Using Fact-orientation for Educational Design

Peter Bollen

Department of Organization and Strategy,
Faculty of Economics and Business Administration
University of Maastricht, 6200 MD Maastricht, The Netherlands

Abstract. In this paper we will show how fact-orientation can be used as a knowledge structuring approach for verbalizable knowledge domains, e.g. knowledge that is contained in articles, text books and instruction manuals further to be referred to as 'subject matter'. We will also show that the fact-oriented modeling constructs allow us to structure knowledge on the first five levels of Bloom's taxonomy of educational objectives and we will show how the fact-oriented approach complies to the 4C/ID model for educational design. Moreover, we will derive a 'knowledge structure metrics' model that can be empirically estimated and that can be used to estimate the complexity metric of a subject matter.

1 Introduction

In the body of literature on fact-oriented conceptual modeling, a number of publications define a hierarchy in knowledge elements for a specific knowledge domain [7, 8, 9]. This research has generalized the fact-oriented modeling constructs and CSDP into a knowledge reference model for subject matters, thereby applying fact-orientation on a much larger playing field than the field of schema design for relational databases.

In this paper we will illustrate the applicability of fact-orientation for the objective of structuring knowledge, by showing that a fact-oriented knowledge reference model (KRM) can also be used for determining the complexity of a given subject domain and subsequently for the educational design of a course on a such a subject. We will illustrate this with examples in the field of university education on two generally accepted sub-domains within the business administration subject: operations management and marketing. Earlier work that discussed the application of a predecessor to this KRM on the field of logistics can be found in [4]. In that paper the following knowledge classes are distinguished: *sentence instances*, *sentence types* (including *associated constraints*) and *derivation rules*.

A subject matter has its own intrinsic structure [9]. Educational programs on a subject matter therefore, need to enable students to access such a structure or 'conceptual schema'. Unfortunately, in many available descriptions of a subject matter, e.g. text books, lecture notes, manuals, the intrinsic structure is (at best) hidden among non-structural descriptions of such a subject matter. In analogy with the Conceptual Schema Design Procedure [5: 58-60] for application domains, that

Bollen P..
Using Fact-orientation for Educational Design.
DOI: 10.5220/0004539800140023
In *Proceedings of the 2nd International Workshop on Interaction Design in Educational Environments* (IDEE-2013), pages 14-23
ISBN: 978-989-8565-65-5

serves as a ‘knowledge extractor’ by structuring the explicit and eliciting the implicit knowledge of domain experts in a user-analyst dialogue, we can define a knowledge extracting procedure (KEP) [3] that can be applied on explicit subject knowledge that is documented in a web-document, a text book or an instruction manual.

2 Deriving the Intrinsic Structure of a Subject Domain

In most, if not all cases, a verbalizable knowledge source is a document that often is incomplete, informal, ambiguous, possibly redundant and possibly inconsistent. As a result of applying the fact-oriented knowledge extracting procedure (KEP) [3, 8], we will yield a document that only contains structured knowledge or a knowledge grammar which structures verbalizable knowledge into the following elements (*knowledge reference model(KRM)*):

1. Knowledge domain sentences
2. Definitions and naming conventions for concepts used in domain sentences
3. Knowledge domain fact types including sentence group templates
4. Population state (transition) constraints for the knowledge domain
5. Derivation rules that specify *how* specific domain sentences can be derived from other domain sentences.
6. Rules that specify *what* fact instances can be inserted, updated or deleted.
7. Event rules that specify *when* a fact is derived from other facts or when a fact must be inserted , updated or deleted.

A KRM of a complete text book would contain hundreds, possibly thousands of concept definitions, naming conventions, fact types, population constraints, derivation rules and event rules. The knowledge extracting procedure (KEP) specifies *how* we can transform an informal, mostly incomplete, mostly undetermined, possibly redundant and possibly inconsistent description of domain knowledge into the following classes: *informal comment*, *non-verbalizable knowledge* and *verbalizable knowledge* to be classified into types 1 through 7 of the KRM. In section 3 we will give a sample of the results of applying the knowledge extracting procedure on an operations management text book and a marketing text book.

