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1 Scope of this report

This deliverable is described in Prolearn JPA3 as:

"A joint framework to integrate PROLEARN concept mapping activities of the Network of Excellence partners. Most partners have their own models of visualizations for knowledge work that are used in a variety of professional and other contexts. This deliverable framework aims to unify this work."

In this paper we introduce the art of concept mapping and then present a literature survey where the different kinds of conceptual modelling techniques are identified, both with respect to theoretical foundations and supportive tools. On top of this background we introduce a conceptual model for conceptual modelling, which is used to categorize the results of a survey about concept mapping techniques and tools carried out within the Prolearn community.

2 Background – a Literature survey

2.1 Limitations

There are many styles of modelling, not all of which will be considered to belong to the category of conceptual modelling. For concept mapping, there are several definitions available already, see the Eric report for a more complete listing:

- Plotnick said in 1997 that: "*graphical representation where nodes (points or vertices) represent concepts, and links (arcs or lines) represent the relationships between concepts"*
- Novak said that: concept maps are *"tools for organizing and representing knowledge."*
- Buzan says that: *"It is in the shimmering and incessant embraces that the infinite patterns, the infinite Maps of the Mind, are created, nurtured, and grown. Radiant Thinking reflects your internal structure and processes. The Mind Map (Concept Map) is your external mirror of your own radiant thinking and allows you to access this vast thinking powerhouse."*
- etc.

However, in this report we try to adopt a wider scope when considering conceptual modelling, e.g. also including things like UML. In fact, we have arrived at a list of requirements, all of which need to be fulfilled for the modelling style to be further discussed. The modelling style should:

1. aim at capturing, analysing, or communicating human knowledge.
2. have a graphical and typical diagrammatic presentation.
3. have support for 'concepts' and connecting 'relations' of some kind.

These requirements do not represent a formal consensus but have been formulated pragmatically for the needs of this report. We have arrived at them by starting from modelling styles that clearly belong to the conceptual modelling category and identifying the distinctions to nearby modelling styles that fall outside of the category.

Examples of modelling styles that do not fulfil these requirements are Peirce Existential Graphs, Vector graphics (e.g. SVG), neural networks, Venn-diagrams, the more modern Spider diagrams etc.

2.2 Theoretical foundations / practices

When doing conceptual modelling there are several supportive theories / practices to lean against. Below we list the most well-known and provide a short overview of each:

- Mind Maps may go as far back as the 3:rd century but are often attributed as an invention of the psychologist Tony Buzan. The main trait of MindMaps are a central piece of information wherefrom other information is connected in radial tree, typically by using colours and pictures to make the map more appealing. The distinction between concepts and relations is rather vague, with the relations being represented as labelled connecting lines between ideas.
- Concept Maps were introduced by Joseph D. Novak in 1972 for the purpose of better understanding children’s conceptual understanding. The use of Concept Maps have since then been used for note-taking, knowledge-creation, knowledge-preservation, many aspects of learning etc. A concept map includes a set of concepts that are centred on a focus question and ordered in a hierarchy with the most generic concepts at the top. Relations given with a label, which indicates what the relation expresses. There are also cross-links that have a more associative character and examples tied to individual concepts. There are many reports on the usefulness of concept mapping in various settings.
- IBIS Maps were introduced by Rittel in 1970 as a way to deal with argumentation. The maps consist of three kinds of elements: questions, ideas and arguments, i.e. the “pros and cons” of the ideas. Jeff Conklin improved the technique, first by visualizing the maps and later by introducing the dialogue mapping technique for real time facilitation of a group’s argumentation process via IBIS maps, mediated in some manner.
- Conceptual Graphs were introduced by John F. Sowa in 1976 in order to capture logically precise information in a manner that is human-readable. The language has a visual as well as a written syntax, and semantically it is an extension to Peirce’s existential graphs. This makes it at least as powerful as first order predicate logic. In the simplest case, occurrences of concepts in a graph are interpreted as existence of individuals according to indicated types and relations are propositions made on these individuals. Relations may have any arity.
- Unified Modelling Language (UML) was introduced by OMG in 1997 as an unification of the plethora of modelling languages used to analyse and design object oriented software projects. UML has proven to be useful in many contexts beyond software design such as business process and organizational structure modelling. It has consequently been further developed and in 2004 the UML2.0 was published. The language strives to be neutral

regarding methodology and to be useful in as many contexts as possible. This has resulted in a quite large set of notational systems, grouped into 13 various diagram types. At least object, class, activity, and state-machine diagrams fulfil the requirements to be included in our comparison. An important distinction between UML and other techniques is the heavy focus on forming a consensus on notational style for both concepts and relations. For example, different kinds of relations are drawn in a distinctive manner rather than providing an explanatory label. This type of "standardized visual semantics" makes the semantics of the diagrams much easier to communicate within any community, which takes the trouble to learn it.

