Digital Literacy or Computer Science: Where do Information Technology Related Primary Education Models Focus on?

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***Abstract*— The present deep impact of information technology on society results in an increasing number of countries starting to introduce information technology related topics even in primary schools. However, the resulting curricula, educational standards and competence models differ in several aspects like in their structure or competence focus, making them hard to assess and to compare. This contribution presents a graph-based approach that eases the comparison and that can be used to exemplify different focal points easily. In order to do so, we looked at several educational models and used a graph-based representation form to display the emphasis on either Digital Literacy and/or Computer Science concepts.**

I. Introduction

The information technology's deep impact on present society has also high influence on developments in education. So, countries all over the world increase their effort to establish reasonable education in related areas already in primary schools. For this purpose, different curricula, educational standards or competence models were developed and implemented. A report from the European Schoolnet in 2015 [1] points out that in most cases, information technology related content is part of curricula or educational standards for *Computer Science*, *Computing* or *Informatics*. It further shows that in 19 of 21 participating countries *Digital Competence* or *Digital Literacy* is focused, whereas only 10 countries set their focal points on "Computing and Coding skills" [1], with other words *Computer Science*.

Based on the idea of classifying the focus of curricula, this contribution aims at, in a first step, analyzing and, in a second step, comparing different curricula and competence models. For the categorization nine experts participated in a survey and rated elements of curricula and competence models to be part of either *Digital Literacy* and/or *Computer science*. A graph-based representation form presented by Pasterk and Bollin [2] is used to display an overview of the priorities within three selected educational models.

This contribution is structured as follows: chapter two gives an overview of related literature and in chapter three the selected educational models are described. Chapter four presents the graph-based approach used in this paper and chapter five defines the two categories as well as the process of categorization. In chapter six the results are presented and discussed.

II. Related Work

The increasing number of published literature concerning *Computer Science* in primary education reflects the fact that the research interest for this field of study rose during the last years. A lot of these articles present new best practices or the development of a new educational model [3].

Only a few works include an analysis and comparison of different educational models. On their way to develop a Computer Science and Programming course for primary education, Duncan and Bell [4] studied four English-language curricula for primary school, including the Australian "Digital Technologies" curriculum [5]. Duncan and Bell defined the following six categories of themes: *Algorithms*, *Programming*, *Data representation*, *Digital devices and infrastructure*, *Digital applications*, and *Humans and computers*. In a further step they classified the single elements of the selected curricula among these new themes and compared the topics for different school grades, resulting in a list of differences and similarities [4].

An additional example for a analysis of curricula for K-9 Computer Science education based on categorization is the work of Barendsen et al. [6]. Besides teacher interviews and the investigation of assessment, the article also contains a classification of Computer Science subjects into knowledge categories, based on the knowledge areas from the *ACM/IEEE Computer Science Curricula* [7]. They define the following list of knowledge categories: *Algorithms*, *Architecture*, *Modeling*, *Data*, *Engineering*, *Intelligence*, *Mathematics*, *Networking*, *Programming*, *Security*, *Society*, and *Usability*.

To identify the focus of four selected curricula the occurrences of special codes defined for each knowledge category are counted. These numbers indicate the relative importance of individual categories within a curriculum. Results show that *Algorithms* is considered in all analyzed documents as a major concept [6].

Looking over the borders of primary education more approaches of curriculum analysis and comparison are to be found. Most of them focus on undergraduate degree programs or academic courses. A promising example based on graph theory comes from Lightfoot [8]. His article focuses on the improvement of the structure and the correct placement of assessment within a Bachelor degree curriculum. For this purpose the curriculum is mapped to a simple acyclic directed graph, in which courses correspond to vectors, and prerequisite requirements display the edges, and basic graph-theoretic metrics are calculated and visualized. With the help of the selected metrics (like degree, structural centrality, and clustering density) interesting vertices and good positions for topic introduction or assessments are determined [8].

A further graph-theoretic approach is presented by Marshall [9], aiming at identifying major changes of three undergraduate degree Computer Science curricula from 2001, 2008 and 2013, including the ACM/IEEE Computer Science Curriculum from 2013 [7]. The topics, knowledge areas, knowledge units or modules are mapped to vertices and the connecting edges represent dependencies between these vertices. The comparison of the directed graphs of the three curricula is conducted visually, to get a quick overview of the differences, as well as algorithmically, for a quantification of differences and similarities. Results of this analysis show that the content of Computer Science curricula changed from 2001 to 2013 significantly [9].

