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### Knowledge acquisition techniques: a comprehensive review

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#### ABSTRACT

In many knowledge systems there are knowledge-acquisition (KA) techniques to help knowledge engineers and domain experts build and maintain the system's knowledge base. These techniques can be classified in many ways. Some of these ways are kind of Knowledge which obtained, type of knowledge which captured, purpose of technique, tool type, out put and result of techniques. In this paper we compared different techniques according to above items, in a table. Also this table includes the description, strengths and weaknesses for each technique.

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#### Introduction

In all knowledge management projects there is a primary phase which is important in success of the project. (Hashemian & afraze, 2006) This phase that called Knowledge Acquisition help knowledge engineers and domain experts build and maintain the system's knowledge base (Runkel et al). Its objective is to reduce the communication gap between the expert or knowledge work and the knowledge engineer, allowing the knowledge to become independent of its sources (Baptista Nunes et al., 2005).

Nick Milton 2003 describes knowledge acquisition as: Knowledge acquisition includes the elicitation, collection, analysis, modeling and validation of knowledge for knowledge engineering and knowledge management projects.

##### Types of technique (bechhofer)

Protocol-generation techniques: The aim of these techniques is to produce a protocol, i.e. a record of behaviour, whether in audio, video or electronic media. Audio recording is the usual method, which is then transcribed to produce a transcript (Epismetics), include various types of interviews (unstructured, semi-structured and structured), reporting techniques (such as self-report and shadowing) and observational techniques

Protocol analysis techniques: In some cases, depending on the requirements of the project. For instance, more detailed categories will be used for the identification. Such categories may be taken from generic ontologies and problem-solving models (Epismetics). PA involves the identification of basic knowledge objects within a protocol, usually a transcript. For most projects, this makes use of categories of fundamental knowledge such as concepts, attributes, values, tasks and relationships (Epismetics). (PA) is a generic term for a number of different ways of performing some form of analysis of the expert(s) actually solving problems in the domain. (shadbolt & burton, 1995). These techniques such as goals, decisions, relationships and attributes. This acts as a bridge between the use of protocol-based techniques and knowledge modeling techniques (Epismetics).

Matrix-based techniques: involve the construction of grids indicating such things as problems encountered against possible solutions. Important types include the use of frames for representing the properties of concepts and the repertory grid technique used to elicit, rate, analyze and categories the properties of concepts.

Sorting techniques: used for capturing the way people compare and order concepts, and can lead to the revelation of knowledge about classes, properties and priorities (bechhofer). Classification techniques aim to identify the terms and concepts of the domain and how these concepts are organized in classes, groups or components, according to the expert (Wright & Ayton, 1987; Abel et al., 2005).

Limited-information and constrained-processing task: These are techniques which either limit the time and/or information available to the expert when performing tasks that would normally require a lot of time and information to perform. This provides a quick and efficient way of establishing the key tasks and information used. These techniques include the generation and use of network diagrams, such as concept maps, state transition networks and process maps (Epismetics).

In knowledge management projects, we will face different types of experts and there are many different types of knowledge presented by experts, so different techniques are required to access the different types of knowledge from different types of personalities. It is referred to the Differential Access Hypothesis, and it has been shown experimentally supporting evidence (Rrru et al., 1991).

Many Knowledge Acquisition techniques have been used to obtain the information required to solve problems. These methods can be classified in many ways. (Janet E. Burge) . Some of this ways are kind of Knowledge which obtained, type of knowledge which captured, purpose of technique, tool type, out put and result of techniques:

There are various ways of looking at knowledge and describing it as being one thing or another. Two important dimensions with which to describe knowledge are: (i)

Procedural knowledge vs. Conceptual knowledge; (ii) explicit knowledge vs. tacit knowledge (Emberey et al., 2007).

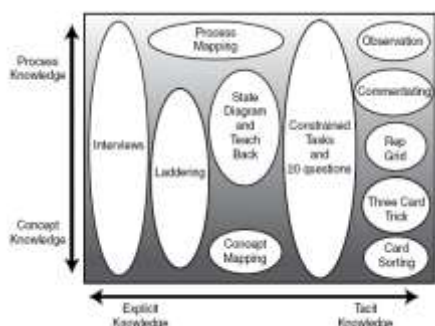
Procedural knowledge is about processes, tasks and activities. It is about the conditions under which specific tasks are performed and the order in which tasks are performed. It is about the resources required to perform tasks and it is about the sub-tasks that are required (Emberey et al, 2007).

