation and logistics have to be additionally accounted for.

Educational processes in progress are typically apt to changes to ensure that instructional objectives are indeed accomplished [5,6]. The capability of making adjustments depends on the didactic policies adopted. Learners, for example, may be assigned different levels of learner control in respect to course adaptations [7]. Tele-education thus appears to be a very dynamic phenomenon and should therefore be designed to enable participants to dynamically plan, perform and evaluate courses in compliance with typical course management policies [8].

One may conclude that tele-education courses form a complex and multi-faceted educational landscape, which structure needs to be modelled to become visible. In this paper, we investigate the support for the organisation of the teaching and learning activities, the communication between the participants, and the information involved in the teaching and learning process. In our view, an infrastructure that supports such organisation in a flexible, i.e. adaptable, manner could improve the quality of tele-education courses and assist teachers in organising their courses. The design of such infrastructure should moreover be based on a multi-disciplinary collaboration involving, amongst others, the expertise available in the disciplines of educational and computer science. In this work, we use the Open Distributed Processing (ODP) Enterprise Viewpoints [9] to provide a suitable framework for the collaboration. The Unified Modelling Language (UML) [10] is used to expressively communicate the models between the two disciplines. An early-developed prototype of the infrastructure has also been used to provide modelling feedback towards the two disciplines.

This paper is structured as follows. The next section describes the early-developed prototype. Section 3 discusses a space used to identify the educational modelling context. The development of the Enterprise models for the infrastructure is explained in Section 4 and Section 5 describes the assignments that link the entities of the model. Finally, Section 6 presents the conclusion of the work.

# 2. AN EARLY-DEVELOPED PROTOTYPE

In educational research, early feedback is a typical vehicle to evaluate and to improve educational models. Accordingly, a prototype of the infrastructure has been used as a first step to capture structures of relations between education entities. In this section, we briefly introduce the underlying model of the prototype, describe the involved entities and their relations, and briefly report small-scale experiences of users of this prototype.

## 2.1 The underlying model

A so-called project driven model is applied to combine didactic and process plan-do-check models, which in combination typically describe education. A didactic model is a structural model that organises the major variables in course design, e.g. educational objectives, educational activities, learning resources, media and tools, time schedules, grouping schemes, and evaluation activities [2,4]. The plan-do-check model is an educational process model that organises three classes of activities that are not necessarily consecutive, i.e. course planning, course performance and course evaluation.

Course planning involves educational actors specifying the contents for the design variables in the didactic model, resulting in concrete course plans. Course performance implies educational actors to accomplish educational objectives according the activities described in course plans. The checking part refers to the evaluation of the (intermediate) course results, and may cause the cycle to close by requiring appropriate course plan adaptations.

## 2.2 The project driven structure

Figure 1 shows the project driven structure of educational entities that details the planning part of education. The 'tasks' entity represents combined educational activities of a course. This structure of the entity offers the possibilities for breaking the work down into composite task structures and including associated leaf-tasks, which comprise information resources required to accomplish a particular task. The 'teams' entity enables the definition of team structures. Team structures comprise sub-teams and educational roles, they allow for structured resourcing in project organisation. The 'flows' entity supports the specification of the permissible patterns of communication and information relations in respect to resources or roles in a particular project. This entity is considered useful to avoid message and information overload during performance of a project. Finally, the 'project' entity, which is the integrating element, links the entity components as assignments. It enables a planner to assign the teams to particular tasks, to set time schedules and to define authorisations (i.e. privileges) in respect to project management.