In this contribution and different to the above mentioned we present an approach for Computer Science in primary education that uses ideas from analysis and comparison based on graph theory combined with the categorization of curricula based on an expert rating. As supporting technology we chose the graph database neo4j to store and represent the single elements of the curricula as graphs.

III. Educational Models

As a preparation for this contribution three educational models had to be selected for analysis and comparison. We chose one of the main English-language curricula, the curriculum from Australia [5], and two German-language models, the curriculum from Switzerland [10] and the Austrian Digital Competence model "digikomp" [11], because of their local importance. Parts of the German-language educational models cited in this contribution were translated into English by the authors.

A. Curriculum from Australia (AC)

The Australian curriculum for the learning area "Technologies" was implemented in 2014 [12]. In 2015 and 2016 the version 8.3 of the curriculum was established. The learning area is part of the curriculum from Foundation (F), which represents the first school year, and ends at the tenth grade as an elective subject. It combines the two subjects "Design and Technologies" and "Digital Technologies", which are described as being "distinct but related" [5]. Where "Digital Technologies" focuses on use and technical background of digital technology, "Design and Technologies" deals with topics related to design and technology's impact on society. In this contribution, the curriculum for the subject "Digital Technologies" is considered. The levels of this curriculum start as mentioned with F and contain two school grades, so F-2, 3-4, 5-6, 7-8, and 9-10. For this contribution, the first three levels are of interest, because they cover the school grades of primary education. Two major themes, "Knowledge and understanding" and "Processes and production skills", divide the content of the curriculum and are further subdivided into the following sub-strands: Digital systems, Representation of data, Collecting, managing and analyzing data, Creating digital solutions by investigating and defining, Creating digital solutions by generating and designing, Creating digital solutions by producing and implementing, Creating digital solutions by evaluating, and Creating digital solutions by collaborating and managing [5].

B. Curriculum from Switzerland (Curriculum 21)

The curriculum for primary and lower secondary school in Switzerland called "Lehrplan 21" was presented in 2014 and established by 21 of the 26 cantons with individual adaptations. The subject "Media and informatics (Medien und Informatik)" is part of it from first year at school. The "media" part deals with the understanding and responsible use of different media, whereas the "informatics" part focuses on problem solving and basic concepts of Computer Science [10]. Additionally, the other subjects have to foster their individually required application competence. So called "cycles" represent the level system and contain three to four school grades. Cycle one covers kindergarten and school grade one and two, cycle two grades three to six, and cycle three grades seven to nine. In this contribution cycles one and two are considered, because they cover primary school grades. Seven major competences are defined in the curriculum, which are reached step by step by passing competence levels assigned to a specific cycle. Each major competence deals with one of the following content areas: Life in media society, Understand media and media products, Produce media and media products, Communicate and cooperate with media, Data structures, Algorithms, and Informatics systems [10].

C. Digital Competence Model from Austria (digiKomp)

In Austria, a new curriculum for "Basic Digital Education (Digitale Grundbildung)" is under development at this time. Therefore, the competence model, which can be seen as a building block of the new curriculum [13], is analyzed and compared in this contribution. This model called "digikomp" is no national curriculum yet, but can give interested teachers some information and suggestions what can be taught in Computer Science. There are versions of this model for primary ("digikomp4"), lower secondary ("digikomp8") and higher secondary education ("digikomp12"), which contain similar content areas but with more details in higher levels. The competence model for primary education was presented in 2013 by Mulley and Zuliani [14] and focuses on the responsible use of digital technology including some concepts of Computer Science. The following four content areas are defined in the "digikomp4" competence model: Informationtechnology, humans and society, Informaticssystems - Usage of digital devices and networks, Applications - Digital tools in everyday life, and Informaticsconcepts - First steps in informatics [11].

IV. A Graph-based Approach

As mentioned in the introduction, the two objectives of this contribution are firstly to analyze and secondly to compare curricula and competence models using a graph-based representation form. This idea is not new but has never been done for Computer Science related curricula in primary education. Our approach uses labeled and typed edges and vertices, which enables the inclusion of additional attributes for edges and vertices, and maps them to a graph database [2]. In this section, the steps for this process are described and the advantages and technical opportunities of this approach are illustrated.

