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Modeling at School

Intellectual Output 1

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Table of Content

1 Introduction 2

2 Descriptive Curricula Analysis 3

2.1 Austria 3

2.1.1 Education System 3

2.1.2 Descriptive Curricula Analysis: Procedure & Results 4

2.2 Finland 20

2.2.1 Education System 20

2.2.2 Descriptive Curricula Analysis: Procedure & Results 22

2.3 Spain 29

2.3.1 Introduction 29

2.3.2 Education System 29

2.3.3 Descriptive Curricula Analysis: Procedure & Results 31

3 Analysis of Key Competencies 44

3.1 European Competence Framework 44

3.2 Digital Competence Development in the European Union 47

3.3 Spain 48

3.3.1 Description of relevant competencies in Spanish Education System 48

3.4 Finland 51

3.4.1 The current National Core Curriculum for Basic Education in Finland 51

3.4.2 Key Competencies in the Finnish National Core Curriculum 54

3.5 Austria 55

3.5.1 Procedure – Analysis of Key Competencies 55

3.6 Summary & Final Outcome 59

4 References 62

5 List of Tables 63

6 List of Figures 63

1 Introduction

This report presents the final results of intellectual output 1. All the three partners from Austria, Spain and Finland have been working on the first output of the Erasmus+ project Modeling at School from November 2019 until July 2019. In order to recall the aims of the first output, a detailed description can be read in the following paragraph.

Output description:

The analysis of different curricula in different subjects of primary and secondary education aims at checking (1) where modeling is already integrated and (2) in which subjects and contexts an integration of modeling is possible and useful. The review of the analysis will show where, in which situation and contexts, for which purposes, activities, tasks and competencies etc. different modeling techniques may be used by teachers without computer science background in their subjects. It will give an overview of key competencies, activities topics etc. that are related to or may be connected to modeling and computational thinking. The result of this analysis will be a table that lists the detected key competences and topics in different curricula and appropriate diagram types that may help to train them. This table then serves as the basis of intellectual output O2.

To sum up, the tasks of intellectual output 1 can be divided into two major fields: descriptive curricula analysis and analysis of key competencies. In the first period of intellectual output 1, a detailed curriculum analysis has been conducted by all partners. The aim was to find out whether modeling is already integrated into various subjects and also school types. Then, the task of all partners was to determine key competencies which are part of all subjects and to find out where modeling can be an effective tool. The following chapters are divided into two main sections, (1) the descriptive analysis, and (2) the analysis of key competencies. Besides the descriptive analysis, an overview of the partner countries' education system is also provided in section 1. This should help to get a deeper understanding of the different systems. Section 2 starts with the European Framework of Competences and is followed by the current situation of each of the countries. A final summary and outlook conclude the report.

2 Descriptive Curricula Analysis

2.1 Austria

2.1.1 Education System

In comparison to many other countries, Austria has numerous school types in its educational system: after Kindergarten, children with the age of six can attend pre- and primary school (grade 1-4). Primary school is then followed by the new secondary school or the lower grade of academic secondary school (grade 5-8). After primary and secondary 1 level, students have a variety of schools to choose from. On the one hand, there is the possibility to attend the upper grade of a secondary school. On the other hand, students can choose from a variety of vocational schools, which focus on the training of vocations in different fields such as business, tourism or technical vocations. Besides these main areas, there are even more types of schools that can be attended. The illustration below demonstrates the Austrian educational system and its school types and should help to get a deeper understanding of the Austrian educational system.