3 Application of the KEP on the Business Subject Matter

In this section we will show the KRMs, which are a result of the application of the fact-oriented KEP on the content of textbooks on the operations management and marketing subjects of business administration. Because of space limitations in this article we haven chosen to select a very small subset of concepts contained in these subjects.

3.1 The Operations Management Subject of the Economic Order Quantity

We have selected a widely-used text book on the field of operations and process management: Ritzman, Krajewski and Malhotra: Operations Management: Processes and Value Chains, 8th edition, Pearson/Prentice-Hall, 2007 [11]. We will now provide a self-contained sample of the KRM for this text book (see the list of definitions for operations management and the diagrammatic part of KRM elements 3, 4 and 5 expressed as a *knowledge structure diagram* in ORM-1 notation in figure 1).

Partial List of Definitions for Operations man. Subject: Economic Order Quantity EOQ

Item	An individual product that has an identifying item code and is held in inventory somewhere along the value chain (p.524[1]) Synonym: Stock Keeping Unit
Item Code	An item code is a unique signification for an [Item] that enables us to identify a specific [Item] within the set of all [Item]s within the context of a business organization
Lot	A lot is a quantity of [Item]s that are processed together.(p.350)
Cost	A sacrifice or expenditure
Ordering Cost	The [Cost] of preparing a purchase order for a supplier or a production order for the shop. (p. 464) Synonym: Set Up cost (p.472)
Inventory Holding Cost	The sum of the [Cost] of capital and the variable [Cost]s of keeping [Item]s on hand, such as storage and handling, taxes, insurance and shrinking (p.463)

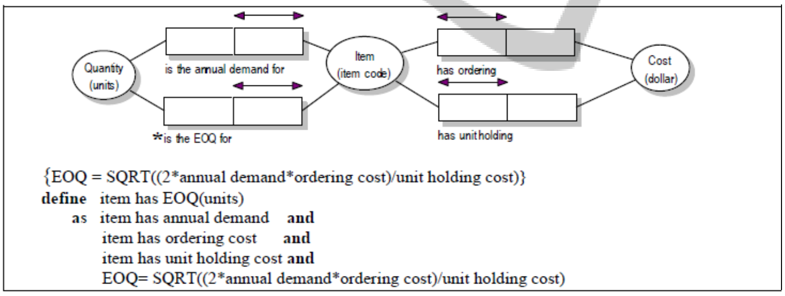

Fig. 1. Knowledge structure diagram in ORM-(1) notation for EOQ from [12].

3.2 The Marketing Subject of Branding

We have chosen the following text book on the field of marketing: David Jobber, Principles and Practice of Marketing, 4th edition, McGraw-Hill, 2004 [6]. We will now provide a KRM for a sample from this text book in the list of definitions for marketing management and the diagrammatic part of KRM elements 3 and 4 (expressed as a *knowledge structure diagram* in ORM-1 notation) in figure 2.

1 The referenced pages in the list of definitions refer to [12].

Partial List of Definitions for Marketing Management Subject: Branding

Product	Anything that is capable of satisfying customer needs (p. 260[2]).
Brand	A distinctive name, packaging and design for a [Product] (p.261)
Brand name	A brand name is a unique signification for an [Brand] that enables us to identify a specific [Brand] within the set of all [Brand]s within the context of a specific company.
Product line	A group of [Brand]s of a Company that are closely related in terms of their function and the benefits they provide (p.262)
Product line name	A product line name is a unique signification for a [Product Line] that enables us to identify a specific [Product Line] within the set of all [Product Line]s within a specific company.

