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Determining the set of concept map based tasks for computerized knowledge self-assessment

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Abstract

Demands for educated labor force with well-integrated cognitive structures call for necessity to use in educational institutions appropriate teaching and knowledge assessment methods directed towards fine development and assessment of students' conceptual understanding. Concept maps as a kind of mental models have great potential in knowledge assessment due to several significant advantages. However, a taxonomy of possible concept mapping tasks has not been developed yet. The paper considers the problem of extending a set of concept mapping tasks in the already developed concept map based knowledge assessment system. The possible types of tasks are investigated from the point of view of the degree of directedness. As a result, a taxonomy of concept mapping tasks directly related to externalization of students' knowledge structures are given and explained in detail.

Keywords: concept map; knowledge self-assessment; degree of directedness

1. Introduction

Development of knowledge-based economy demands educated labor force with well-integrated cognitive structures allowing effective manipulations with existent knowledge and assimilation of new ones, solving up-to-date challenging problems, and effective decision making in unfamiliar situations. These characteristics are typically related to qualitative expert's knowledge organization which differs from novice's one in its structure and volume of domain knowledge. Therefore, educational institutions should use teaching and knowledge assessment methods directed towards fine development and assessment of students' cognitive structures in order to prepare students for their professional activity in better way. One of such methods is concept mapping.

Regardless the fact, that concept maps (CM) have been studied and used already for 40 years, a taxonomy of possible CM tasks has not been developed yet. Moreover, the author's experience of 7 years participation in development of a CM based knowledge assessment computerized system (called IKAS) shows that despite the fact that in general students like working with the system, there is evidence that tasks offered are not suitable for all

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students because the most part of them has difficulties in completing CM tasks. This fact allows thinking that it is necessary to extend a set of tasks with purspose to give students possibility to find such a degree of task difficulty which suits best their current knowledge level. Therefore, the paper summarizes students' opinion concerning most suitable types of CM tasks and provides a taxonomy of tasks considering their degree of directedness.

The paper is structured as follows. Section 2 describes the main building elements of CMs. Section 3 discusses usage of CMs in knowledge assessment. Section 4 provides overview of the developed system and summarizes students' opinion in relation to CM tasks. Section 5 presents the developed taxonomy of CM tasks taking into account the degree of directedness. Conclusions are given at the end of the paper.

2. Notion of concept maps

CMs are a kind of mental models. They can be used to externalize conceptual knowledge (both correct and erroneous) or, in other words, a cognitive structure hold by a person in a knowledge domain (Cañas, 2003; Novak & Gowin, 1984). This tool was developed by Novak in 1972. It grounds on constructivist epistemological ideas stating that concepts and propositions are building blocks of knowledge in any field and Ausubel's cognitive psychology declaring that learning happens by assimilating new concepts and propositions in student's existent structures of concepts and propositions and meaningful learning is a necessary prerequisite for developing individual's conceptual understanding (Cañas & Novak, 2006; Novak & Cañas, 2008).

CMs represent knowledge in the form of a graph which consists of labelled nodes displaying concepts in a knowledge domain and arcs showing relations between pairs of concepts. Table 1 specifies the main building elements of a CM. They are extracted from works of Novak (Novak & Gowin, 1984; Novak & Cañas, 2008; Novak, 2009) and few other authors (Cañas, 2003; Anohina-Naumeca, Grundspenkis, & Strautmane, 2011).

In general, structure of a CM is defined by the layout of nodes and arcs. Novak grounding on the fact that meaningful learning proceeds most easily when new concepts are subsumed under broader, more inclusive concepts emphasizes hierarchical structure of CMs and points out that more general, more inclusive concepts should be at the top of the map, but more specific, less inclusive concepts arranged below them (Novak & Gowin, 1984; Novak & Cañas, 2008). According to (Cañas, 2003), in practice CMs are not strictly hierarchical, but are arranged in semi-hierarchical manner. Non-hierarchical relations are displayed by cross-links. However, there are also research (Ruiz-Primo & Shavelson, 1996; Ruiz-Primo, Schultz, & Shavelson, 1997) which provide evidence that structure of CMs may depend on content represented by it, for example, Yin identified (Yin, Vanides, Ruiz-Primo, Ayala, & Shavelson, 2005) five different types of the structure.