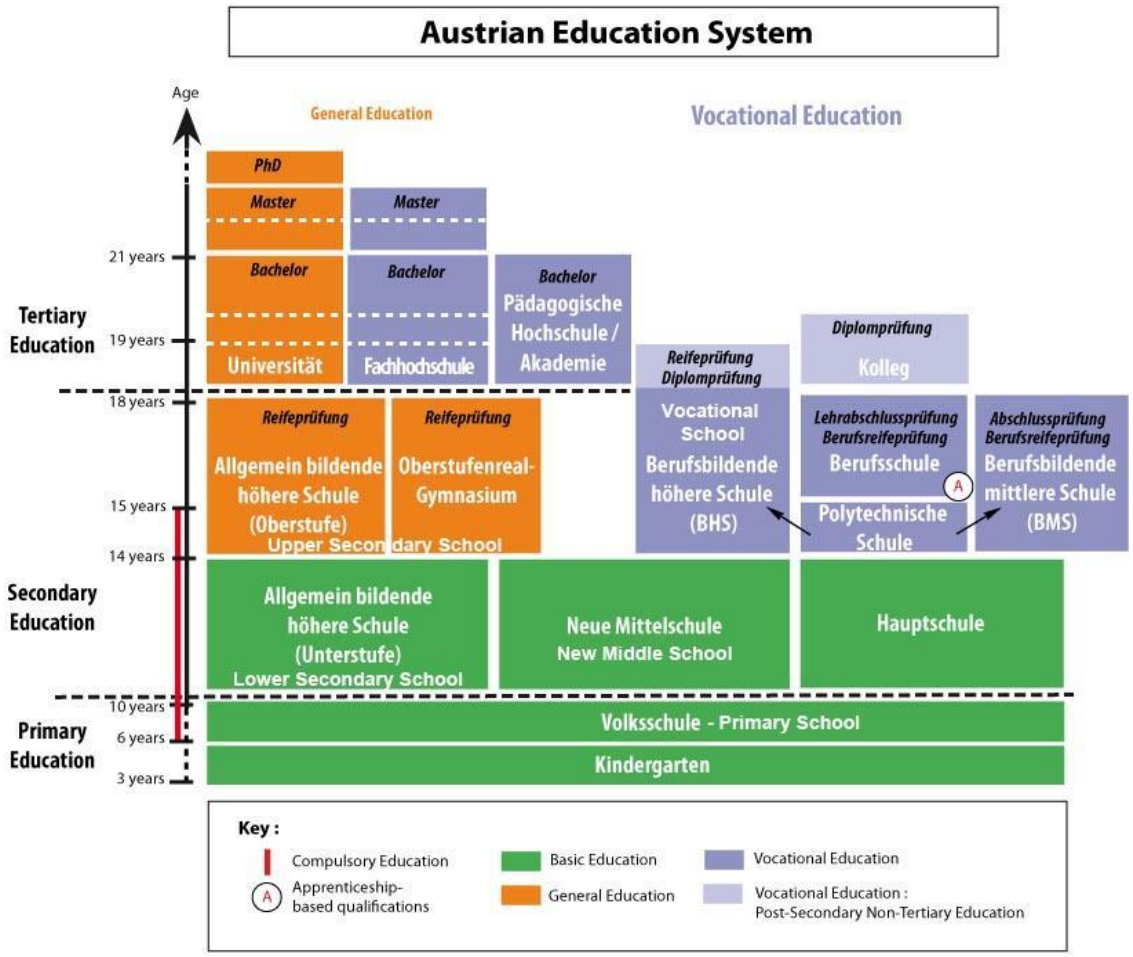


Figure 1: Austrian Education System

Source: http://mavoieproeurope.onisep.fr/en/file 1

Each curriculum consists of a few hundred pages and especially vocational schools have so many different types that it was soon clear, that restrictions had to be made in order to keep the curricula analysis manageable. Therefore, we decided to take the curricula of our partner schools, which cover all school levels and types, as a basis for our analysis. In the table below, the school types of our current partner schools are listed:

Table 1: School Types of Partner Schools

LEVEL	SCHOOL TYPE	YEAR
PRIMARY EDUCATION	Pre- & Primary School	1-4
SECONDARY EDUCATION 1	New Secondary School	5-8
SECONDARY EDUCATION 1/2	Secondary School (Lower & Upper Grade)	5-8 / 9-12
SECONDARY EDUCATION 2	Vocational School (IT- Technical)	9-13
SECONDARY EDUCATION 2	Vocational School (Business)	9-13

2.1.2 Descriptive Curricula Analysis: Procedure & Results

For the descriptive analysis, a list of terms that strongly relate to the field of modeling and computational thinking in general has been developed in accordance with the consortium. In order to obtain accurate results, also derivations of the terms were used. For instance, we changed word classes (noun, verb, adjective…) and other morphological characteristics (number, case…) or used synonyms (e.g. Latin vs. German term). Depending on the occurrence of the keywords and its derivations, the lengths of the list changes respectively. In the table below, German and English keywords are divided into three main categories: The most important terms in reference to modeling, words that strongly relate to the concept of computational thinking and lastly, other terms that also correlate with the concept of computer science.

Table 2: List of Keywords

	ENGLISH	GERMAN
CRUCIAL TERMS	modeling	Modellierung
	modeling	Modellbildung
	model	Modell
	diagram	Diagramm
	visualization	Visualisierung
	visualize	visualisieren
	illustration	Abbildung
	illustrate	abbilden
	represent	darstellen
	representation	Darstellung
	present	präsentieren
	presentation	Präsentation
TERMS STRONGLY RELATED TO COMPUTATIONAL THINKING	*computational thinking*	*computational thinking*
	algorithms	*Algorithmen*
	process	*Prozesse*
	procedure	*Abläufe*
	instructions	*Instruktionen*
	instructions	*Anweisungen*
	algorithmic thinking	*algorithmisches Denken*
	classification	*klassifizieren*
	form/build categories	*Kategorien bilden*
	categorize	*kategorisieren*
	represent hierarchies	*Hierarchien darstellen*
	abstraction	*Abstraktion*
	generalization	*generalisieren*
	pattern recognition	*Mustererkennung*
	analysing	*analysieren*
	decomposition	*zerlegung*
	coding	*programmieren*
	summarizing, sum up	*zusammenfassen*
	summary	*Zusammenfassung*

OTHER TERMS RELATED TO COMPUTER SCIENCE	structure knowledge	Wissen strukturieren
	develop/ elaborate knowledge	Wissen erarbeiten
	text comprehension	Textverständnis
	reading comprehension	Leseverständnis
	solve problems	Problemlösen
	logic	Logik
	logical thinking	logisches Denken
	relations	Beziehungen
	relations	Relationen
	describe properties, characteristics	Eigenschaften beschreiben
	describe attributes	Attribute beschreiben
	sequencing	Reihenfolge ordnen (sequenzen)

For the curricula analysis, not only the chapters related to the school subjects were scanned, but also general chapters, such as educational goals, didactical principles etc. We soon found out, that modeling and other computational thinking skills play a crucial role when it comes to general educational goals and basic teaching principles and therefore, cannot be ignored. The following paragraph shows a translated abstract of the chapter "general educational goals" of the curriculum of secondary education:

"An understanding of phenomena, questions and problems in the fields of maths, natural sciences and technology forms the basis for the orientation in a modern society that is characterized by technology. Therefore, education has to convey fundamental knowledge and decision-making abilities. It is the student's task to deal with values and ethical matters related to nature, technology, humans and society. The key requirements for ***analysing*** *and* ***solving problems****, that need to be conveyed by the teacher, are formalization,* ***modeling****, abstraction- and space imagination ability* (RIS 2018)."