A. Extraction of Competences

As a first step, the documents of the curricula, educational standards, and competence models are analyzed to identify small and comparable key elements. Possible comparable elements are the content and the learning outcomes. But it has to be considered that these learning outcomes are often formulated similarly and denoted differently in the curriculum documents. As in Austria and neighboring countries competence-orientation is an important topic in the development of curricula, in our approach, we define competences as our comparable key elements and understand them following Weinert as "the cognitive abilities and skills possessed by or able to be learned by individuals that enable them to solve particular problems, as well as the motivational, volitional and social readiness and capacity to use the solutions successfully and responsibly in variable situations." [15]

An example of a competence from the Austrian Digital Competence model shows, how they are formulated:

"I can understand and execute easy instructions." [11]

It defines, from the perspective of a student, what she or he should be able to do. Whenever a curriculum is competence-oriented (like in Switzerland) comparable key elements can easily be extracted. But not all of the selected educational models are competence-oriented. This is the case for the Australian curriculum, which uses the term "learning objectives" [12] to describe the expected learning outcomes. The following example objective shows, how they are formulated:

"Follow, describe and represent a sequence of steps and decisions (algorithms) needed to solve simple problems." [5]

Although the formulation is different to the previous two examples, the content is either similar or at least mappable.

Now, to represent the selected curricula and competence models as graphs, those content specific competences or learning objectives were extracted based on the rating of experts and labeled with a unique ID number, the original text, and attributes like the related curriculum, the level, minimum and maximum age, or keywords. They are displayed as the vertices in the graphs.

B. Relations

The edges of the graph-based representation of the educational models were added in form of relations between the extracted competences or learning outcomes within one curriculum. We classified the two relation types "required by", meaning one vertex is required by another one, and "expanded by", representing either a generalization or a specialization relationship. This step resulted in one simple, acyclic and directed graph for each curriculum, which were in a first step evaluated and revised by two experts.

Please note, the results shown in this contribution focus on the categorization and not on the types of relations. Therefore, the figures show graphs with directed edges, but without type-labels.

C. Graph Database

As supportive technology, the graph database *neo4j* [16] was selected. The graph-based representations of the educational models are mapped to this NoSQL database, which differs in several aspects from relational databases. Data and connections are not stored in tables but as vertices and edges of a graph [17]. Neo4j uses the own query language *cypher* to calculate several graph-theoretic metrics or retrieve needed information.

V. CATEGORIZATION

The main questions during our efforts was to find out, if and to what extend the focal points of curricula and competence models differ. We decided to start with two categories first: either a focus on *Computer Science* or on *Digital Literacy*. This section provides a definition for both categories and further describes how the categorization process was executed.

A. Computer Science and Digital Literacy

Defining the term *Computer Science* needs an additional clarification of the used terminology. Whereas *Computer Science* is a common term in US, in Europe the term *Informatics* is broadly used and also *Computing Science* can be found [18]. Formerly also \textit{Information and Communication Technology (ICT)} was a common term in education, with the varying meaning from "teaching basic concepts" to "application of systems" [19].

In the report of the joint Informatics Europe and ACM Europe Working Group on Informatics Education from 2013 [18] the terms *Informatics* and *Computer Science* are used synonymously and are defined as follows:

"Informatics covers the science behind information technology. Informatics is a distinct science, characterized by its own concepts, methods, body of knowledge and open issues." [18]

In this contribution, we build up on this definition of *Computer Science* and use the abbreviation *CS*.

A detailed definition of *Digital Competence* was presented in connection with the DIGCOMP framework for Developing and Understanding Digital Competence in Europe [20]:

"Digital Competence can be broadly defined as the confident, critical and creative use of ICT to achieve goals related to work, employability, learning, leisure, inclusion and/or participation in society." [20]

For this contribution, we use *Digital Competence* and *Digital Literacy* synonymously and refer to it with *DL*.

B. The Process of Categorization

As mentioned in section II, there are different ways to categorize the elements of a curriculum. Most of them focus on the content and the learning outcomes [4, 6] and classify these element by using specific codes for each knowledge categories. For our contribution nine experts (three females, six male), four of them were Informatics teachers and five were researchers in the field of Informatics didactics, participated in a survey to categorize the competences and learning objectives. Each of them completed a questionnaire including all competences and learning objectives of the three selected models in a random order with the possibility to classify them into *CS*, *DL*, *Both* or *None*. From the results of this survey enough data could be collected, to represent the focus of each of the analyzed educational model in graphs, which are discussed in the following section.