3. Concept maps in knowledge assessment

CMs can be effectively used in knowledge assessment serving as a tool for identification of valid patterns and misunderstandings in students' cognitive structures (Novak & Gowin, 1984; Novak & Cañas, 2008). Considering usage of CMs in knowledge assessment the following advantages should be mentioned (Anohina, 2007):

- CMs can be used in any stage of the learning process: at the beginning of a learning course in order to determine which knowledge students already have, during the learning course to identify changes in students' knowledge and to adjust content and teaching methods of the course, and at the end of the learning course in order to determine the achieved knowledge level;
- Concepts maps can be used also for any type of knowledge assessment, inter alia for knowledge self-assessment. In the latter case, results of CM can serve as a basis for discussing the meaning of concepts with the teacher;
- Regular usage of CMs provides valuable information both for the student and for the teacher. The student can make sure that learning material and relations between studied concepts are correctly understood, and can reveal problems timely. The teacher can keep track of students' understanding of learning material and their misconceptions, and to make corrections when necessary;
- CMs allow revealing of the whole organization of knowledge (understanding of linkage between acquired concepts) instead of memorization degree of separate facts;
- CMs allow evaluation of higher order levels of cognitive development in Bloom's taxonomy, especially when students must choose the most prominent and most useful linking phrases and cross-links;

- CMs are universal enough and independent from subject matter, because a definite number of concepts and relations between them is an integral part of any learning course.

Table 1: Main elements of CMs

<table>
<tr><th>Element</th><th>Explanation</th><th>Visual representation</th></tr>
<tr><td>Concept</td><td>• A concept is a perceived regularity in events or objects, or a record of objects or events designated by a label;
• An event is anything that happens and can be made to happen;
• An object is anything that exists and can be observed;
• Concepts are denoted by names, symbols, and signs available in human language;
• A label for most concepts is a word. However, it can contain also different symbols like + or %, or more than one word.</td><td>A node consisting of:
• A node symbol (some graphic shape like oval or rectangle);
• A node label located inside the node symbol.</td></tr>
<tr><td>Relation</td><td>• A relation displays linkage between two concepts;
• Relations are characterized by linking phrases (for example, “is a”, “part of”, etc.) which explain the essence of them;
• One and only one correct linking phrase does not exist and therefore CM theory does not provide restrictions on linking phrases which can be used;
• A relation can have a weight which displays relative importance of the relation in the overall knowledge structure.</td><td rowspan="3">An arc consisting of:
• A connecting line between two nodes of the graph;
• A label located close to the connecting line;
• An arrowhead showing the direction of the arc (mostly for cross-links);
• A weight which can be displayed in different ways, for example, with distinct thickness or type of the connecting line or with an additional label.</td></tr>
<tr><td>Hierarchical relation</td><td>• It is a sub-type of relations (see above);
• By Novak’s notation, hierarchical relations are undirected, because to reduce clutter on the map, no arrows are shown unless the relation indicated is something other than a superordinate to subordinate linkage.</td></tr>
<tr><td>Cross-link</td><td>• It is a sub-type of relations (see above);
• Cross-links display non-hierarchical relations between concepts located in different segments of the CM and show how these segments are related.</td></tr>
<tr><td>Concept example</td><td>An example of a concept is a specific instance of the concept which helps to clarify the meaning of the concept.</td><td>Graphic shapes are usually not used for concept examples. Examples are added as text connected with a concept by an arc.</td></tr>
<tr><td>Proposition</td><td>• A proposition is a statement about some object or event in the universe;
• Propositions, which include a specific concept, clarify the meaning of this concept.
• A proposition is two or more concepts related with relations;
• In the simplest case, a proposition is a triple “concept-relation-concept”;
• Propositions are semantic units or units of meaning;
• Propositions are distinctive for each individual.</td><td>Node-arc-node</td></tr>
</table>