Conceptual knowledge is about the ways in which things (which we call 'concepts') are related to one another and about their properties. An important form of conceptual knowledge concerns taxonomies. Another type of conceptual knowledge is about the attributes of concepts. (Emberey et al, 2007)

Explicit knowledge: knowledge that can be easily articulated stored and transferred. Within IT, explicit knowledge is the information that can be transferred from domain experts to business analysts and developers - the information which is found within requirements documents. Deals with objective, rational, and technical knowledge.

Explicit knowledge is the cumulative store of Data, Policies, Procedures, Software, Documents, Products, Strategies, Goals, Mission, Core competencies (Turban et al, 2004).

Tacit knowledge: knowledge that cannot be easily expressed or understood, or is not readily visible. Even if it can be transmitted, this knowledge often requires complex shared activities to be fully expressed. Tacit Knowledge is thought about at the back of one's brain, in what some people call the 'subconscious'. It is often built up from experiences rather than being taught. Hence, it is the sort of knowledge that someone gains when they practice something. It often leads to automatic activities that seem to require no thought at all (at least no conscious thought). It is described in everyday words and phrases such as 'gut feel', 'hunches', 'intuition', 'instinct' and 'inspiration' (Emberey et al, 2007). Tacit knowledge is the cumulative store of the corporate experiences, Mental maps, Insights ,Acumen, Expertise ,Know-how , Trade secrets ,Skill sets, Learning of an organization , The organizational culture (Turban et al, 2004).



**Figure 1, The Knowledge Acquisition Matrix provides several tools in order to acquire various types of knowledge. (Emberey et al, 2007)**

Another common way for classified KA techniques is by how directly they obtain information from the domain expert:

Direct methods: Some methods approach expert knowledge directly by observing behavior of the expert(s) during the execution of a knowledgeable task. So these techniques are used in order to obtain information that can not be easily expressed directly (Janet E. Burge).

Indirect methods: Not all circumstances allow direct perception we then have to fall back on perception of behavior in an artificial task-environment but then arguments must be given that the perceived behavior is similar to the behavior that

we originally wanted to perceive. Other forms of indirect perception are eyewitness reports, literature etc. from which we deduct our own mental model of the behavior of interest. An important and often forgotten indirect perception approach is artifact analysis. By literally studying foot- and fingerprints we can find out what documents are really important, what places are visited a lot etc (Enger). Many of the indirect KE methods are best at obtaining classification knowledge while direct methods are more suited for obtaining procedural knowledge.

Type of knowledge: Besides being grouped into direct and indirect categories, KE methods can also be grouped (to some extent) by the type of knowledge obtained.

Information types used here are: Procedures, Problem solving strategy/Rationale, Goals, sub-goals, Classification, Relationships, Evaluation.

On the other hand the purpose of KA techniques can be a factor for classify techniques. According to this option we can classify KA techniques in two classes: techniques which purpose of them is analyzing knowledge and techniques which purpose of them is generation knowledge:

Knowledge generation includes the creation of new ideas, the recognition of new patterns, the interaction and synergy of separate disciplines and the development of new processes [Ruggles, 1997; Castells, 2000]. Knowledge generation encompasses both creating new knowledge and acquiring existing knowledge from somewhere else (Crawford, 1996). argues that the most valuable knowledge generation involves identifying problems and suggesting solutions to rectify them. Knowledge generation requires tools, which pushes individuals to think beyond their current functional and organizational boundaries (ROCKET, 2002)

Knowledge Generation refers to the transformation of raw data or summarized information into actionable knowledge. (Brash, 2000; Giaglis, 2003).

Knowledge analysis is aimed at studying knowledge-intensive tasks at a conceptual level. The analysis results in a description of the information and knowledge structures and functions involved in the task. The results of knowledge analysis are documented in the "knowledge model". It contains a specification of the information and knowledge structures involved in a knowledge-intensive task ([www.commonkads.uva.nl](http://www.commonkads.uva.nl)).