3 Usage in the Prolearn Community – a Survey

3.1 The survey questions

We decided on a survey with six questions as listed in table 1. The purpose of the first three questions was to find out information about the modelling technique used - if any. This included both the name of the modelling technique as well as possible supportive tools.

Table 1: The survey questions sent to the Prolearn core partners

Nr:	Question:
1	Are you using any kind of modelling technique(s) in your work (*)? (Yes/No)
2	How would you label your modelling technique? If there is no established name for it, please give a short description of its characteristics.
3	Do you use any tool in support of your modelling technique?
4	What is the **context** for the models you build, e.g. programming, research, business modelling, learning/teaching, project management, knowledge management etc.?
5	What is the **purpose** of the models you build, e.g. developing/analysing ideas, communicating with other people, externalising/internalising knowledge for yourself, as a complement to written documentation etc.
6	Who are the **target groups** of the resulting models, e.g. yourself, partners in projects, colleagues, students, employees in companies, reviewers, the public etc.?

3.2 Results of the survey

The survey was sent out to the Prolearn core partners, reaching about 200 persons at 21 different partner institutions. We received 19 responses, of which 15 gave an affirmative answer to the first question, i.e., whether or not they were using any modelling technique(s) at all. However, out of these 15 responses, 3 were discarded because of how they answered the rest of the questions, because the modelling technique(s) described did not fulfil our criteria. Conversely, 1 respondent who answered "no" to the first question was nonetheless deemed to qualify according to the criteria. This left us with 13 "valid responses" that are summarized in Table 2.

Table 2: The shortened and grouped answers to the survey questions

Nr:	Answer:
1	Yes(12), No(3), Erroneous No(1)[†], Erroneous Yes(3)[††] [†] = answered the other questions in a manner that fulfils our requirements for a modelling technique. [††] = opposite of [†].
2	My own drawing-technique(3), MindMaps(7), ConceptMaps(3), UML(7), ULM(2), Argument

	maps(1), Web map(1), Spreading activation(1), flow-charts(1), Process models(1), Systems diagrams(1), Discrete event simulation(1), System dynamics(1), six sigma/lean(1), RDFS/OWL(1), GANTT/PERT(1), Role Activity Diagrams(1),
3	Plain yes(3), graphic tools(2), Pen and paper(2), Conzilla(2), Mindmanager Pro6(2), MS Powerpoint(2), Visio(2), Compendium(1), ARIS(1), TogetherJ(1), Protege(1), MS-Project(1), gliffy.com(1), ARKINET(1), ArgoUML(1), fabForce.net DB Designer(1), MagicDraw(1), Freemap(1), Nestor Web-Cartographer(1)
4	Research(7), Software engineering(5), Business modelling(4), Learning(5), Teaching(4), Knowledge management(3), Project management(3), Organizing and visualising(2), The large document(1), Consultancy(1), System design(1), Meetings(1), Simulation(1)
5	Communication(8), Consensus building(2), Externalising knowledge(5), Internalising knowledge(3), Analyse/develop ideas(8), Capturing ideas (2), Developing systems(2), Documentation(1)
6	Myself(3), Workgroup(3), Colleagues(10), Project partners(10), Industry partner(1), The public(2), Teacher and students(4), Research community(1), Employees(2), Seminar participants(2), Users of the document(1), Clients(1)

The full answers were shortened into representative terms and also grouped together. The representative terms have been established by going through the answers and identifying common semantics. The most appropriate terms given have been selected as representative. This process has by necessity involved generalization and qualified guessing on the behalf of the respondent. Most of this grouping has been done for the questions 4-6. The motivation for finding these common terms is three-fold: It gives a better overview of the answers, it minimizes the amount of space needed, and it allows for a better analysis. Below we list some of the non-trivial grouping into terms that has been performed:

Question 4 regarding the context:

- "Knowledge management" also includes "knowledge representation" and "knowledge sharing".
- "Project management" includes "project design" and "planning/programming of complex project work".
- "Organizing and visualizing" includes "cluster ideas".

Question 5 regarding the purpose:

- 5: "Capturing ideas" includes "identifying critical points".
- 5: "Consensus-building" includes "Creating common ground".
- 5: "Analyse/develop ideas" includes "develop ideas", "structure ideas", and "solve specific questions".
- 5: "Externalising knowledge" includes "complement written text".
- 5: "Internalising knowledge" includes "reflecting".

Question 6 regarding the target group:

- 6: "seminar participants" includes "participants in presentation events" and "audiences in meetings and conferences".