In (Ruiz-Primo, 2004), three components of CM as an assessment tool are defined: a task eliciting students’ understanding, a response format, and a scoring system allowing accurate and consistent evaluation of students’ CMs. In relation to CM tasks, the effects of two types of tasks – “fill-in-the-map” task, where students were asked to fill blank nodes or blank linking phrases in the provided structure of the CM, and “construct-the-map” task, where students were asked to construct a map using given set of concepts and without considering linking phrases – on assessing students’ understanding were analyzed in (Ruiz-Primo, Schultz, Li, & Shavelson, 2001). The conclusions made pointed out that “construct-the-map” tasks are more effective for revealing differences in students’ cognitive structures. Similar conclusions about tasks where students can freely choose concepts and linking phrases are provided in (Chung, Baker, & Cheak, 2002). In other research (Yin, Vanides, Riuz-Primo, Ayala, & Shavelson, 2005), students CMs in two tasks with the provided set of concepts and possibility to define or used already given linking phrases were compared taken into account several criteria and conclusions were made that the first type of tasks is more effective in revealing students partial knowledge and identifying misunderstandings, but the second type – for large-scale assessment. Grundspenkis (Grundspenkis, 2011) paid attention to types of CM tasks by considering restrictions on concepts and linking phrases available to students.

4. Overview of IKAS

Since 2005, the CM based ***i***ntelligent ***k***nowledge ***a***ssessment ***s***ystem called IKAS has been developed at Riga Technical University, Latvia (Anohina-Naumeca, Grundspenkis, & Strautmane, 2011; Grundspenkis, 2011). It has two main goals: 1) to support students in self-assessment process of their knowledge, and 2) to support teachers in improvement of learning courses through systematic analysis of students' knowledge. Concepts maps are used as a basis of assessment process in IKAS.

The system is used in the following way. The teacher divides a study course into several stages and builds a CM for each of them in such a way, that a CM of each stage is nothing else than an extension of the previous one. Therefore, the CM of the last stage includes all concepts studied in the course and all relations among them. At the end of each stage, the created CMs in the form of CM tasks are offered to students for knowledge self-assessment. After completion of a task, the system performs automatic comparison of CMs of the student and the teacher and provides feedback.

At the moment six tasks are implemented in the system: four of them provide the structure of a CM and the student must fill it using the offered set of concepts and/or linking phrases, and two tasks assume construction of a CM by the student using the offered set of concepts and/or linking phrases. Ten transitions between the tasks are realised. Five of them increase the degree of task difficulty. They are carried out automatically if the student has reached the teacher's specified number of points in the current assessment stage without reducing the degree of task difficulty of the original task. Other five transitions reduce the degree of task difficulty after a voluntary request from the student during task solving. Teachers set the initial degree of task difficulty for their learning courses.

During the period from 2005 till 2012, IKAS has been evaluated in 21 study courses. After use of the system, students are always offered to provide answers on a questionnaire eliciting their opinion about CMs as a knowledge assessment method and functional capabilities of IKAS. So far 582 questionnaires were processed. Regardless the fact that in general students evaluate positively their experience with IKAS, answers give evidence that the offered tasks are not suitable for all students (Table 2). First of all, there are students who do not like working with CMs. Secondly, always there are students who do not want to use CMs in future. Thirdly, the most part of students have difficulties in completing CM tasks. These facts, by the opinion of the system's developers, call for necessity to extend the set of tasks implemented in IKAS in order to support diversity of students in terms of their knowledge level and way of construction of knowledge structures and to provide more objective assessment process.

Table 2: Students' answers on the questionnaire

Question	Answer	Number of students' answers (%)
Do you like to use concept maps as a knowledge assessment method?	Yes	393 (67,5%)
	Neutral	114 (19,5%)
	No	75 (13%)
Would you like to use such a knowledge assessment method in other courses?	Yes	215 (36,9%)
	Probably	276 (47,4%)
	No	91 (15,7%)
Was it difficult for you to complete concept mapping tasks?	Very difficult	49 (8,4%)
	Difficult	344 (59,1%)
	Easy	177 (30,4%)
	Very easy	12 (2,1%)