Knowledge Analysis (KA): In Knowledge Analysis we model a knowledge source in such a way that we can analyze its usefulness, its weaknesses and its appropriateness within the organization. Knowledge Analysis is a necessary step for the ability to manage knowledge. Within Knowledge Analysis we can use knowledge modeling and knowledge acquisition techniques ([www.km-forum.org](http://www.km-forum.org)).

### Conclusion

In this paper we compared different techniques according to kind of Knowledge which obtained, type of knowledge which captured, purpose of technique, tool type, out put, result of techniques, time consuming and type of interaction for all techniques in a table. Also this table includes the description, strengths and weaknesses for each technique.

According to this study tool type include of interview ,cards and software; out put include of Procedures followed, knowledge used, Procedures, problem-solving strategy, Correction of misconceptions, Taxonomy of tasks/subtasks or functions Procedure, Knowledge and skills needed for task, A hierarchical map of the task domain, Hierarchical cluster

diagram (classification), Amount and type of information used to solve problems; how problem space is organized, or how, Attributes (and entities if provided by subject), representing the properties of concepts, flowchart, Hyper text, web pages, Attribute matrix Relationship matrix.

The results can include of Varies depending on questions which asked, include of Procedure followed, Correction of Misconceptions, rationale, Classification of entities (dimension chosen by subject), Information used to solve problems, organization of problem space, Entities, attributes, sometimes relationships, Validating captured knowledge, Capture the basic of processes, Hyper text, web pages.

The kind of Knowledge which obtained include of tacit and explicit.

The type of knowledge which captured include of concept and process

The purpose of technique include of analyzing and generation

The time consuming of techniques divide to time consuming which one show by " \* "and time non consuming which one show by " - "

The type of interaction include of direct and indirect.

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Table 1 : characteristics of knowledge acquisition techniques

Technique	Description	strengths	weaknesses	Tool Type	out put	result	Type of knowledge				purpose of technique		Time consuming	type of interaction
							tacit	explicit	process	concept	analyzing	generation		
Interviews	Unstructured	Very open interviews. Usually an outline, used as a guide, with a limited set of broad questions to ask. Stratified Semi Structured. Stratified representative sample of the organization is interviewed (e.g., employees, managers, directors, etc.). Interviewer has a predetermined set of issues that will be asked about, but follow up questions depend on the responses of the interviewees	<ul style="list-style-type: none"> <li>1) Useful for identifying possible areas for more detailed analysis</li> <li>2) Easy to conduct and direct</li> <li>3) The data collected provides information about general rules and principles and is faster than observational techniques.</li> <li>4) Useful for investigating events which occur infrequently.</li> <li>5) Can be recorded for a future analysis</li> <li>6) gives knowledge engineer orientation to domain</li> <li>7) use early to get the basic vocabulary</li> <li>8) little demand on expert</li> <li>9) generates much knowledge cheaply and naturally</li> </ul>	<ul style="list-style-type: none"> <li>1)Tendency to hear what we want to hear instead of what is being said 2)The interviewer may need to acquire domain knowledge in order to know what questions to ask.3)There is a range of considerable bias due to the understanding by the users of the questions, and the subjective collected information might be misleading or inaccurate4)incomplete and arbitrary coverage,the knowledge engineer needs appropriate training and/or social skills 5)Tend to miss heuristics of the expert's knowledge6)Time consuming 7)More complex subjects require high levels of concentration 8)Interview fatigue 9)Tend to extract basal knowledge</li> </ul>	Interview	Procedures followed, knowledge used	Varies depending on questions asked		*		*		*	direct
	Structured	Like a questionnaire, except that the questions are asked by the interviewer. This allows no flexibility on the part of the knowledge engineer whose questions are all pre-established						*	*		*			direct
	Semi Structured	A semi-structured interview combines a highly structured agenda with the flexibility to ask subsequent questions. The questions for a semi-structured interview are ideally constructed some time before the interview and are sent to the expert so he/she can start to prepare responses						*	*	*		*	app	direct
References	[Hendrick, H. W. (1997). ],[Gammack John G(1987)] , [Hudlicka, 1997], [Geiwitz, et al., 1990] , [ Nezafati et al (2007) ] , [www.osiris.sunderland.ac.uk]													