In summary, computational thinking competencies, such as problem-solving, analysing, modeling or abstraction ability are mentioned as key requirements that should be taught in every subject and school level.

In the following chapters, the results of each curriculum and school type are summarized. After presenting a comparison of all the schools involved, two different diagrams for each of the schools are presented. The first one shows the frequency of all the keywords and its derivations and the second one demonstrates how many keywords in total were found in each of the subjects.

2.1.2.1 Comparison of Schools

In this chapter, all the five schools, that were being analysed, are compared. The first illustration deals with the frequency of all the keywords and the second chart demonstrates the frequency of all the single keywords.

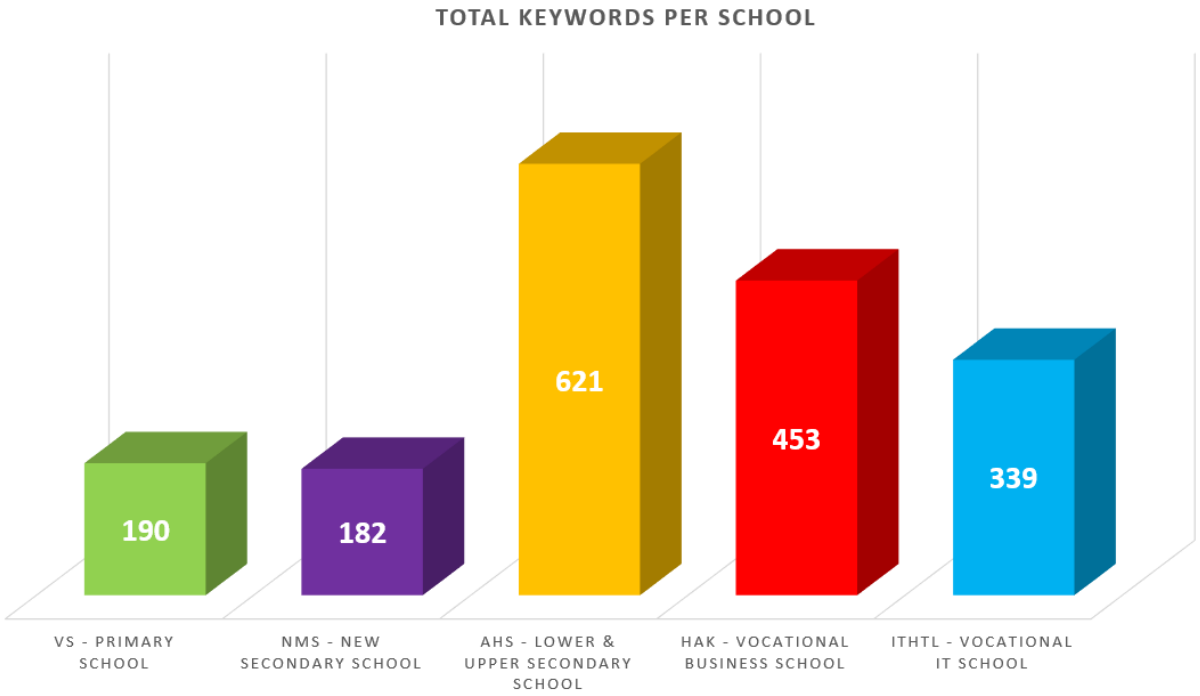


Figure 2: Total Keywords per School

The bar chart deals with the total sum of all the keywords according to the five school types that were analysed. The largest number of keywords definitely represents the AHS secondary school with a frequency of 621. However, it is important to keep in mind that this school consists of lower and upper grade, whereas the other school types only cover one school level. It can be seen that the number of keywords of the primary school and secondary school is almost equivalent, with only a difference of 78. With a frequency below 200, these two schools represent the lowest frequency of keywords. A significantly higher frequency is represented by both of the vocational schools with the IT-HTL with a frequency of 339 words and the HAK with 453. Surprisingly, although the HTL is a vocational school that focuses on IT, the HAK business school overtakes the HTL with a difference of 114 words. In summary, it can be said that keywords related to modeling are indeed already established in the curricula of Austrian schools and that the frequency of keywords increases according to the school level.

In the table below, the frequency of the single keywords is displayed. It can be seen, that in most cases one of the two vocational schools or the secondary school outnumbers the new secondary school and primary school. However, when it comes to the term “Beziehung” (relation), “Darstellung” (representation) or “darstellen” (to

represent), new secondary school and primary school outnumber at least one of the higher educational schools. The highest frequency reaches the vocational business school with the term “analysieren” (to analyze). In order to get a deeper insight, the results of each of the schools are represented below.