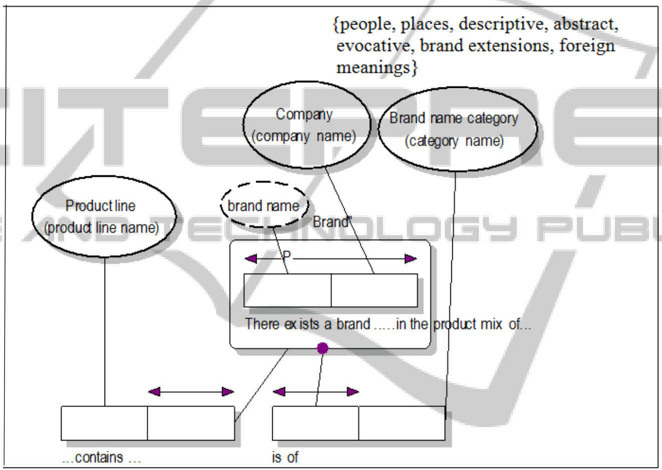

Fig. 2. Knowledge structure diagram in ORM-(1) notation for Branding from [6].

4 Using Fact-orientation to Compare Subject Matters

When the relative amount of *informal comment* and *non-verbalizable knowledge* in such a knowledge field is large we can consider the knowledge field to be of the ‘phenomenological’ type. This normally points at knowledge fields that are beginning to develop and in which no clearly agreed upon relevant concepts and their definitions exist. When the relative amount of informal comment and non-verbalizable knowledge of the subject matter, on the other hand, is small, the knowledge domain can be considered relatively structured, this means that basic domain concepts are agreed upon and their definitions are known. Furthermore, semantic relationships between those concepts exist and are known to the extent that they can be verbalized. In the latter types of knowledge domains, it is possible that more complex rules, laws, derivation rules and event rules can be defined. The former analysis naturally applies,

2 The referenced pages in the list of definitions refer to [7].

in those situations in which a text book is well-written from an educational point of view. In some cases the actual quality of writing can be insufficient, which can lead to a ‘phenomenological’ text book for a very well-structured knowledge domain or a text book in which the order of comprehension for the introduction and definition of concepts is practically random. In the next section we will postulate a model that can be used to estimate the size and complexity of a subject matter.

5 Using the Building Blocks of Fact-orientation as Size and Complexity Metrics

As was illustrated in section 3 of this paper, for the text books on marketing and operations management, it is possible to apply the KRM and its accompanying KEP on the field of business administration. In many situations, educational programs at colleges and (professional) universities are built up around acknowledged subjects or topics. The study load for such a subject or topic is mostly determined by the number of contact hours and the *quantity* of literature that must be read and studied. In our view, this practice does not acknowledge the differences between knowledge fields in terms of the building blocks of the KRM. We will restrict the fields of knowledge of interest to ‘structurally relevant verbalizable’ knowledge domains. We will furthermore divide the fourth element of the Knowledge Reference Model: population state (transition) constraints (see section 2) into a discrete number of pre-defined constraint types and general constraints.

We will now give a linear model (see equation (1)) that can be used for determining the size and complexity of a subject domain and determining the study load and the educational design for a course on the subject matter.

$$SL=(a*DEF)+(b*FT)+(\Sigma(c_j*PSC_j))+(d*PTC)+(e*GC) + (f*DR) + (g*ER) . \quad (1)$$

Where SL is the study load (in hours) of a knowledge field or a ‘size and complexity’ metric that can be easily transformed into a study load equivalent and where a, b, c_j , d, e, f, g, respectively are weight factors for the number of definitions in the list of definitions, the number of fact types, the number of population constraints of type PSC $_j$, the number of state transition constraints, the number of general population constraints, the number of derivation rules , the number of event rules in the application knowledge structure (diagram). Finally, DEF, FT, PSC_j , PTC, GC, DR and ER are the total number of definitions, the total number of fact types, the total number of constraints, the total number of state transition constraints, the total number of general population constraints, the total number of derivation rules and the total number of event rules, respectively in the application knowledge structure.

This model can be empirically determined by estimating the weight factors: a, b, c_j, d, e, f, g after a large number of samples of knowledge fields (e.g. text books, instruction manuals) have been analyzed in terms of the knowledge reference model. For this future empirical research we need to define standardized test that enable us to determine to what extent students have sufficient knowledge of the relevant parts of the text book.