In May of 2012, additional questions were offered to third year students of the bachelor programs at the Faculty of Computer Science and Information Technology in Riga Technical University. One hundred twenty six respondents took part after using IKAS for knowledge self-assessment in different stages of the learning course "Fundamentals of Artificial Intelligence". The questionnaire contained general questions about knowledge self-assessment and questions on most suitable types of CM tasks. The most part of students think that it is necessary to provide possibilities for students to perform knowledge self-assessment in learning courses (Yes – 85/67,5%, Probably- 34/27%, No – 5/3,9%, Other answer – 2/1,6%). Moreover, they support idea to use for knowledge self-assessment a computer system which can closed to the manner of human to check correctness of task solution and to provide feedback on mistakes made and their reasons (Support – 110/87,3%, Neutral – 10/7,9%, Do not support – 6/4,8%). Considering the main types of tasks, 73/57,9% students mentioned "fill-in-the-map" tasks as most suitable tasks for them, 45/35,7% – “construct-the-map” tasks, and 8/6,4% gave other answer. After this question both groups were asked to indicate 3 features which most characterize tasks suitable for them. Distribution of students’ answers is displayed in Table 3 and Table 4. Therefore, analysis of students’ opinion shows that there is no one universal task suitable for all students. In contrast, different combinations of features preferred by students call for necessity to make the set of offered tasks as broad as possible.

Table 3: Students’ opinion about features of the “fill-in-the-map” tasks characterizing most suitable tasks

Feature	Number of students’ answers (%)
Linking phrases are not used	36 (49,3%)
Linking phrases are used, but I can freely define which to include	11(15%)
Linking phrases are used, but they are provided as a list	31 (42,5%)
Part or all linking phrases are inserted in the structure of a concept map	24 (32,9%)
Arcs are undirected	19 (26%)
Arcs are directed	41 (56,2%)
Concepts are given as a list and a part of them are already inserted in the structure of a concept map	23 (31,5%)
I can freely define concepts which to include	8 (11%)
Concepts have not only a text label, but also visual information	21 (28,8%)

Table 4: Students’ opinion about features of the “construct-the-map” tasks characterizing most suitable tasks

Feature	Number of students’ answers (%)
Linking phrases are not used	9 (20%)
Linking phrases are used, but I can freely define which to include	19 (42,2%)
Linking phrases are used, but they are provided as a list	21 (46,6%)
Arcs are undirected	9 (20%)
Arcs are directed	29 (64,4%)
Concepts are given as a list	31 (68,8%)
I can freely define concepts which to include	4 (8,8%)
Concepts have not only a text label, but also visual information	13 (28,8%)

5. Taxonomy of tasks

CMs have been used in different assessment tasks. In general, tasks can be divided into two main groups (Anohina-Naumeca & Graudina, 2012): a) simple CM tasks, which apply CMs as the main assessment instrument and do not use other types of tasks simultaneously; b) compound CM tasks, in which a simple CM task is only a part of assessment, for example, a student writes an essay and gives its summary as a CM, or gives an answer as a CM which is followed by an individual interview about the content of the constructed CM (Rojas, Sánchez, Barrios, Vergara, Torres, & Bravo, 2008), or vice versa, the interview is at first and then a CM is constructed on the basis of the answers received (Wehry, Algina, Hunter, & Monroe-Ossi, 2008).

The diversity of the simple CM tasks is determined by the fact that a task consists of a combination of three parts (Ruiz-Primo & Shavelson, 1996): a) task demands, which correspond to a task statement or, in other words, specify what the student needs to do, for example, the student needs to fill in the structure of a CM, to compare two CMs, to evaluate correctness of a CM, to construct a CM, etc.; b) task constraints, which restrict student’s activities, for example, they determine what kind of the topology should be provided, does the student receives all concepts needed for task solving or only part of them, etc.; c) task content structures, which are an intersection between task statement and constraints and the structure of the problem domain, i.e., how the problem domain affects a task, for example, the student needs to draw a linear CM representing sequence of processes.

Task demands determine the type of a task. Here, two main categories can be identified: a) tasks directly related to externalization of students’ knowledge structures (internal representation of knowledge), for example, construct a CM for a specific topic or fill the missing concepts in the structure; b) tasks where the student manipulates provided CMs or their elements, for example, evaluation of correctness of a CM, evaluation of correctness of a proposition, concept sorting (Ruiz-Primo & Shavelson, 1996), comparison of CMs, etc.

Further in this paper attention is paid only to the simple CM tasks related to externalization of students' knowledge structures.

The CM tasks can be characterized with directedness continuum (degree), i.e., the degree of task difficulty is influenced by the fact how much the student has been directed during task solving, more precisely, how much information about the CM the student receives (Ruiz-Primo, 2004). The higher is the degree of directedness, the simpler is the task. The degree of directedness is associated with the task constraints mentioned above.