Table 1 : Continue

Technique	Description	strengths	weaknesses	Tool Type	out put	result	Type of knowledge				purpose of technique		Time consuming	type of interaction
							tacit	explicit	process	concept	analyzing	generation		
Commentary*	In the "think-aloud" protocol the user performs a number of tasks and is asked to think aloud to explain what they are doing at each stage, and why. The evaluator records the users actions (sometimes using tape recordings or video) for each of the tasks, as well as noting any problems	1) Think-aloud is simple and requires little expertise to perform. 2) It can provide a useful insight into the problems with an interface. 3) It can help to understand how users view the system	1) Use for quantitative data is questionable 2) The information is necessarily subjective. 3) User thoughts may not be a correct source of what is going on, and can be selective depending on the tasks chosen. 4) Being observed and having to describe what you are doing can also affect the way in which you complete a task		Procedures, problem-solving strategy		*		*			*	*	direct
References	* Nielsen, J. (1997)., [Hudlicka, 1997], [Ericsson & Simon, 1984], [Geiwitz, et al., 1990] [Nezafati et al (2007)], [Cordingley, 1989]													
Teach back**	Teachback is a process of knowledge elicitation in which the subject matter expert (SME) describes a concept to the human factors researcher. The researcher then explains the concept back to the SME until the SME is satisfied that the researcher has grasped the concept	elicited many forgotten areas in experts' mind		Verbal Question	Correction of misconceptions*	Correction of Misconceptions	*	*	*	*		*	,	direct
References	**[Johnson L. & Johnson N. ], [Nezafati et al (2007)],[Milton N.(2007)]													
observation	The Observer is a system for the collection, analysis, presentation and management of observational data. It can be used to record activities, postures, movements, positions, facial expressions, social interactions or any other aspect of human behavior. (Source: Noldus Information Technology, Inc.)		time-consuming process and inefficient means of capturing the required knowledge.	observation	Taxonomy of tasks/subtasks or functions*Procedure, problem solving strategies Knowledge and skills needed for task	Procedure followed	*		*			*	*	direct
References	http://www.hf.faa.gov/docs/508/docs/46855a.pdf 2) Department of Defense (DoD) - Handbook - Human Engineering Program Process and Procedures [MIL-HDBK-46855A, *[OTT, 1998], [Belkin & Brooks, 1988], [Nezafati et al (2007)], [Hudlicka, 1997], [Geiwitz, et al., 1990], [ Burge Janet E. ], [Cordingley, 1989]													

Table 1 : Continue

Technique	Description	strengths	weaknesses	Tool Type	out put	result	Type of knowledge				purpose of technique		Time consuming	type of interaction
							tacit	explicit	process	concept	analyzing	generation		
Concept Ladder	A concept ladder shows classes of concepts and their sub-types. All relationships in the ladder are the <i>is a</i> relationship, e.g. car is a vehicle. A concept ladder is more commonly known as a taxonomy and is vital to representing knowledge in almost all domains	<p>-can be used on a variety of knowledge types; objects, actions, tasks, goals, etc..</p> <p>-excellent way of carrying out a structured interview(shadbo;t)</p> <p>This technique is useful to apply when the domain constructs are known but the interrelationships</p>		Interview	A hierarchical map of the task domain*	Procedures followed, rationale		*		*	*		app	indirect
Composition Ladder	A composition ladder shows the way a knowledge object is composed of its constituent parts. All relationships in the ladder are the <i>has part</i> or <i>part-of</i> relationship, e.g. wheel is part of car. A composition ladder is a useful way of understanding complex entities such as machines, organisations and documents							*		*	*		app	indirect
Decision Ladder	A decision ladder shows the alternative courses of action for a particular decision. It also shows the pros and cons for each course of action, and possibly the assumptions for each pro and con. A decision ladder is a useful way of representing detailed process knowledge							*		*	*		app	indirect
Attribute Ladder	An attribute ladder shows attributes and values. All the adjectival values relevant to an attribute are shown as sub-nodes, but numerical values are not usually shown. For example, the attribute <i>colour</i> would have as sub-nodes those colours appropriate in the domain as values, e.g. <i>red, blue, green</i> . An attribute ladder is a useful way of representing knowledge of all the properties that can be associated with concepts in a domain							*		*	*		app	indirect
Process Ladder	This ladder shows processes (tasks, activities) and the sub-processes (sub-tasks, sub-activities) of which they are composed. All relationships are the <i>part of</i> relationship, e.g. boil the kettle <i>is part of</i> make the tea. A process ladder is a useful way of representing process knowledge							*		*	*		app	indirect
References	Diederich, J., Ruhmann, I., & May, M. " (1987)] , [ Shadbolt, N. & Burton, M. 1990) * [Geiwitz, et al., 1990], [Cordingley, 1989] , [Nezafati et al (2007)]													