When we compare the two knowledge reference models for the *operations management* and the *marketing management* examples, we see that relative extent of concept definitions is about equal for both example fields, the number of constraints is bigger for the *operations management* example. The operations management example contains a derivation rule whereas the *marketing management* KRM does not have a derivation rule (see table 1).

Table 1. Sample data for Linear Model.

Variable\subject	EOQ (operations man.)	Branding (marketing)
DEF	10	12
FT	4	2
PSC_1 (uniqueness)	4	1
PSC_2 (mandatory role)	0	1
PSC_2 (value)	0	1
DR	1	0

6 Application of Fact-orientation in Educational Design

In this section we will show how the fact-oriented analysis and abstraction of (a) subject matter(s) in combination with the determined weight factors from our study load estimation model in section 5 can be used for educational design. The total study load can be determined using the linear model in section 5. The next decision that has to be made is to design the tasks, exercises, assignments, chapters to study and so forth in a way that optimizes the productivity of teachers and instructors and that also optimizes the required time for a student to fully understand the subject. The fact-oriented knowledge reference model (KRM), provides the blue-print for the creation of educational material and its accompanying educational design and test-design. In [8] this is called *knowledge driven educational design* which contains (amongst others) the step ‘didactizing’ which can lead to the following instance of an educational design:

1) In educational design, the existing knowledge network of the prospective students will (partly) determine the sequence in which concepts should be introduced and it will determine the way in which competencies should be trained [8, 10]. In some cases available representations of subject matter, e.g. manuals, text-books do not provide the explicit structure to do this at all times [12: 633]. Fact-orientation can help structuring the subject matter by creating a list of definitions that can be anchored in the student’s existing knowledge network and it can be sequenced in order of comprehension. Furthermore, a knowledge structure diagram that contains fact types, population constraints and derivation- and event-rules can be added (see figures 1and 2 and the accompanying lists of definitions).

2) Let the students prepare a number of pages of the text book (preferably in the fact-oriented KRM format) that contain α concept definitions and β fact types

and the accompanying population constraints, derivation rules and event rules.

3) Design an educational session in which the comprehension of the concepts, fact types and constraints is tested by providing 'sentence instances' or scaled down 'real-life' examples in such a way that in the beginning in each example, one rule is confirmed or violated (see figure 3a), leading to exercises in which multiple constraints are violated/confirmed at the same time (see figure 3b).

4) A final set of exercises can be constructed in such a way that the comprehension of the concepts, fact types, constraints and derivation rules is tested by providing students with instances of fact types and values for parameters that are contained in one or more derivation rules. The students will subsequently be asked to apply the derivation and/or event rules (see figure 3c).

5) On a program level it is recommended to provide integrated exercises that cover subject matter that has been covered in earlier courses on a specific subject.

Item	ordering cost
ab105	$ 43,--
ab106	$ 56,--
ab105	$ 66.--

<u>Question:</u> is this an allowed example of communication ?

(A)

Company	Brand	Brand category
Masterfoods	Mars	people
Masterfoods	Whiskas	--
Masterfoods	Mars	brand extension

<u>Question:</u> is this an allowed example of communication ?

(B)

The company Ajaxfan, produces all kinds of accessories for the Amsterdam football team Ajax ranging from shawls to coffee cups. For the stock keeping unit with item code a345 the annual demand is estimated at 12 000 units. There is a fairly constant demand throughout the year. The ordering cost with the chinese supplier for this item is Euro 234.--. The unit holding cost for this SKU at Ajaxfan is Euro 1.25/unit/year.

<u>Question:</u> calculate the EOQ for item a345

(C)

Fig. 3. Examples of exercises to be used for instruction.

In addition we can use the same underlying KRM to design exams and test questions that can range from problems on an application instance level to problems on a meta level. The design of course evaluations, exams or tests goes hand in hand with the aforementioned educational design. The test will exactly reflect the level of instruction, since the underlying test objectives have been clearly laid down in the KRM of the subject matter.