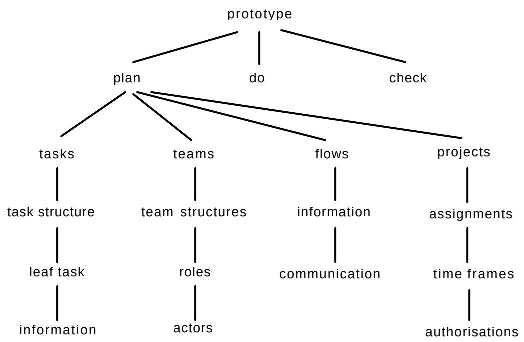


Figure 1 The project driven structure

Together with the 'plan' entity, the 'do' and 'check' entities represent the educational plan-do-check process model. The 'do' entity provides the educational actors access to (authorised parts of) the project plan in order to carry out activities aiming at accomplishing the project objectives. The 'check' option provides access to (authorised parts of) the project plan in order to evaluate (intermediate) project outcomes.

## 2.3 First experiences with the prototype

The first prototype has been explored in respect to two main questions:

1. Does the prototype provide a usable set of functions for planning, performing and evaluating courses in an efficient, effective and satisfactory manner?
2. Does the logical ordering of the functions comply to user requirements while working with projects?

In a class on courseware design, learners who were not familiar with the prototype were asked to evaluate the prototype. These learners participated in a test to implement a pre-specified course plan in the prototype. Afterwards, they were asked to indicate their general opinion, the usefulness, and the ease-of-use regarding the prototype. Beside this questionnaire, the duration of implementing the plan was measured and this was compared to the performance of an experienced prototype user.

The results suggest that the prototype does not fully meet the requirements of the actors. The prototype shows only one implementation model of the structures of relations between education entities and does not indicate generic and flexible models as discussed earlier. The prototyping approach alone does not provide the means for a systematic design of the intended infrastructure. In our view, the identification of alternative models of these structures in education requires a complementary conceptual approach.

# 3. THE EDUCATIONAL MODEL SPACE

As expected, the models of the infrastructure depend for a large part on the problem domain context. The evaluation of the prototype described in the previous section also has emphasised the need to identify the type of the model, the scope of the educational organisation under consideration and the level of the modelling details. For this, the Educational Model Space presented in Figure 2 is applied. Three dimensions mark this space, namely the organisational dimension of the problem domain, the ODP viewpoint dimension and the granularity dimension of the modelling domain.

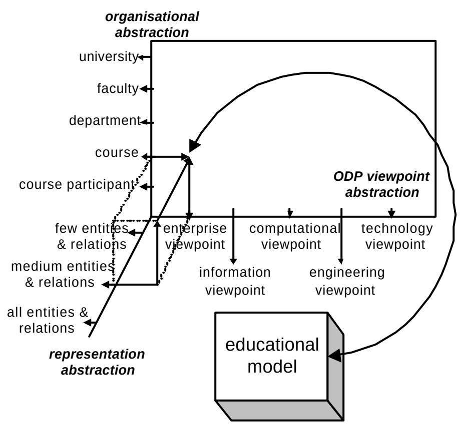


Figure 2 The Educational Model Space

The first dimension involves the scope of the real-life system under consideration, referred to as the *organisational abstraction*. Since the infrastructure is designed particularly for educational environments, such levels of scope are represented as a University, Faculties or Departments, Courses and Tasks.

The second dimension concerns the amount of details involved in a particular model, referred to as the *representation abstraction*. A particular granularity level may reflect all the conceptual entities and their relations as identified in the project driven model discussed earlier.

The third dimension is concerned with ODP Enterprise, Information, Computation, Engineering and Technology Viewpoints. In this paper, the focus will be mainly on the Enterprise Viewpoint. This viewpoint provides the common ground for collaboration between educational science and computer science, among others because no distinction is necessarily to be made between 'system' roles and activities (which can be automated) and the 'user' roles and activities (which have to be performed manually). As an ODP system, the intended infrastructure is viewed as a community constituted to the purpose of accomplishing educational objectives. This community is described in terms of roles, policies and activities for each of the involved educational entities that are considered essential from educational or didactical point of view [8].