3.3 Interpretation of responses

3.3.1 Responses to question 1-3

An additional purpose of the three initial questions was to find indications of whether respondents perceive a clear *distinction between theory and tools*. This is detected by comparing the clarity and distinctiveness of the answers to questions 2 and 3. Furthermore, if the respondent provided names of modelling techniques in response to question 2, but mentioned vaguely or no tools at all in response to question 3, we interpret this as an indication that the respondent is *knowledgable of only theory*. I.e., the respondent is more interested in modelling techniques on a theoretical plane than in their everyday use. On the other hand, if no clear names were given in response to question 2 but a clear listing of tools was provided in response to question 3, then we interpret this as an indication that the respondent is *knowledgable of only tools* - i.e., that the respondent is more tool-centric and practically oriented. A respondent that provided both specific names of modelling techniques and a list of appropriate tools is considered to be *knowledgable of both* theory and tools. The table X shows a summary of these distinctions as well as well as the corresponding number of respondents.

Table 3: The interpretation of survey responses about modelling theories and tools

Interpretation	Nr of respondents
Distinction between theory and tools	6
Knowledgable of only theory	2
Knowledgable of only tools	4
Knowledgable of both	7
Discarded (Erroneous yes)	3

The question about modelling techniques clearly shows that there are three dominant forms: MindMaps(7), UML(7), and ConceptMaps(3). Furthermore, ULM (Unified Language Modelling which is a dialect of UML) is mentioned by two respondents, “free form modelling” is indicated by three respondents, and then there are 12 other modelling techniques mentioned. Looking at them we find a possible categorization as shown in Table 4.

Table 4: The categorized responses to the question about modelling techniques

Categories of Modelling Techniques	Modelling Techniques mentioned by respondents
Static Modelling	Concept Maps, MindMaps, Web maps, ULM, UML class diagrams
Dynamic Modelling	Flow-charts, Role activity diagrams, Systems diagrams, Discrete event simulation, System dynamics, Argument maps, UML activity, UML sequence, and UML state diagrams.
Business Modelling	Process models, lean, six sigma, and many UML diagrams.
Formal Modelling	RDFS/OWL

The two categories, *static* and *dynamic modelling* indicates whether there is a time aspect or not. *Business modelling* consists of modelling techniques for understanding / improving the processes of a company. And finally the *formal modelling* category encompasses modelling techniques where a narrow/careful semantics has been specified to the effect of making the models more or less machine-processable.

The given categorization is not completely satisfactory since the business modelling category is defined more based on the context, purpose and target group of the modelling activity rather than the modelling technique itself. Furthermore, there are three modelling techniques that do not fit into this categorization:

- My own drawing technique – does not fit anywhere because it is undefined.
- Spreading activation – seems to be more of a methodology for determining the strengths of relations rather than a modelling technique in its own right.
- GANTT/PERT – is useful for project management and only part of it, i.e. the pert networks, could really be said to fulfil our requirements.

However, on the positive side, this categorization corresponds quite well to the actual answers of the respondents.

3.3.2 Responses to question 4-6

The answers to question 4 are not surprising. The survey was carried out within the Prolearn core partner group, which consists mostly of academic scholars. Hence, the resulting emphasis on research, software engineering and learning/teaching is quite natural.

The answers to questions 5 and 6 regarding purpose and target group show that the most common usage of modelling is for communicating with others, especially within communities of various sizes, e.g. the workgroup, in a seminar, within a project, or between colleagues. In such situations the receivers are known and the model(s) can be adapted accordingly. However, when the community grows larger - including e.g., Prolearn project partners (which is a large group of people), employees within a big company, or just the public in general - the modelling cannot be as easily adapted to the target group anymore. This is reflected in the way that the respondents have answered - many use modelling for smaller communities but few use it for larger- or unknown communities.

3.4 Clarifications to be made for a possible second survey

Some respondents have interpreted question 3 as a yes/no question, while our intention was that if they use tools, they should list them in their answer.

To simplify categorization of modelling techniques and clarity it would be nice if the 'context', 'purpose', and 'target group' where clearly distinguishable. Furthermore, the answers of the first survey indicated that respondents tended to partly answer these questions indirectly already in question 2, i.e. when specifying the modelling technique, they also indicated the purpose, context, and/or target group. A possible improvement of the questionnaire with respect to this is to give a list of modelling techniques to choose from, and, when not appropriate, let the respondents give one for themselves. Another option would be to change the order of the questions, having questions 2 and 3 at the end of the questionnaire.