In general, the task constraints emerge from possible constraints on the elements of a CM as a graph and their characteristics. These elements are: a) the whole structure of a CM which is characterized by its availability to the student, presence of arc direction, and presence of arc weights; b) nodes representing a set of concepts in the problem domain; c) arcs defining relations between concepts and characterized by a set of linking phrases.

With regard to availability of the structure of a CM, three possible values can be defined: a) a full structure (it corresponds to the so called "fill-in-the-map" tasks where the student must operate with the already provided structure of a CM taking into account constraints on other elements of the CM); b) an absent structure (it corresponds to the so called "construct-the-map" tasks (opposite to the "fill-in-the-map" tasks) where the structure of a CM is not provided and the student must create it in the framework of constraints on other elements of the CM); c) a partial structure (in this case a part of the structure is already given ("fill-in-the-map" task), but it must be extended by the student by adding new nodes and arcs to it ("construct-the-map" task); this type of tasks can be called "adjust-the-map" tasks).

Figure 1 displays the degree of directedness in relation to the previously described constraints on availability of the structure of a CM. As "adjust-the-map" tasks are a combination of "fill-in-the-map" and "construct-the-map" tasks, further in the paper attention is paid to detailed analysis of the these two types of tasks.

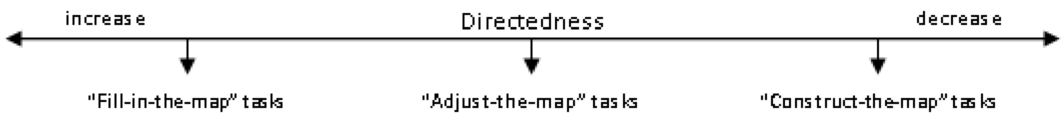

Figure 1. Task characterization with directedness

Necessity to process arc directions increases the degree of task difficulty. Here, it is possible to define three main cases with some variations for "fill-in-the-map" and "construct-the-map" tasks:

- Direction of arcs is not important in the context of the task and, therefore, the CM is an undirected graph; it is suitable for tasks where linking phrases have not used and only the fact that concepts are related is important;
- Direction of all arcs is important in the context of the task and, therefore, the CM is a directed graph:
  – for "construct-the-map" tasks: the student must provide direction of arcs where it is necessary;
  – for "fill-in-the-map" tasks: a) direction of all arcs is provided in the structure of the CM; b) none of arcs are directed in the structure and the student must provide direction of arcs; c) a part of arcs in the structure is directed, for the other part the student must provide direction;
- Arcs are partly directed according to Novak's notation, where hierarchal relations are undirected and should be read from bottom to top, and horizontal cross-links are directed (Novak& Gowin, 1984):
  – for "construct-the-map" tasks: the student must provide direction of arcs where it is necessary;
  – for "fill-in-the-map" tasks: a) direction for arcs that need it is provided in the structure; b) none of arcs are directed in the structure and the student must provide direction of arcs that need it; c) a part of arcs in the structure is directed, for the other part the student must provide direction.

Figure 2 shows the degree of directedness taking into account constraints on direction of arcs in a CM.

According to Grundspenkis (Grundspenkis, 2011), CMs are homogeneous graphs if all arcs in a CM have the same weights or heterogeneous graphs if weights are different. In the former case, the student must not care about determination of arc weights in CM tasks. In the latter case, constructing a CM a student must provide weights of arcs. However, in "fill-in-the-map" tasks three different cases need to be considered (Figure 3): a) arc weights are provided in the structure of the CM; b) arc weights are not provided in the structure and they must be determined by the student; c) a part of arc weights are provided in the structure, the other part must be determined by the student.

A set of concepts is an integral part of any CM task, because without it tasks do not have sense. However, linking phrases are optional as they only explain semantics of relations which presence is displayed by arcs.