# 4. ENTERPRISE MODELS IN EDUCATION

This section describes the design trajectory of the modelling of the educational information infrastructure. Based on a chosen reference point in the Educational Model Space (Section 3), an initial Enterprise model for educational entities will be discussed. This model will then be refined in a stepwise manner yielding an Enterprise model capturing structural educational relations suitable for a wide range of didactic policies.

The chosen design decisions embody our modelling purpose to capture invariant relations between education entities as much as possible in object models. It must be remarked that the object models do not only capture static structural relations identified in the educational problem domain. These models also capture invariance of the dynamics in education, such as the nested plan, performance, and evaluation activities in courses applying so-called 'open' didactic policy, where learners have a high degree of freedom in planning and organizing parts of their courses. Though the followed modelling approach gives the risks in defining models that are possibly too rigid for very specific educational processes, this approach improves clarity of the models and exposes the weak and strong properties of these models better. It also is expected that correct procedures for dynamic educational information processing can then be constructed more easily. Further, the design decisions incorporate the so-called task-oriented educational approach, where educational tasks and their objectives play a central role in education design (e.g. courseware design) [11,12].

## 4.1 The reference point

Though a reference point as discussed in Section 3 is not immediately necessary for the first (not refined) Enterprise model, an educational context provides a better hook for examples.

In accordance with the prototype, a Course has been taken as the reference value at the organisational dimension of the Educational Model Space. Moreover, the focus will be on the Enterprise models and the granularity of details is selected at the component level of the project driven model discussed in Section 2.

## 4.2 The applied UML concepts

In this work, we apply UML (Unified Modelling Language) [10] to express the developed Enterprise models. The visual representation of the UML notation makes our educational enterprise models more accessible for both educational scientists and system engineers. The modelling elements are moreover sufficiently expressive, enabling both groups to reason about the specified models and to provide modelling input in respect to their domain of expertise.

UML concepts that are used in this paper are shown in Figure 3.

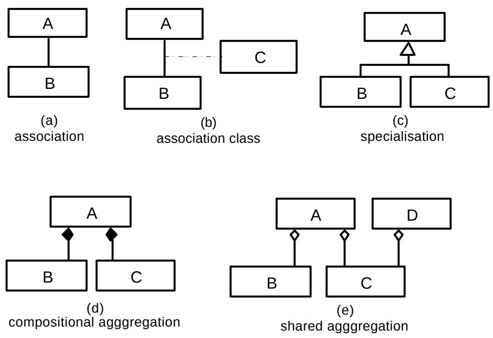


Figure 3 Class aggregations and associations

A box represents a class, which is a set of objects with similar structure, behaviour and relations. Figure 3a shows an association (represented by a line) between class A and class B. Figure 3b shows the concept of 'association class', which is an extension of the concept ‘association’. The box with the dashed line represents the class property of the association. For clarity, multiplicity in associations will be omitted in most of the figures.

Figure 3c illustrates the concept of specialization, represented by a triangular symbol. This concept is suitable to express the distinction between the different roles, e.g. teacher’s and tutor’s roles.

Figure 3d shows a compositional aggregation in which class B and class C are genuine components of class A. This means that deletion of an instance of class A implies deletion of the component instances of class B and class C and that instances of class B or class C may not be shared by compositional aggregation instances other than that of class A. This type of aggregation is represented by a black diamond symbol.

Figure 3e shows a weaker aggregation form, namely a ‘shared aggregation’, and is visually represented by an open diamond symbol. In this case, deletion of an instance of class A does not necessarily mean the deletion of the component instances of class B or class C. Moreover, instances of class B or class C may be shared by shared aggregation instances, e.g. shared by D.

## 4.3 The initial Enterprise model

The first Enterprise model (Figure 4) shows an educational entity class as a central entity (e.g. a Course in respect to the previously chosen reference point).