6.1 The Fact-oriented KRM and Bloom's Taxonomy

In educational sciences, Bloom's taxonomy of educational objectives [2] is an accepted framework to divide objectives in the cognitive domain. Bloom's taxonomy can be considered a pyramid, in which every next-higher level includes the lower level as a subset. *Level 1* in Bloom's taxonomy: *knowledge*, is defined as the remembering or recall of previous learned material. *Level 2*: *comprehension* is defined as the understanding of the material or the ability to interpret the material. *Level 3* of Bloom's taxonomy: *application refers* to the ability to use the learning material in new situations. Bloom's *level 4* of educational objectives refers to the ability to break down material into component parts. *Level 5* in Bloom's taxonomy: synthesis, refers to the ability to put parts together.

We will now match the levels and elements from the KRM with the levels in Bloom's taxonomy. The availability of domain sentences without an accompanying list of definitions for the concepts can be considered to refer to the knowledge *level 1*. If we add the (relevant) concept definitions and naming conventions we will be able to communicate 'knowingly' about a subject domain (*level 2* of Bloom's taxonomy). For polytechnic and university level educations, we require the content of the courses to be on *at least level 3* of Bloom's framework which implies that students must at least be able to apply derivation rules to derive new sentences if 'knowledgeable' ingredient sentences (including a list of definitions) is provided in a practical case setting. Bloom's *level 4* of educational objectives refers to the meta-level of the KRM. This basically is the same KRM, albeit applied on a specific UoD, namely the UoD of creating a knowledge reference model [7, 8]. Level 5 refers to the ability to put parts together. Our claim is that this involves multi-disciplinary knowledge and therefore can only be achieved when knowledge for different domains is integrated and therefore, level 5 (and this implies level 6) can in general not be achieved by the educational objectives laid down in a single text book. Level 5, however can be achieved by integrating multiple relevant subjects. If we would consider the synthesis of two subjects that we have given in this article, we could for example derive the knowledge that the manufacturing of more brands would lead to more production set ups. Level 6 in Bloom's taxonomy: *evaluation,* is a level that is normally achieved after students have had experience in a specific field for a number of years, and thereby have achieved the ability to evaluate their way of working in the field.

6.2 The Fact-oriented KRM and the 4C/ID-Model for Educational Design

In this section we will show that the application of the fact-oriented approach for educational design complies to the interrelated components of van Merriënboer's four-component educational design model (the 4C/ID-model) for competence based education [13].

The first component of the 4C/ID model is *learning tasks.* In [1] task classes are given in which simple-to-complex categories of learning tasks are defined. In this section it was already illustrated how this can be done in the fact-oriented KRM.

The second component of the 4C/ID model is *supportive information*. This component deals with the availability of additional information that is coupled to tasks classes that may contain general knowledge and concrete cases that exemplify the 'theoretical' knowledge [1]. In terms of the fact-oriented approach it means, that the example information on a UoD is provided, that allow learners to abstract from tangible examples and to test the presence/absence of constraints by inspecting the supplied case information in the taks.

The third component of the 4C/ID model is *Just-In-Time information* which refers to the specification of routines that are identical for many learning tasks [1]. In terms of fact-orientation we can consider the different steps in the 'knowledge extracting procedure' (KEP), to be the most important example(s) of this. This means that students must acquire these skills in order to be able to 'grasp' the content of the course in the fact-oriented format, but most of all acquiring these skills will allow the students to handle every future situation in which knowledge must be absorbed and applied.

The fourth component of the 4C/ID model is *part-task practice.* In this component provisions are made for additional learning of particular routine aspects that need a high degree of automaticity [1]. In the application of the fact-oriented approach on the field of educational design, this part-task practice can be directed at meta-level cognitive skills (applying (parts of the) KEP) or on application-level skills (the application of derivation rules, e.g. a calculation of a EOQ).

We now have shown how the fact-oriented KRM enables us to fulfill educational objectives up to level 5 of Bloom's taxonomy and how the fact-oriented approach complies to the 4C/ID model for educational design.

In the past 20 years, a large number of students on a polytechnical level in the field of computer science, business administration and law have been [8] trained using educational material expressed in a knowledge reference model format based upon standard text books on the subject matter. The time investment needed for the students in such an 'accelerated' learning program turned out to be substantially lower than in a 'conventional' educational setting [10:434-435].