Therefore, considering constraints related to sets of concepts and linking phrases (if linking phrases are used), it is necessary to take into account the previously specified constraints on the structure of the CM. Then, two different sets can be identified:

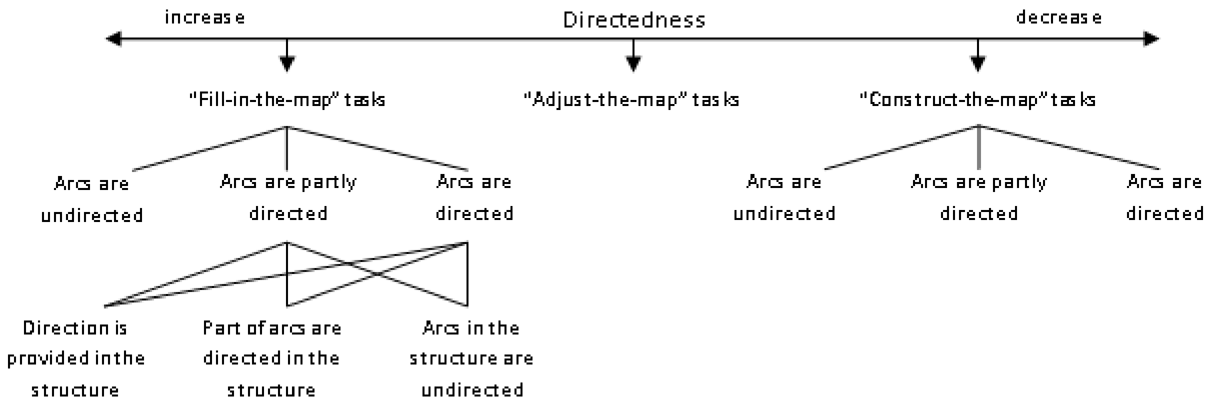

Figure 2. The degree of directedness in relation to constraints on arc direction

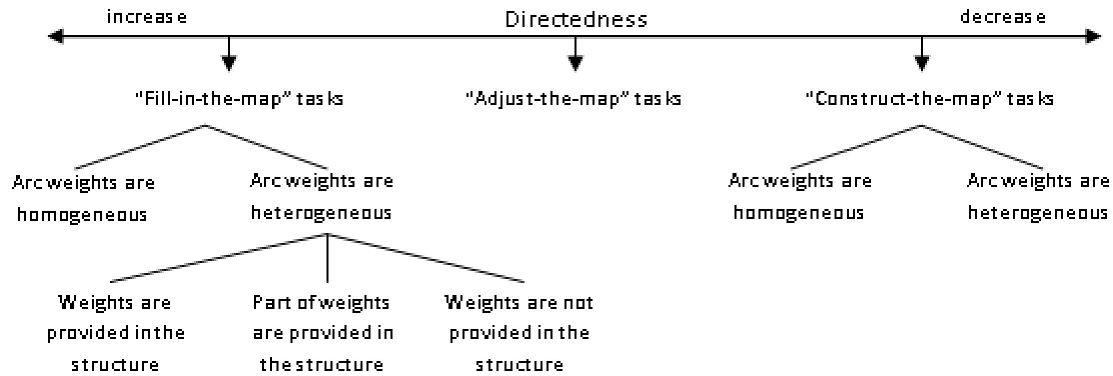

Figure 3. The degree of directedness in relation to constraints on arc weights

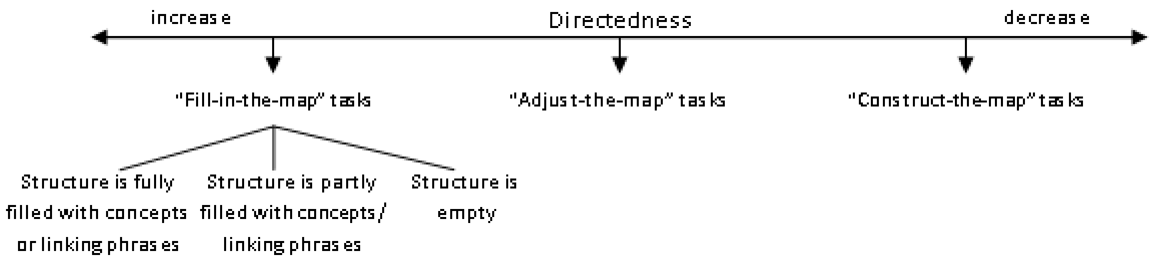

Figure 4. The degree of directedness taking into account constraints on concepts/linking phrases already inserted in the structure of a CM

- Sets of concepts/linking phrases already inserted in the structure of a CM and serving as anchors/hints for completion of the task. There three values are possible: a) an empty set (this case corresponds to "construct-the-map" tasks, because they do not offer the already provided structure of a CM); b) a full set (it is a case of "fill-in-the-map" tasks when all concepts or linking phrases are already inserted in the structure of a CM); c) a partial set (this case is also related to "fill-in-the-map" tasks when a part of concepts and/or linking phrases are already inserted in the structure of a CM, but the other part must be filled in by the student). Figure 4 shows the degree of directedness taking into account constraints on sets of concepts/linking phrases already inserted in the structure of a CM.