Table 1 : Continue

Technique	Description	strengths	weaknesses	Tool Type	out put	result	Type of knowledge				purpose of technique		Time consuming	type of interaction
							tacit	explicit	process	concept	analyzing	generation		
Card Sorting	Here the expert is given a number of cards each displaying the name of a concept. The expert has the task of repeatedly sorting the cards into piles such that the cards in each pile have something in common.	It is fast to apply and easy to analyse. It forces an explicit format on the constructs that are underlie an experts understanding  gives clusters of concepts and hierarchical organization • splits large domains into manageable sub-areas • easy and widely applicable useful method to reveal the hierarchical organization of the domain	<ul style="list-style-type: none"> <li>• strict hierarchy is usually too restrictive</li> <li>• incomplete and unguided</li> </ul>	Interview ,cards, software	Hierarchical cluster diagram (classification)*	Classification of entities (dimension chosen by subject)	*			*	*	*	-	indirect
References	[Gammack John G(1987) , [Geiwitz, et al., 1990], [Cordingley, 1989] , [Nezafati et al (2007)] , [ Shadbolt, N. & Burton, M. 1995]													
Triadic elicitation	This technique prompts the expert to generate new attributes. This involves asking the expert what is similar and different about three randomly chosen concepts, i.e. in what way are two of them similar and different from the other.	This is a way of eliciting attributes that are not immediately and easily articulated by the expert.		Interview ,cards, software	Hierarchical cluster diagram	Classification of entities	*			*	*	*	-	indirect
References	*[1], [Geiwitz, et al., 1990], [Cordingley, 1989] , [Nezafati et al (2007)]													



Table 1 : Continue

Technique	Description	strengths	weaknesses	Tool Type	out put	result	Type of knowledge				purpose of technique		Time consuming	type of interaction
							tacit	explicit	process	concept	analyzing	generation		
Twenty Questions Tech.	In this novel technique the expert tries to guess something that the knowledge engineer is thinking about. The expert is allowed to ask questions of the knowledge engineer who is only allowed to respond yes or no. As the expert asks each question, the knowledge engineer notes this down. The questions asked and the order in which they are asked give important knowledge such as key properties or categories in a prioritized order.	a quick and efficient way of establishing the key tasks and information used.	elicitor needs a good understanding of the domain in order to make sense of the experts' questions, and to provide meaningful responses.	Interview	Amount and type of information used to solve problems; how problem space is organized, or how expert has	Information used to solve problems, organization of problem space			*	*	*	*	.	indirect
References	[1] B. J. & W. B.,1987] , [Grover, M. D. (1983)] , [ Shadbolt, N. & Burton, M. 1990] , [Welbank, M. (1990) * [Cordingley, 1989], [Geiwitz, et al., 1990], [Nezafati et al (2007)], [Milton N.(2007)]													
Repertory Grid Tech.	The Repertory Grid is a simple knowledge elicitation technique devised by clinical psychologists (Kelly, 1955). After identifying a small set of elements (a.k.a objects, entities), the user is asked to define some constructs (a.k.a. attributes, slots), which characterize those elements. Construct values can be given for each element on a limited scale between two range end points (the left and right poles). This is essentially qualitative information which can be elicited through the repertory grid tool. To accommodate more quantitative information, the method would have to be extended to accommodate a much more sophisticated type mechanism.	1)build the conceptual structure without direct elicitation of concepts and their structures and relationships.2)A free software product for constructing repertory grids is available 3) Useful technique for eliciting components in the domain, and their relationships to one another 4) Widely used in automatic KA systems	1)it is time consuming when we have large elements sets involved. 2)difficult to find aspects that are common to two elements which cannot be found in a third element. While carrying out our group exercise using Web Grid 3) using linguistic descriptions like “very close”, “high”, “low”, and so on, than using crisp values to judge the closeness of an element to a construct by experts4)Number of elements can become very large 5)Only elicits the results of problem-solving exercises	Software , Interview	Attributes (and entities if provided by subject)*	Entities, attributes, sometimes relationships	*		*	*	*		App	indirect
Reference s	[Hudlicka, 1997], [Thordsen, 1991], [Klein et al., 1986] [OTT, 1998], [Woods & Hollnagel, 1987] , [ Shadbolt, N. & Burton, M. 1990] , [www.osiris.sunderland.ac.uk]													