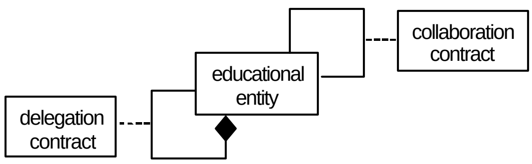


Figure 4 The initial Enterprise Model

**The hierarchical relations**

The model exposes the relations of the central entity with a higher level as well as lower level entities in respect to the organisational dimension of the educational model space. The relation is modelled as a compositional aggregation with the class ‘Delegation Contract’ attached to it. In the Enterprise Viewpoint, the combination of a compositional aggregation with an association class is considered expressive in the capturing of hierarchical relations as found in many didactic models [2,4], for example in mastery learning approaches. In these models, educational entities are strongly coupled with their objectives and are typically hierarchically decomposed in smaller entities, each of them possesses objectives derived from the aggregating entity (e.g. derived learning goals of course lessons). The association class as is applied here elegantly justifies the relations of the course-tasks *in* the course setting. In other learning approaches (e.g. in thematic learning), this dependence relation in the hierarchy is less constrained. This hierarchical top-down and goal directed structure is considered appropriate in Enterprise models. Analogous structures are also found in other fields and are often expressed in a similar way, for example in Hospital Information Systems [13].

*Example:*

A Course is a compositional aggregation of so-called course tasks. These tasks are related to each other via the association class “Delegation Contract” which for example contain a strict ordering of tasks in the context of a closed didactic policy or a partially ordered task structure in the context of a more open policy. This flexibility supports a wide range of didactic approaches, such as the mastery or the thematic learning approaches.

Complexity of a Delegation Contract depends for a large part on the applied policies of the hierarchically higher-level entities. At universities, some faculties may demand complete micro planning of courses, some others may only require course content lists and learning objectives. Besides structures for course descriptions or micro-plans, a delegation contract at course level often contain structures for incorporating policies for Learners’ Control (e.g. learners’ authorisation to plan, perform or evaluate a particular educational task), in general, or Learning Control authorisation tables, in particular.

Moreover, likelihood of use of specific educational tools, e.g. ICT applications or the educational information infrastructure reported here, may be improved by formulating the associated Faculty or University mission related to ICT in a Delegation Contract, see for example [14].

**The collaboration relations**

On the other hand, a top-down delegation from a higher-level to a lower-level entity, such as the Delegation Contract, is not sufficient in many dynamic and collaborative educational environments. Nowadays, Faculties start to collaborate with sister faculties of other institutes. In tele-education projects, courses may also be organised between faculties of different universities, but typically with maintaining student administrations under local university regime. To facilitate these dynamic inter-faculty collaborations, the educational entity class (e.g. modelling faculties) has a self-referring association with class Collaboration Contract. This structure is also found in other business models [15].

## 4.4 The refined task-oriented object model

As was mentioned earlier, the Enterprise models discussed in this paper have been influenced by the task-oriented educational approach. Accordingly, course tasks have been modelled explicitly and take an important place in these models. It has to be remarked that the task-oriented approach does not constraint the usability of the targeted infrastructure for other types of educational approaches.

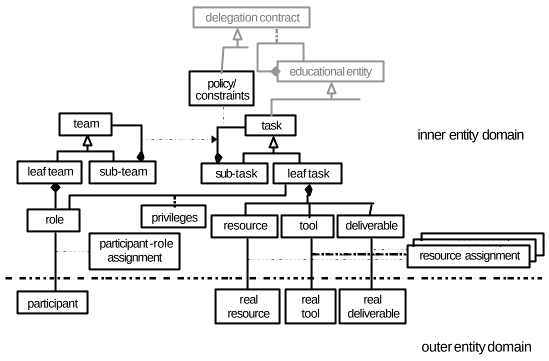


Figure 5 Refined Educational Enterprise Model

**Task hierarchy**

Figure 5 shows a refinement of a part of the model depicted in Figure 4. A course task, which is a specialisation of the educational entity, is hierarchically decomposed in sub-tasks. Though a sub-task may contain attributes or component objects, e.g. to model task roll-ups, summary of (expected) results [16], these details are not visible at the chosen granularity level.