VI. Results and Discussion

To accomplish our goal of giving an overview of the focus of the selected educational models, we represent the results from the expert survey as graphs with different colored vertices. For each curriculum or competence model three graphs with different coloring are presented.

The first and the second graphs show the separate numbers of votes for *CS* and *DL*. So, the colors of the vertices in the first graph represent how many experts chose *CS* or *Both* for each of the corresponding competence or learning objective, and the second graph does the same for *DL*. This is of interest because the two categories are often related together, so it can occur that even if more experts chose one category for one competence or learning objective some would classify it to the other category. Similar cases can be identified by a comparison of the first and the second graph.

The third graph divides the vertices into "CS", "Rather CS", "Draw", "Rather DL" or "DL". A vertex is classified as "CS" or "DL", if more than 75 percent of the experts chose CS or DL for the corresponding competence or learning objective. If more than 50 but less than 75 percent of the experts chose CS or DL, the vertex is classified as "Rather CS" or "Rather DL". If exactly the half of the experts voted for CS and the other half for DL, then the vertex is displayed to be "Draw". With nine experts this can only happen, if at least one expert voted with Both at the corresponding competence or learning objective, because it is counted for CS and DL. In this section, the results for each analyzed educational model are presented and discussed.

The separate results for each of the two categories *CS* and *DL* of the Australian curriculum are presented in Fig. 1 and 2. Fig. 1 shows that at least eight experts voted for ten learning objectives to belong to *CS*. Further one learning objective was classified by at least six experts into *CS*, four learning objectives by at least four experts, three learning objectives by at least two experts, and two learning objectives by one expert. Only two learning objectives have not been classified into *CS* by any expert. In comparison to Fig. 2 six learning objectives were never classified to belong to *DL*. Four learning objectives were classified by at least eight experts into *DL*, six learning objectives by at least six experts, three learning objectives by at least four experts, one learning objective by at least two experts, and two learning objectives by one expert. These results don't indicate a focus on one of the two categories, but it seems that the experts agreed on the classification of learning objectives into *CS*, whereas their opinions concerning *DL* were a bit more divided.

For this comparison has to be considered that some vertices are classified by at least eight experts into one category, but have also e.g. four votes for the other category. An example for this case is indicated in Fig. 1 and 2 by a green cycle. That can occur, if several experts chose *Both* for the corresponding learning objectives and several others chose one of the categories "CS" or "DL".

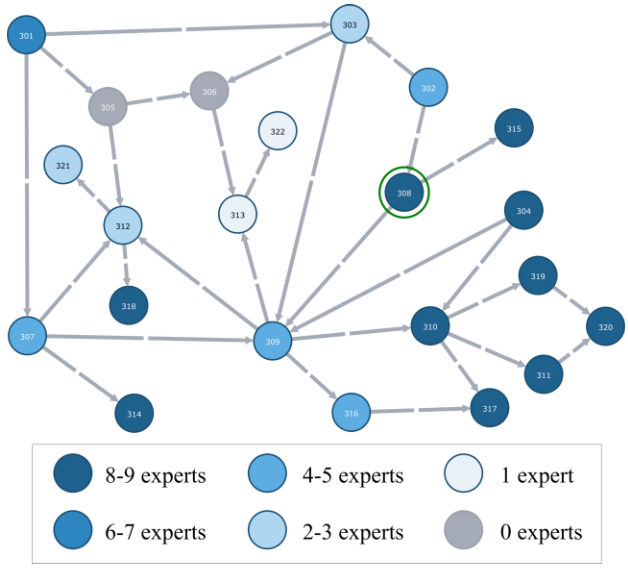

Figure 1. The distribution for CS of experts' choices for the learning objectives from the Australian curriculum

Fig. 3 shows an overall comparison of the Australian curriculum. Exactly the same amount of the learning objectives (ten) were classified into *CS* and into *DL* by the majority of the experts. For *CS* nine learning objectives were classified into "CS", because over 75 percent of the experts chose *CS* for the corresponding learning objectives, and only one into "Rather CS", what means, that between 50 and 75 percent of the experts chose *CS*. On the other hand, only three learning objectives are classified into "DL", because over 75 percent of the experts voted for *DL*, and seven into "Rather DL", because between 50 and 75 percent of the experts voted for *DL*. For two vertices both categories got the same number of votes, that is why they are classified as "Draw". These results show that the Australian curriculum as a balanced number of learning objectives of each category and has no clear focus.