- Sets of concepts/linking phrases available to the student for completion of the task. Constraints on these sets can be dived into five categories (adopted from (Grundspenkis, 2011) and supplemented): a) a full set (the student receives all concepts/linking phrases that are relevant to the task and must be inserted into the given structure of a CM ("fill-in-the-map" tasks) or must be used for construction of a CM ("construct-the-map" tasks)); b) an empty set (the student needs to define all concepts/linking phrases relevant to the task by him/herself); c) a partial set (the student receives only a part of concepts/linking phrases as a list, the other part must be defined by him/herself); d) an overfull set (the student receives not only those concepts/linking phrases that are relevant to the task, but also additional concepts/linking phrases that are misleading, because they are incorrect or irrelevant to the problem domain); e) a hybrid set (the student receives a part of concepts/linking phrases relevant to the task and a number of misleading items as a list, but the other part of concepts/linking phrases must be defined by him/herself).

Figure 5 displays the degree of directedness in relation to constraints on sets of concepts/linking phrases available to the student. The degree of directedness decreases in the following order: full set→ overfull set→ hybrid set→ partial set→ empty set.

Taking into account the task constraints described previously, it is possible to conclude that the degree of task difficulty in both "fill-in-the-map" and "construct-the-map" tasks is influenced by the fact what the student must do by him/herself and what is provided for this activity. However, the degree of task difficulty in "fill-in-the-map" tasks also depends on what is already included in the provided structure of a CM.

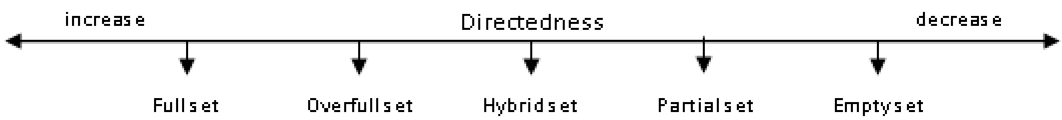

Figure 5. The degree of directedness in relation to the sets of concepts and linking phrases available to the student