4 A conceptual model of conceptual modelling

In this section we introduce a conceptual model (expressed in ULM) of conceptual modelling, as illustrated in Figure 1. First of all, we distinguish between the *model* and the *modelling*. The modelling consists of both a *construction* phase and a *usage* phase, observe that they need not be

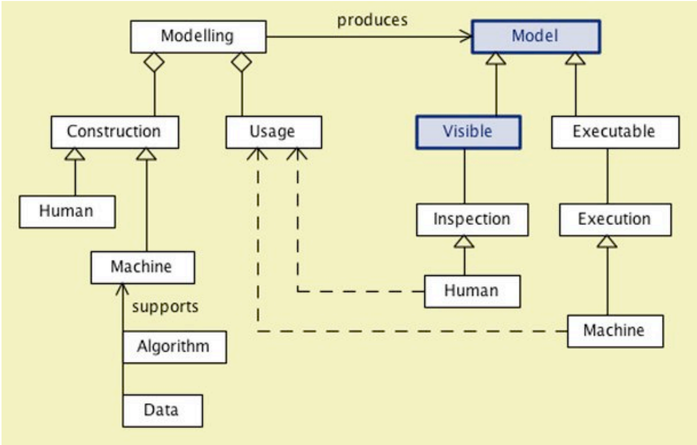

Figure 1. A conceptual model of conceptual modelling

distinct, e.g. the construction phase can be used for consensus building. The model can be of two kinds, *visible* and *executable*. With "visible" we mean what is stated in Requirement 2 in the Limitations section (2.1), i.e., "have a graphical and typical diagrammatic presentation". With "executable" we mean that the modelling technique has a well-defined semantics that allows machine-processing of the expressed models (this is the same as the formal modelling category at the end of section 3.3.1). Modelling usage is exemplified by humans that inspect visible models while machines execute executable models.

In Figure 2, we see the "Model" concept divided into *Static* and *Dynamic* depending on whether there are explicit time aspects or not in the model. ConceptMaps and MindMaps are both examples of static models and Flow charts and Business Process maps are both examples of dynamic models. This division requires further work.

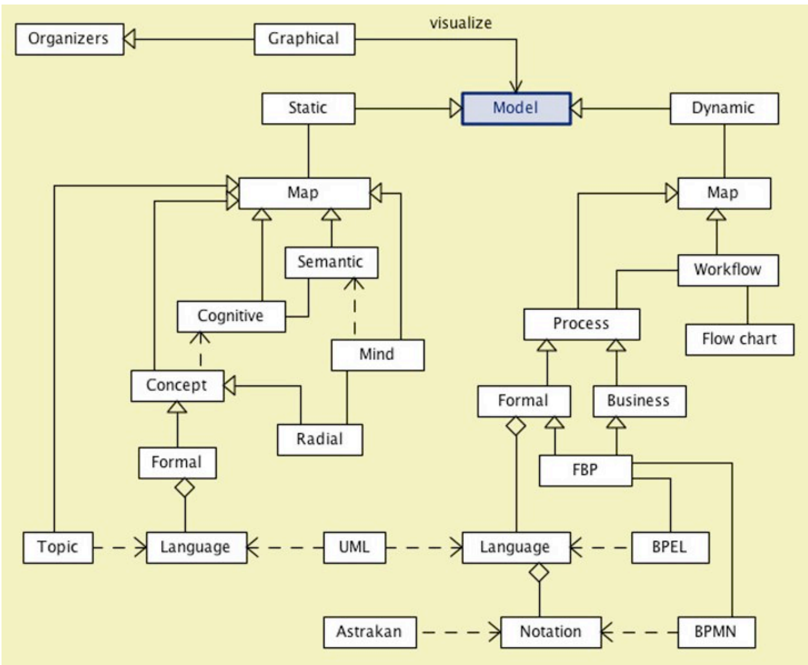

Figure 2. Static and dynamic models

5 Conclusions

In this report we have gained some insight into the use of concept mapping among the Prolearn core partners. The findings include a clear disposition towards commonly known modelling techniques such as Mind maps, Concept maps and UML. If you make a categorization of the modelling techniques into static, dynamic, business and formal modelling we see that the commonly known modelling techniques all end up in the static category (with the exception of some of the diagram types of UML) but there is a lot of evidence for the dynamic category as well but they lack a common name. Hence, one possible interpretation is that *established modelling techniques* for dynamic modelling is essentially missing, at least as perceived by the respondents.

There is a long range of tools that can be used for support, however, there is no superior or widely known tool that deserves to be singled out in this report.

Another observation is that respondents used concept mapping in many different contexts for different purposes (even though there was a clear academic bias) but almost exclusively when the target group was well defined. One possible interpretation is that conceptual models look simple at a glance but - in practice - require some training in order to read and understand them correctly. Within a community, there is a context where the reading- and understanding processes can develop gradually. When there is no such community, reading instructions would need to be supplemented to the conceptual model for accurate understanding, which is perhaps a bit contrary to the impression that conceptual models should be easily understandable.

We have also provided an initial version of a conceptual model of conceptual modelling - based on the ULM modelling technique.

6 References

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