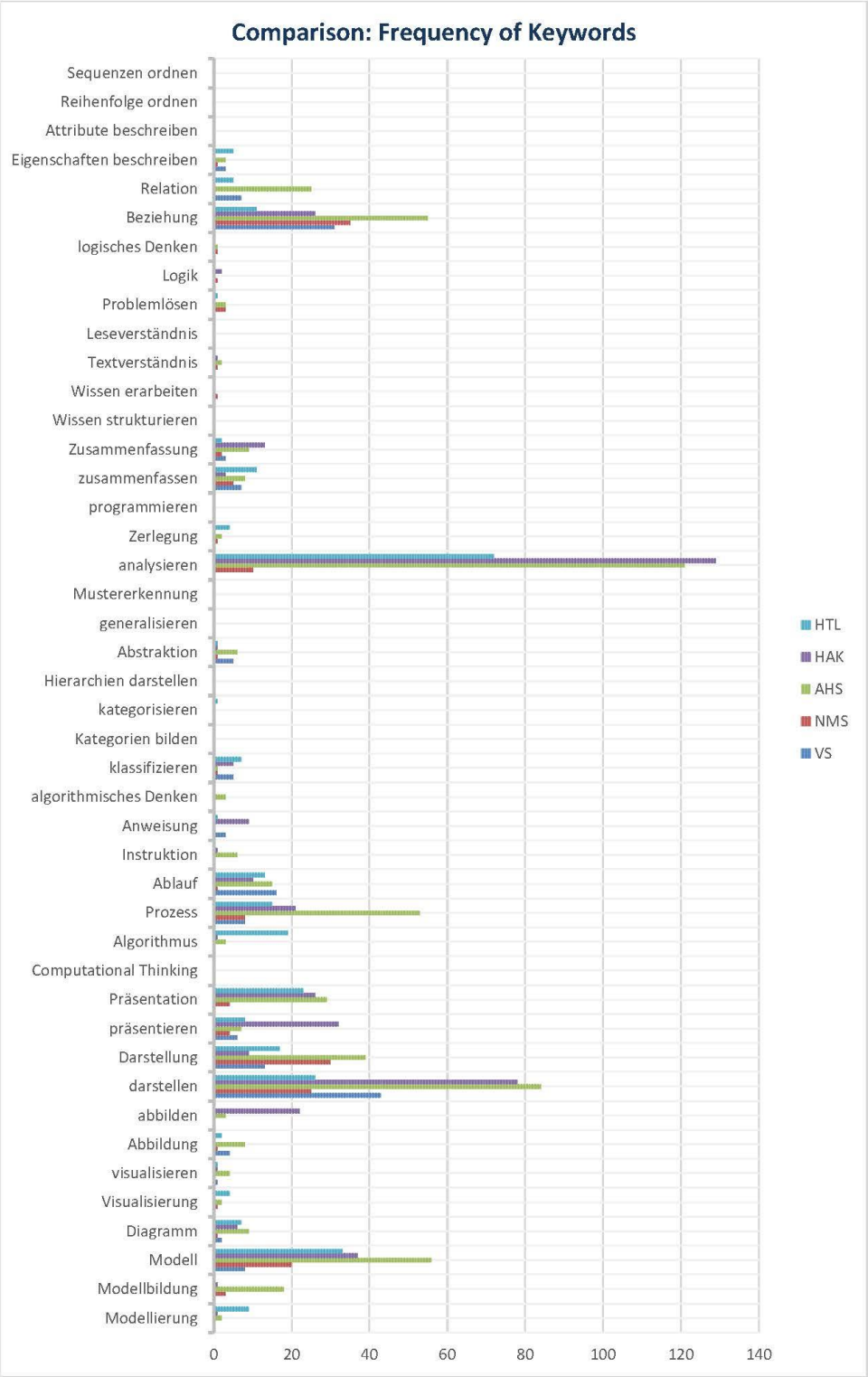


Figure 3: Comparison - Frequency of Keywords

2.1.2.2 Primary & Preschool

As it can be seen in this bar chart, the keywords “darstellen” (to represent) and “Beziehung” (relation) occur most frequently with a number of 43 and 31. Then, the frequency almost halves with the keyword “Ablauf” (procedure) which is closely followed by “zerlegen” (decompose) and “Darstellung” (representation). 27 of 54 keywords did not occur at all. When it comes to modeling, the term “Modell” was represented eight times in the curriculum, which represents the lowest frequency compared to the other schools.