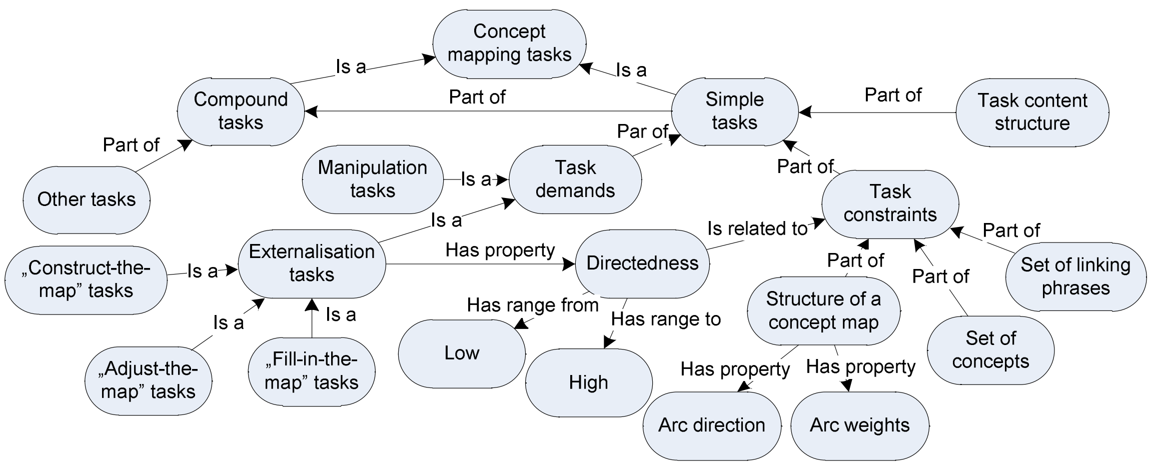

Figure 6. General view on diversity of CM tasks

Figure 6 displays a general view on diversity of CM tasks. Table 5 offers a detailed framework for identification of possible CM tasks taking into account task constraints. Impossible combinations are shown as cells with grey shading. Therefore, "construct-the-map" tasks are a combination from an absent CM structure and: a) one of constraints on the set of concepts available to the student; b) one of constraints on the set of linking phrases available to the student; c) one type of arc direction (from available variations); d) one type of arc weights (from available variations). "Fill-in-the-map" tasks, in their turn, are a combination from the following items: a) one type of full structure taking into account concepts filled in the structure; b) one type of full structure considering linking phrases filled in the structure; c) one of constraints on the set of concepts available to the student (except if the structure is "Full structure with fully filled concepts"); d) one of constraints on the set of linking phrases available to the student (except if the structure is "Full structure with fully filled linking phrases" and except of using "Absent set" together with any type of full structure with filled linking phrases); e) one type of arc direction ("Undirected arcs" are used with "Absent set" of linking phrases); f) one type of arc weights.

Examining Table 5, the following tasks can be given as examples:

- "Construct-the-map" task: the structure of a CM is not provided; it must be constructed by students from a set of concepts containing not only concepts that are relevant to the task, but also misleading concepts; students must also provide direction of relations, but linking phrases are not used in the task and arc weights are homogeneous;
- "Fill-in-the-map" task: full structure of the CM with no concepts inserted and with provided direction of relations is given to students; students must fill it using a set of all concepts related to the task and a part of linking phrases relevant to the task together with some misleading items; the other part of linking phrases must be defined by students; moreover, students must also point out weights of relations, because they are heterogeneous and are not provided in the structure.

In several cases the degree of directedness depends also on how relevant and how many items are provided. The following questions help to understand the degree of directedness in case of three values of sets specified previously:

- A partial set (arc direction, concepts and linking phrases available to students, concepts and linking phrases inserted in the structure, arc weights): Does the set contain or display key or less important items? How many items are in the set?
- An overfull set: How many misleading items are in the set?
- A hybrid set: all three questions mentioned before.

Considering weights of arc, one more question arises: What is the range of possible arc weights?

6. Conclusions

The paper focuses on two types of CM tasks – "fill-in-the-map" and "construct-the-map" tasks and provides their taxonomy which further is planned to use for extending a set of tasks in the computerized knowledge assessment system IKAS. This will allow students to find such a degree of task difficulty which suits best their current knowledge level and will ensure more objective assessmen. Moreover, evaluation of students' results in both mentioned types of tasks is possible in automatic way by using a reference (expert) map and considering such criteria of performance as correctness of propositions, number of hierarchy levels, number of concept examples, etc. However, for evaluation not only of correctness of CM elements, but also their quality or importance additional methods must be integrated into the system, for example, ontology.

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Table 5: Taxonomy of CM tasks

		A1	A2	A3	A4	A5	A6	A7
B	B1							
	B2							
	B3							
	B4							
	B5							
C	C1							
	C2							
	C3							
	C4							
	C5							
	C6							
D	D1							
	D2							
	D3							
	D4							
	D5							
	D6							
	D7							
E	E1							
	E2							
	E3							
	E4							

A1 Absent structure A2 Full structure with fully filled concepts A3 Full structure with partly filled concepts A4 Full structure with no concepts inserted A5 Full structure with fully filled linking phrases A6 Full structure with partly filled linking phrases A7 Full structure with no linking phrases inserted	D Arc direction D1 Undirected arcs D2-D4 Directed arcs: D2 direction is provided in the structure; D3 direction is partly provided in the structure; D4 direction is not provided D5-D7 Partly directed (Novakian) arcs: D5 direction is provided in the structure; D6 direction is partly provided in the structure; D7 direction is not provided
B Constraints on the set of concepts available to the student, C Constraints on the set of linking phrases available to the student B1, C1 Full set B2, C2 Partial set B3, C3 Overfull set B4, C4 Empty set B5, C5 Hybrid set C6 Absent set	E Arc weights E1 Homogeneous weights E2-E4 Heterogeneous weights: E2 all weights are provided in the structure; E3 weights are partly provided in the structure; E4 weights are not provided

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