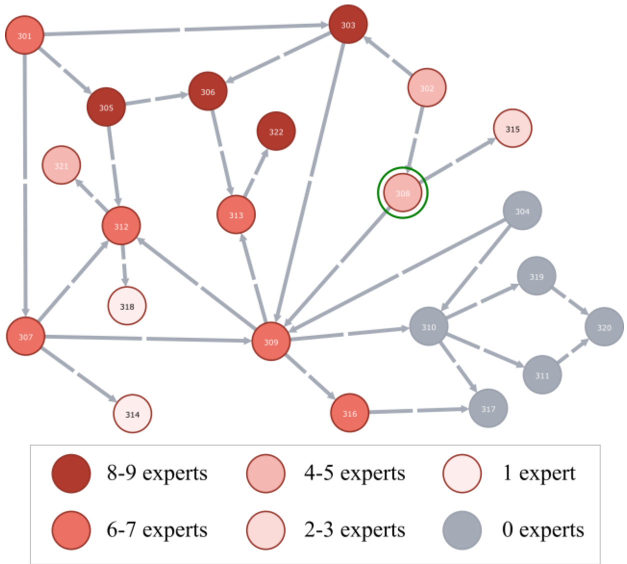

Figure 2. The distribution for DL of experts' choices for the learning objectives from the Australian curriculum

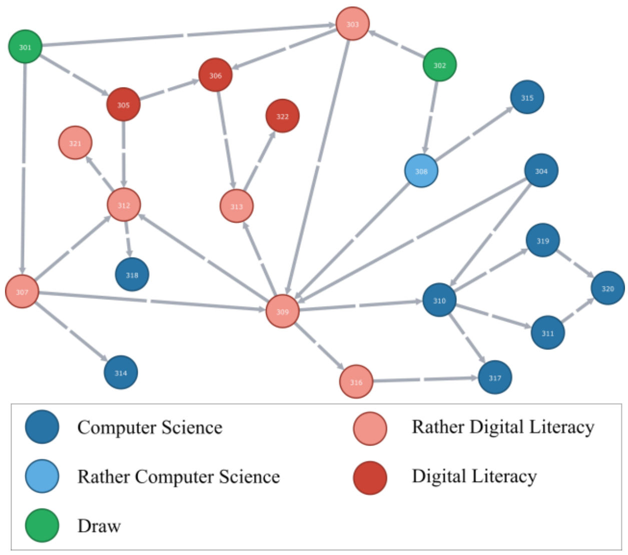

Figure 3. A comparison of learning objectives related to CS or DL from the Australian curriculum

For the curriculum from Switzerland the separate results are presented in Fig. 4 and 5. Fig. 4 shows that the distribution of choices for *CS* is limited to a few vertices. Nine vertices were classified by at least eight experts into *CS*. On the other hand, there are 17 vertices, that don't have any vote for *CS*. Fig. 5 shows also a clear focus on DL, because 25 vertices are classified by at least eight experts into *DL*, whereas only three vertices include no vote for *DL*.

The overall comparison in Fig. 6 shows only five vertices are classified to "CS" and six to "Rather CS", whereas 22 vertices belong to "DL" and ten to "Rather DL". And one vertex is classified into "Draw". Following the decisions of the experts the focus of the curriculum from Switzerland is on *DL*.

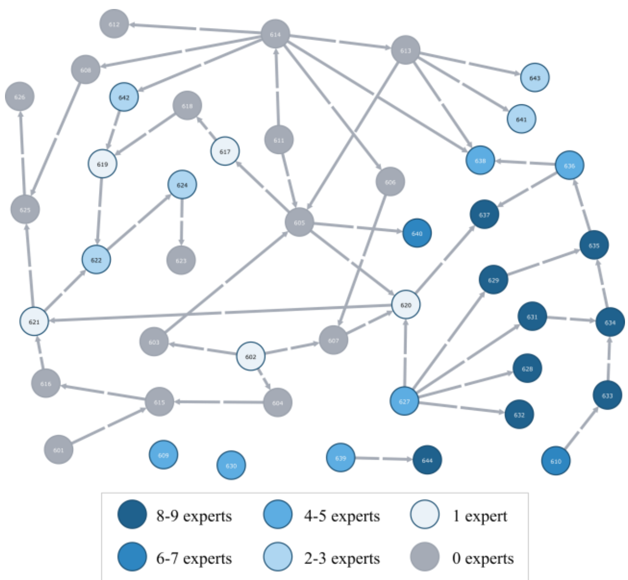

Figure 4. The distribution for CS of experts' choices for the competence levels from the curriculum in Switzerland