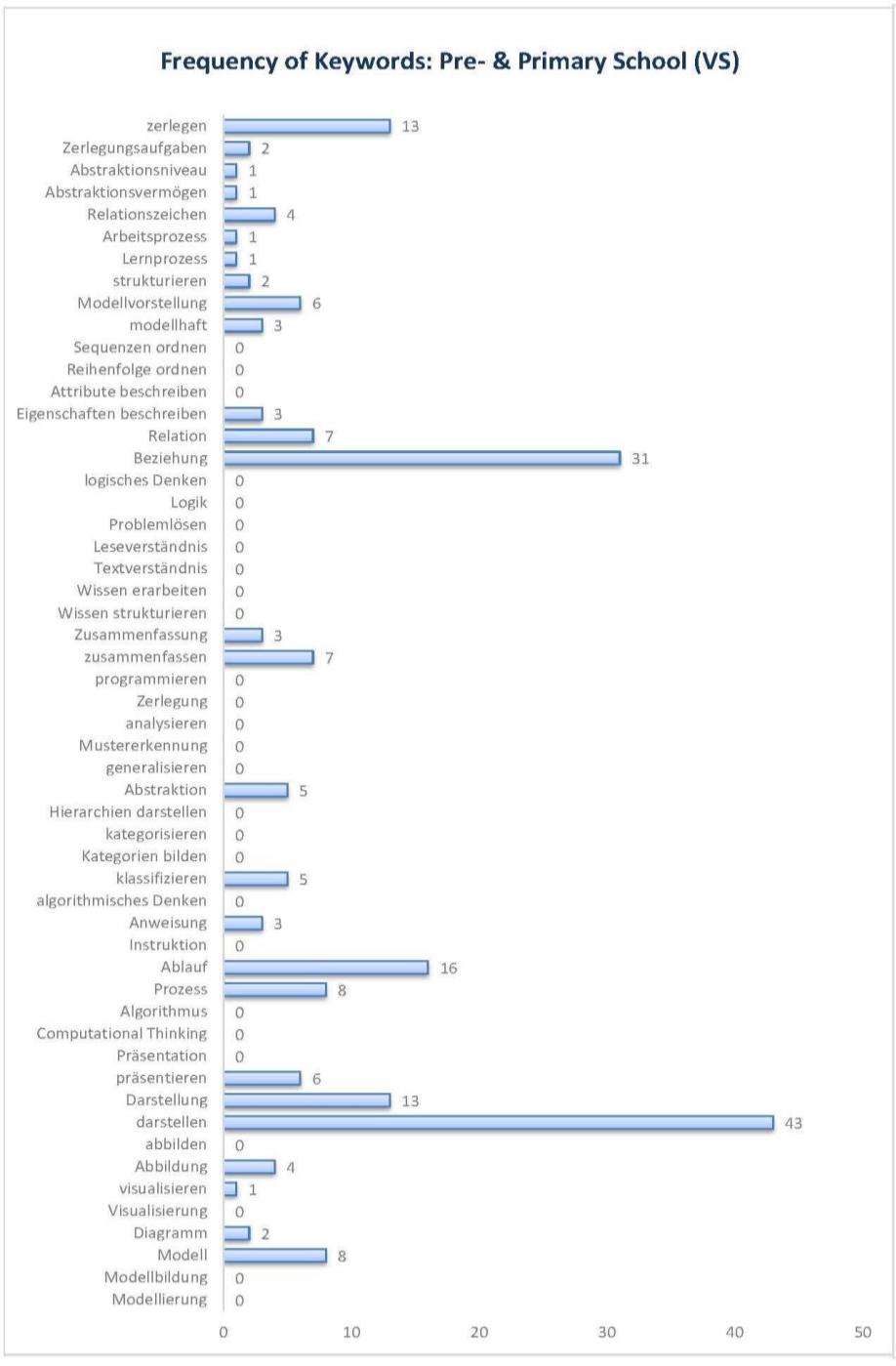


Figure 4: Frequency of Keywords - Pre- & Primary School

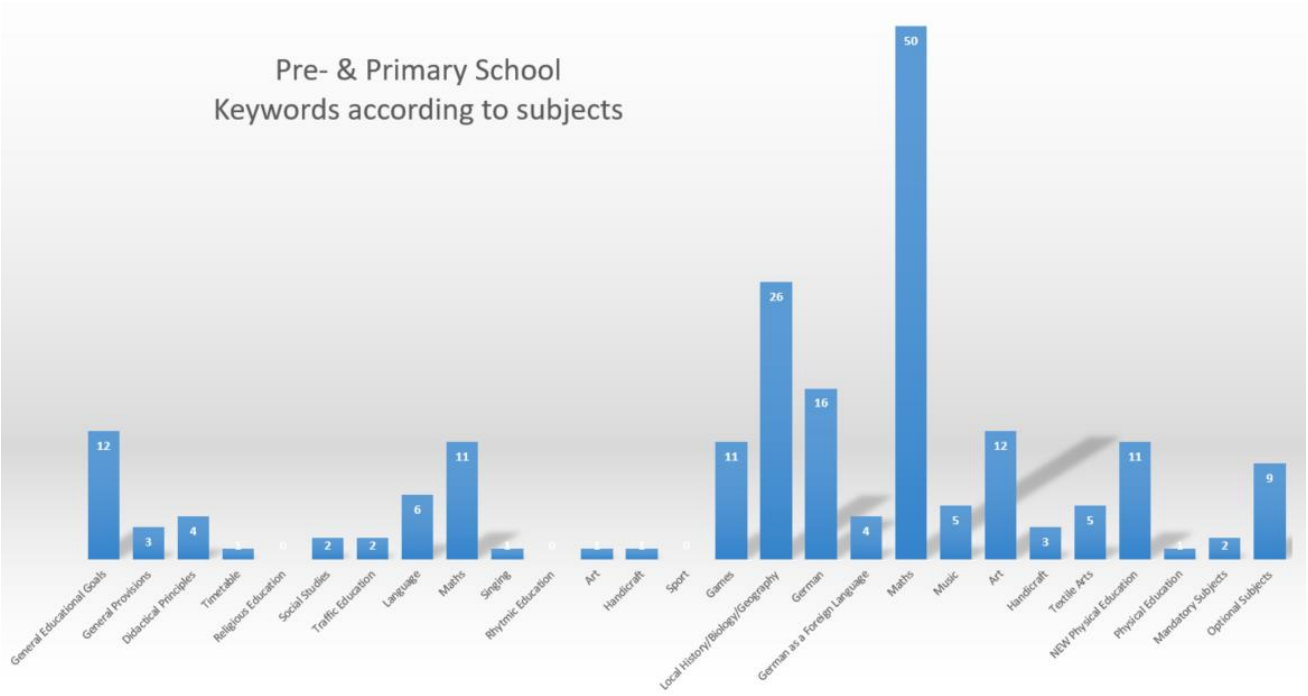


Figure 5: Pre- & Primary School - Keywords according to Subjects

This illustration demonstrates the occurrence of the keywords according to the subjects. Not surprisingly, one of the STEM subjects, Maths, leads the ranking with a frequency of 50. Then, frequency almost halves in the subject “Sachunterricht” which is a subject where local history, biology and geography are taught. The third place is occupied by German with a number of 16.