A leaf element of such tree is called a leaf-task and has a structure that exposes the educational resources (i.e. task inputs), the deliverables (i.e. task outputs), and the tools of this task. Tools represent the utilities and, if appropriate, the logistical means like classrooms, laboratories, network interconnectivity, and computers.

The recursive way of modelling course tasks complies with the different educational practices. Especially open policy courses, in which task decomposition and task classification (i.e. plan, perform, evaluate types) are heavily intertwined [8], will benefit from this recursive structure. During the performance activities of these courses, for example, the performing participants (e.g. teachers or authorised learners) usually further decompose these tasks in smaller units themselves.

The association class of the hierarchical relation is a specialisation of the delegation contract described earlier. If a subtask models a test activity in a course, the association class may contain constraints like the prohibition to assign resources to external learning materials (i.e. a closed book examination). This class may therefore be used to guide course planners to detail the test in a way that the leaf-tasks of the test preserve the test objectives.

**Tasks and roles**

As in many other business organisations, tasks are associated to teams or roles in a homomorphic way. In the planning or performance activities (e.g. during course lessons), planners typically assign tasks to teams or individual learners who have to fulfil specific roles. Accordingly, teams and roles are organised in a homomorphic way to the task hierarchy. In the model, a dashed arrow expresses this.

This homomorphism enables planners to assign the same tasks to different teams, useful for cases where large numbers of learners are enrolled for a course. In the task-oriented educational approach, the task hierarchical structure inherently determines the team structure. These homomorphic structures will guide educational planners to organize the teams and roles (e.g. learners groups, tutors and lecturers) in accordance with the goal directed tasks and task structures, or vice-versa.

Roles that are homomorphically associated to a leaf-task may have constrained access to the task components. This is modelled by the Privileges, which determines the denial or the types of access of the role on the task component. Privileges may be defined in terms like rights to “use”, “re-plan”, and “extend” tasks. These privileges are therefore derived from the delegation contract, e.g. the Learning Control tables mentioned earlier.

## 4.5 The problem domain entities

Opposed to the modelling domain entities that in our case represent the educational modelling concepts like tasks and teams, problem domain entities represent the teachers, the enrolled learners, the books or web-pages used in courses. These so-called *outer* entities of the model complement the *inner* (i.e. educational modelling) entities as they provide the necessary hooks to enable instantiation of the model onto real education cases, e.g. a specific course in a specific course year.

**Participants and roles**

In the planning phase, typically, teams and roles will be assigned to the educational participants (e.g. the learners enrolled for a course in a particular year and the registered tutors or teachers). A many-to-many association has been used to express the relation between the role and participant classes (Figure 5). This multiplicity enables participants to be responsible for several roles and on the other hand, it enables use of shared roles in collaborative work oriented courses. An association class between the two classes makes re-assignment of roles to other participants also possible, for example, in case of re-planning on the fly during performance of courses applying open policies.

**Problem domain entities and task components**

In analogy to the modelling of roles and participants, problem domain entities, in particular, real education resources, tools and deliverables have to be assigned to the aggregated components of a leaf-task. These associations are also many-to-many; association classes are accordingly used to specify them.

# 5. ASSIGNMENTS

By their role, course planners (or designers) have the responsibility to specify and plan the course. Optionally in a hierarchical way, these roles may execute their responsibility or delegate (part of) the role to other course participants by appointing some of them to become planners (of part) of the course. Additionally, planner roles have to assign the instances of the earlier mentioned outer entities to the instances of the specified inner entities (Figure 6). For example, after defining teams and team missions, planners may have to assign also the enrolled learners (or, if appropriate, also teachers, tutors, etc.) to these teams. Depending on the applied didactic policy and the followed educational approach (e.g. a mastery learning approach), resources, tools and deliverables may also be assigned by the same planner role, see also Figure 5.