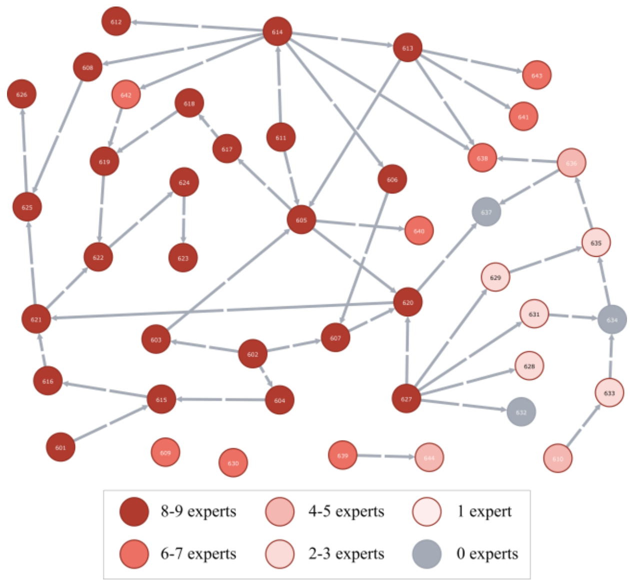

Figure 5. The distribution for DL of experts' choices for the competence levels from the curriculum in Switzerland

The separate results for the Austrian Digital Competence model are presented in Fig. 7 and 8. Fig. 7 shows that only one competence was classified into CS by at least eight experts. On the other hand, 25 competences had no single vote for CS by any expert. Fig. 8 shows the dominance of DL in this model. From overall 49 competences 43 were classified by at least eight experts into DL.

The overall comparison of the Austrian model presented in Fig. 9 shows that there are only two vertices classified into "Rather CS" and two into "Draw". The rest belongs with 38 vertices to "DL" and with seven vertices to "Rather DL". As the Austrian model is a model for Digital Competence it has a strong focus on *DL*.

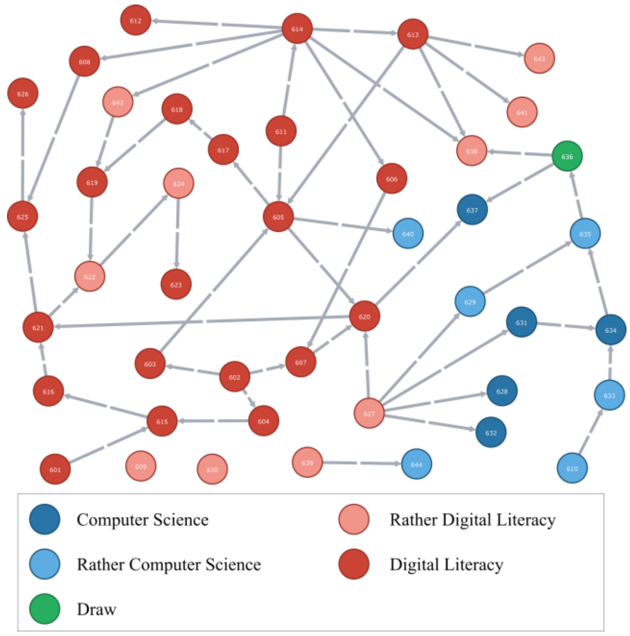

Figure 6. A comparison of competence levels related to CS or DL from the curriculum from Switzerland

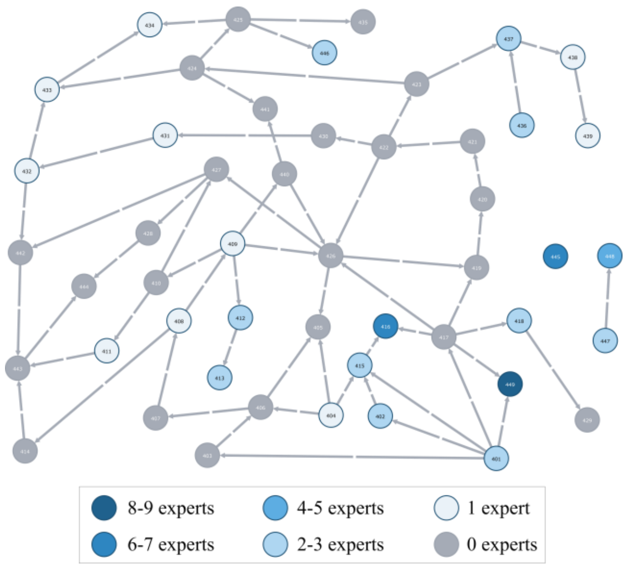

Figure 7. The distribution for CS of experts' choices for the competences from the Austrian competence model