2.1.2.3 NMS New Secondary School

With only a difference of 4, also in the curriculum of the new secondary school the term “Beziehung” is at the forefront, closely followed by “darstellen” and “Darstellung”. In comparison to the primary school, the word “Modell” is in the front section with a frequency of 20. Only 19 of 66 keywords did not occur at all.

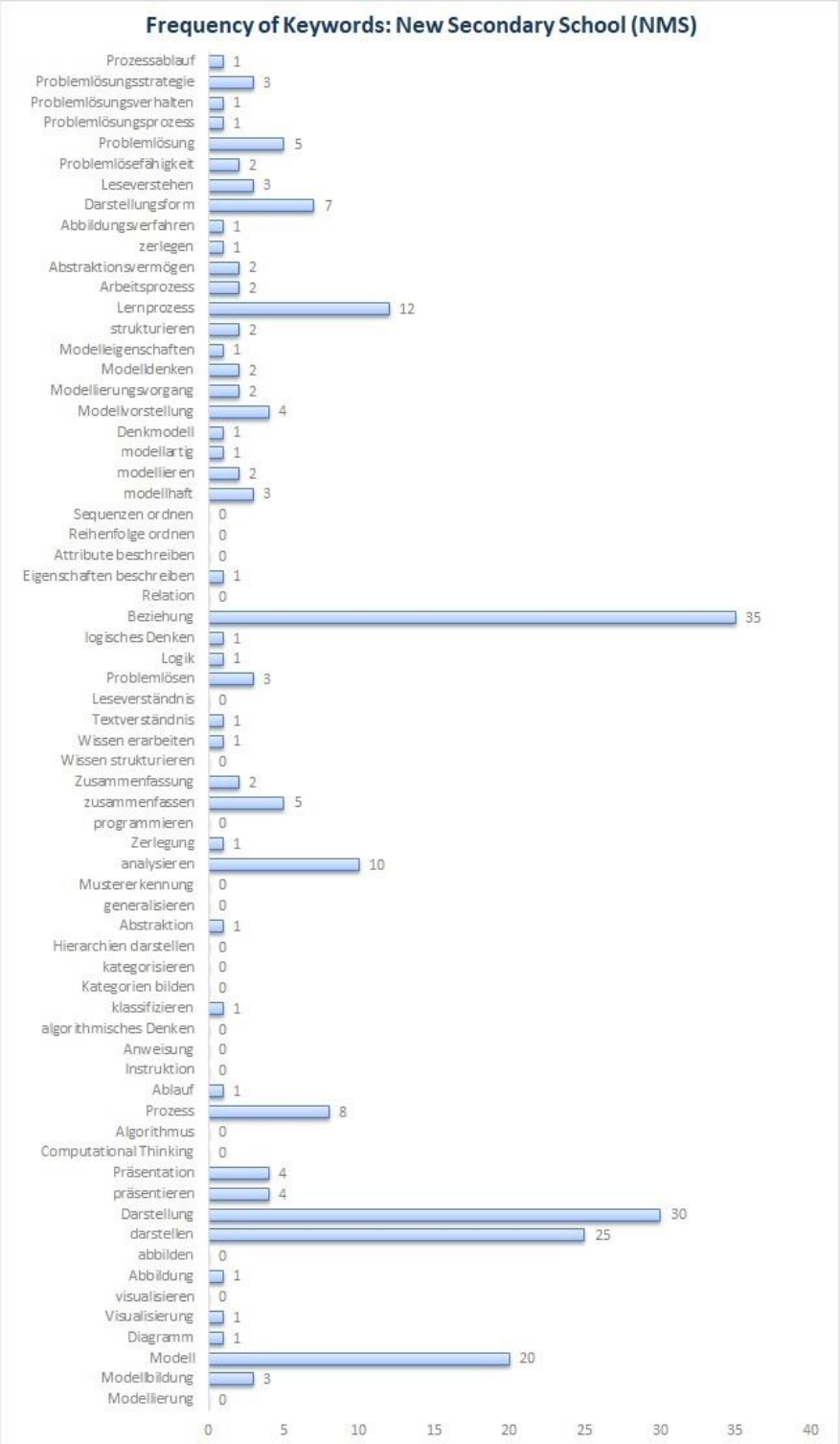


Figure 6: Frequency of Keywords – New Secondary School

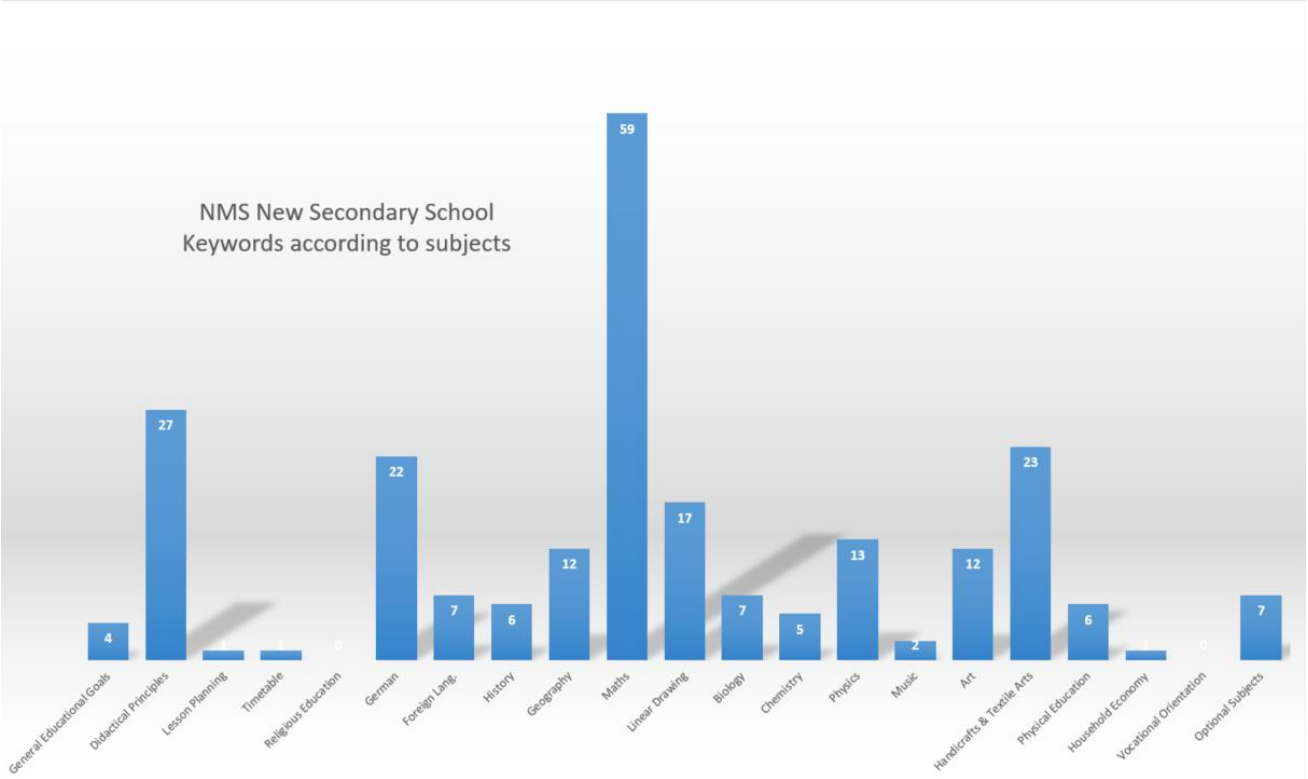


Figure 7: New Secondary School - Keywords according to Subjects

As we have also seen in the previous chapter, also Maths is in the frontline with a number of 59. With a significantly lower frequency, the ranking is followed by the subjects Handicrafts & Textile Arts, German and the Didactical Principles, which belong to the general part of the curriculum.

2.1.2.4 AHS Secondary School (Lower & Upper Grade)

The curriculum of the secondary school contains the highest number of the term “analysieren” (to analyze) with an occurrence of 121. The keyword “darstellen” is again at the forefront with 84. Interestingly, keywords related to modeling are well presented in comparison to the schools that have been analyzed before. The word “Modell” occurs 56 times and also “Modellbildung” and “Modellierung” are represented with a frequency of 18 and 1. Also in the front section are the terms “Beziehung” with 55, “Prozess” with 53, and “Darstellung” with 39.