7 Concluding Remarks

The fact-oriented approach has its roots in the conceptual modeling school for information systems development and database schema design. In this paper we have extended the 'playing field' of this approach as a knowledge structuring approach, illustrated by two samples of subjects within the academic field of business administration. Moreover, we have given a (linear) model that can be used for determining and predicting the size and complexity of a subject matter. The size and complexity of the implicit structure of a subject can range from structures that can be fully modeled by a small number of definitions, via models of implicit structures that contain a large number of definitions and fact types, to 'complex' knowledge reference models in which a large variety of population state (transition) constraints exist eventually having derivation rules, and event rules.

The conclusion and implications for the educational practice of the fact-oriented KRM are threefold. Firstly, the KRM for a text book will give us insights into the context of the knowledge domain in terms of relevant structural knowledge. Secondly, the fact-oriented KRM will allow us to estimate the study-load and contact hours for a specific course having a given text book/domain knowledge by using the complexity model that was given in section 5. Thirdly, the fact oriented approach can be applied as a methodology for educational design that complies to Bloom's taxonomy of educational objectives and the 4C/ID model for educational design.

Our belief is that the 'quantification' of knowledge that is proposed in this article will lead to a more productive and effective 'engineering' of educational systems in a broad sense and will provide a solid foundation for claims as 'better learn one rule than 20 facts'.

References

1. Bastiaens, T., van Merriënboer, J and Hoogveld, B.:A design methodology for Complex (E)-learning. Innovative session 2. AHRD conference, Honolulu Hawai (2002)
2. Bloom, B. and Krathwohl, D.: Taxonomy of educational objecti ves: the classification of educational goals- handbook I: cognitive domain, McKay, New-York (1956)
3. Bollen, P.: The Natural Language Modeling Procedure', In: Fifth Workshop on Next Generation Information Technologies and Systems (NGITS'2002), Lecture Notes in Computer Science 2382, Springer-Verlag, (2002) 123-146.
4. Bollen, P. and Nijssen, G.: Universal Learning as a tool for educational transformation and process control systems in problem-based programs', in: W,Gijselaers, D. Tempelaar, P. Keizer, J. Blommaert, E. Bernard & H. Kasper (eds.), Educational innovation in economics and business administration: the case of problem-based learning, (1995) 436- 443.
5. Halpin, T.: Information Modeling and Relational Data bases, Morgan Kaufmann (2001)
6. Jobber, D.: Principles and practice of marketing, 4^{th} edition, McGraw-Hill (2004).
7. Nijssen, G.: Kenniskunde 1A, PNA Publishing, Heerlen, Netherlands (in dutch) (2001)
8. Nijssen, G. and Bijlsma, R.: Kennis-gebaseerd onderwijs ontwerpen" (Knowledge Driven Educational Design), OnderwijsInnovatie (Educational Innovation) Nr 3, Open Universiteit Nederland, September (2005) pp. 17-26. (in dutch)
9. Nijssen, G. and Bijlsma, R.: A Conceptual Structure of Knowledge as a Basis for Educational Designs. The 6th IEEE International Conference on Advanced Learning Technologies, Theme: Advanced Technologies for Life-LongLearning", ICALT,(2006)
10. Nijssen, G. and Bollen, P.: Universal Learning: A science and methodology for education and training', in: W,Gijselaers, D. Tempelaar, P. Keizer, J. Blommaert, E. Bernard & H. Kasper (eds.), Educational innovation in economics and business administration: the case of problem-based learning, (1995) 428- 435
11. Ritzman, L., Krajewski, L. and Malhotra, M.: Operations Management: Processes and Value Chains, 8^{th} edition, Pearson/Prentice-Hall. (2007).
12. Thomson, J., Greer, J. and Cooke, J.: Automatic generation of educational hypermedia with APHID. Interacting with Computers 13 (2001) 631-654.
13. Van Merriënboer, J.: Training complex cognitive skills: A four- component educational design model for technical training. Englewood Cliffs, NJ (1997)