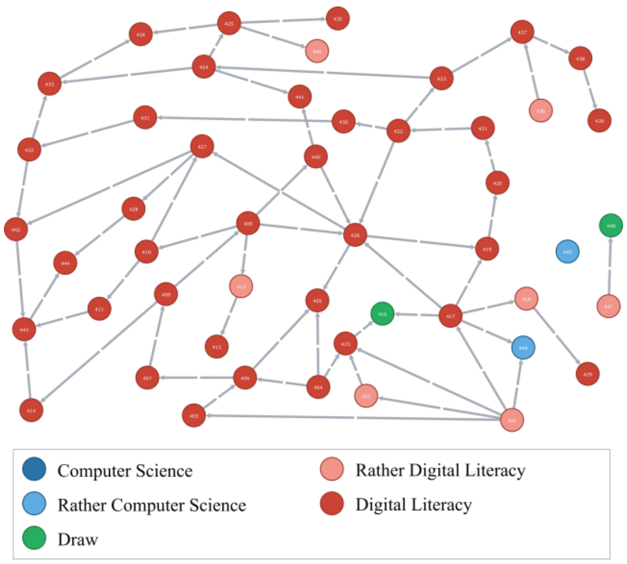

Figure 9. A comparison of competences related to CS or DL from the Austrian competence model

VII. Conclusion and Future Work

This contribution aims at giving an overview of the focus of three selected educational models using a graph-based representation form. For this purpose, nine experts classified the competences and learning objectives into *Computer Science (CS)* or *Digital Literacy (DL)*. In the resulting graphs, these rated competences and learning objectives were represented by the vertices and the different colors displayed their classification. The graphs for the Australian curriculum for "Digital Technology" show a balanced distribution, which indicates that this curriculum has no obvious focus in one of the two categories. In contrast, the resulting graphs for the curriculum 21 for "Media and Informatics" from Switzerland indicate a prioritization of *Digital Literacy*. And, the Austrian Digital Competence model "digikomp" is dominated by competences focusing *Digital Literacy*.

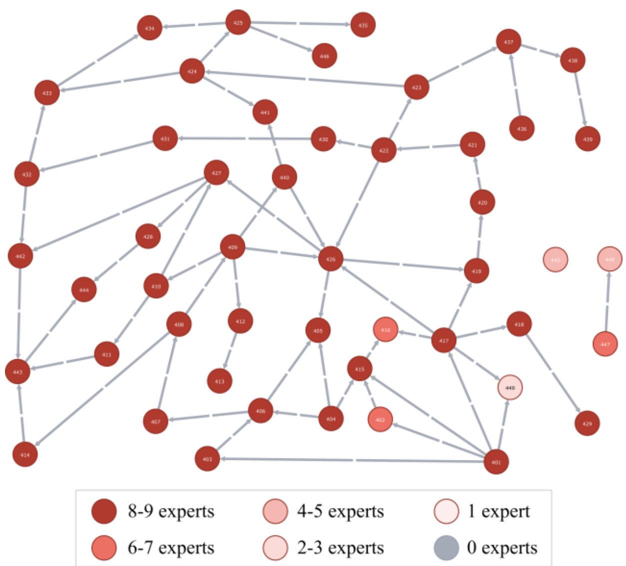

Figure 8. The distribution for DL of experts' choices for the competences from the Austrian competence model

As future work additional curricula, educational standards and competence models for primary and also secondary education will be represented as graphs and mapped to our graph database. Further, a more detailed categorization system will be implemented, based on e.g. the knowledge areas of the ACM/IEEE curriculum. To enable collaborative work and evaluation of the relations within the graphs and the classification of the competences, we are working on an online platform, based on the graph database neo4j. It will offer experts the possibility to evaluate the relations of an existing graph and give suggestions about missing relations. Users like teachers will be able to plan their own learning paths and develop individual curricula based on competences from existing educational models.

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