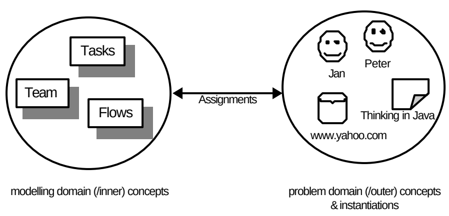


Figure 6 Making the connections between educational entities and instances

Assignment is therefore the making of the connections between the educational instances specified in the educational information infrastructure in respect of the planned course. The patterns of the specification and assignment procedures depend on the didactical policy and the educational approach followed by the course participants (which include the course planners).

The second version of the prototype is object based and is implemented as a web-based application using Active Server Pages and a relational database constructed using MS Access. The left and right columns in Figure 7 illustrate a task hierarchy, in which an indented task represents a sub-task. For example, the task “Assignment 1” comprises of six sub-tasks and subtask “Study ABC tool”, in turn, comprises of the child tasks “Study tool manual” and “Make examples”. The figure represents an activity flow window, which enables a course tutor-planner to assign the possible follow-ups of tasks (illustrated by the arrows) by clicking the appropriate radio and connectivity (symbolized by “<>”) buttons.

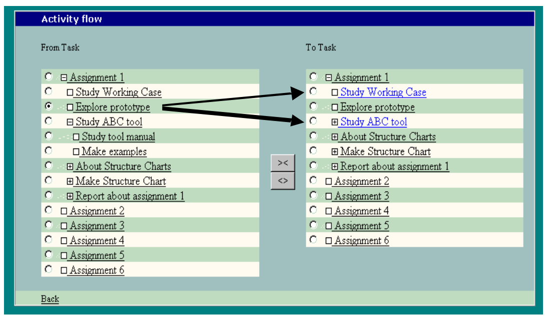


Figure 7 Activity flow represents tasks follow-ups

Some simplifications however have been made in the prototype. Tasks and teams have been implemented in one relational table, which constrains the prototype to support isomorphic team and task structures only. Moreover, real resources, tools and deliverables have been implemented by tables containing string typed attributes, which are sufficient to specify textual descriptions or string references, but URL references are not launchable. Information structures developed in other educational projects, e.g. [16], may be used to extent the prototype.

# 6. CONCLUSIONS AND FUTURE WORK

This paper described the outcomes of an exercise for the modelling of an educational infrastructure that aims to support the organisation of teaching and learning activities. This exercise has been carried out in a multi-disciplinary collaboration in which ODP Enterprise Viewpoint and UML have shown their value in bridging the conceptual gap between educational scientists and computer science engineers. Nonetheless, feedback provided by the developed prototype has been a complementary necessity, especially to validate the perception of the developed models by the researchers of the different disciplines.

The richness and especially the diversity of educational approaches and models make the modelling of an infrastructure that generically has the ability to support educational processes no matter what the applied didactic policy is is very complex. In fact, this complexity has triggered the capturing of invariance in educational relations, resulting in recursive structures that do not only support the hierarchical structure of a typical educational entity, these structures are also uniformly applicable in respect to the educational plan-do-check model. This enables an infrastructure support for intertwined activities of planning, performance, and evaluation type that are typically not consecutive in open didactic policies.

The Enterprise Viewpoint has been used for its emphasis on justification purposes, which provide a better assurance that hierarchically decomposed education entities as a whole fulfils the educational objectives of the aggregation, a property necessary in many educational environments in general or didactic models in particular. However, these Enterprise models are not directly suitable for implementation of the targeted infrastructure. Further work therefore need to concentrate on the derivation of advanced Information and Computation Viewpoint models that are more suitable for processing of information related to educational organisation. The dynamic models of the infrastructure, in alignment with the previously mentioned object models, will also be needed as well.

Educational courses have proven to be highly dynamic organisations. Expressing and explaining the capturing of invariant relations of dynamic enterprises is also one of the major challenges faced in many business environments. It is therefore believed that the results reported in this paper provide useful feedback concerning the modelling of the dynamics in business enterprises as well.

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