Table 1 : Continue

Technique	Description	strengths	weaknesses	Tool Type	out put	result	Type of knowledge				purpose of technique		Time consuming	type of interaction
							tacit	explicit	process	concept	analyzing	generation		
frames	Frames are a way of representing knowledge in which each concept in a domain is described by a group of attributes and values using a matrix representation. The left-hand column represents the attributes associated with the concept and the right-hand column represents the appropriate values. When the concept is a class, typical (default) values are entered in the right-hand column.	this would typically be used for validating previously acquired knowledge rather than for eliciting knowledge from scratch.			representing the properties of concepts	Validating captured knowledge		*		*		*	indirect	
Time Line	A timeline is a type of tabular representation that shows time along the horizontal axis and such things as processes, tasks or project phases along the vertical axis. So time line can be used to acquire time-based knowledge	It is very useful for representing time-based process or role knowledge		interview	flowchart	Capture the basic of processes		*	*	*		*	indirect	
Forms	A more recent form of knowledge model is the use of hypertext and web pages. Here relationships between concepts, or other types of knowledge, are represented by hyperlinks. This affords the use of structured text by making use of templates, i.e. generic headings. Different templates can be created for different knowledge types. For example, the template for a task would include such headings as description, goal, inputs, outputs, resources and typical problems.				Hyper text , web pages	Hyper text , web pages		*	*	*		*	indirect	
Matrix	A matrix (aka grid) is a type of tabular representation that comprises a 2-dimensional grid with filled-in grid cells. One example is a problem-solution matrix that shows the problems that can arise in a particular part of a domain as the rows in the matrix and possible solutions as the columns. Ticks, crosses or comments in the matrix cells indicate which solution is applicable to which problem. Another important type of matrix used by knowledge engineers is a focus grid, described later in this chapter	<ul style="list-style-type: none"> <li>• gives information on the local structure in the form of a network</li> <li>• shows which links are likely to be meaningful</li> <li>• organize elicitation of semantic relationships</li> </ul>	<ul style="list-style-type: none"> <li>• results depend of parameter settings</li> <li>• combinatorics limit its applicability</li> <li>• requires more time from the expert</li> </ul>	interview	Attribute matrix Relationship matrix		*	*	*	*		*	indirect	
References	[Gammack John G(1987), [Nezafati et al (2007)],[ Milton N.(2007)]													

Table 1 : Continue

Technique	Description	strengths	weaknesses	Tool Type	out put	result	Type of knowledge				purpose of technique		Time consuming	type of interaction
							tacit	explicit	process	concept	analyzing	generation		
Concept map*	A concept map is a type of diagram that shows knowledge objects as nodes and the relationships between them as links (usually labelled arrows). Any types of concepts and relationships can be used. The concept map is very similar to a semantic network used in cognitive psychology.			Interview	Procedures followed		*	*	*	*		*	direct	
References	[Nezafati et al (2007)] , * [Hudlicka, 1997], [Thordsen, 1991], [Gowin & Novak, 1984]													
Process map	A third important type of network diagram is a process map. This type of diagram shows the inputs, outputs, resources, roles and decisions associated with each process or task in a domain. The process map is an excellent way of representing information of how and when processes, tasks and activities are performed	an excellent way of representing information of how and when processes, tasks and activities are performed.	1 - Process map are too large and/or too unclear 2 – process maps show too much or too little information	Interview			*	*	*	*		*	direct	
References	[Nezafati et al (2007)] , [Milton N.(2007)]													
State Transition Network	Another important type of network diagram is the state transition network. This type of diagram comprises two elements: (1) nodes that represent the states that a concept can be in, and (2) arrows between the nodes showing all the events and processes/tasks that can cause transitions from one state to another			Interview			*	*	*	*	*	*	direct	
References	* [Hudlicka, 1997], [Thordsen, 1991], [Gowin & Novak, 1984], [Milton N.(2007)]													