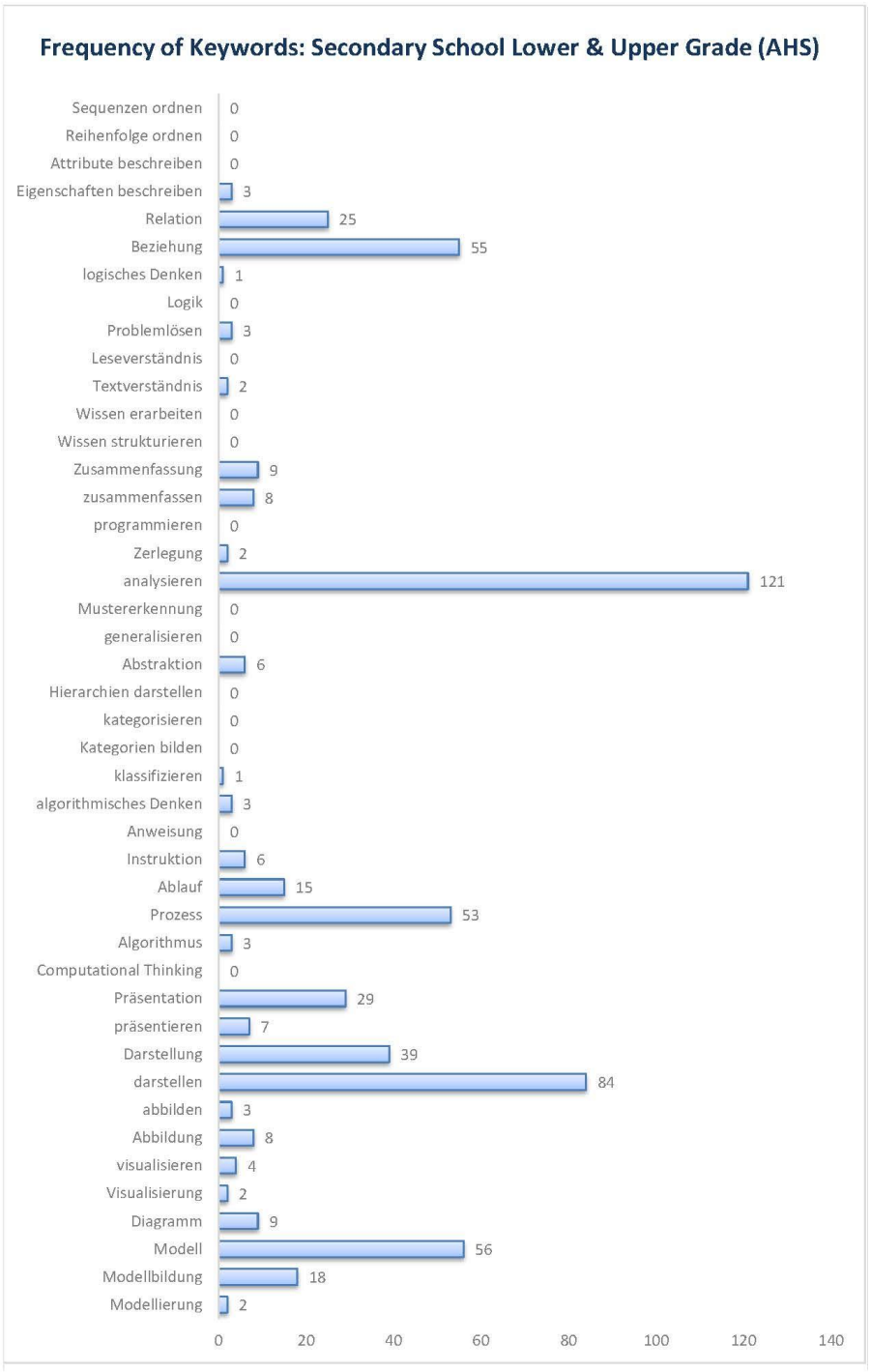


Figure 8: Secondary School LG and UG - Frequency of Keywords

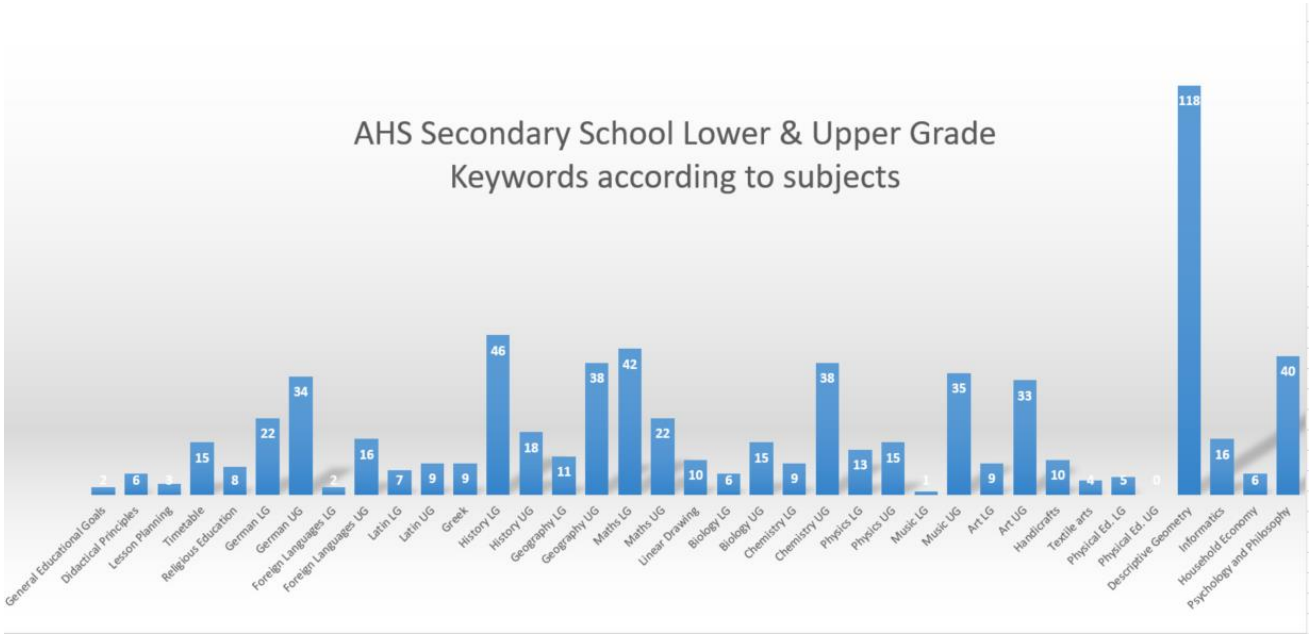


Figure 9: Secondary School LG & UG - Keywords according to Subjects

Talking about the frequency of keywords according to its subjects, Descriptive Geometry significantly outperforms all the other subjects with a number of 118. With a difference of more than a half, the ranking is followed by History in the Lower Grade, Maths in the lower grade and Psychology and Philosophy in the upper grade.

2.1.2.5 HAK Business Vocational School

In the curriculum of the vocational business school, the leading keyword is “analysieren” with a frequency of 129. Again, “darstellen” is at second place with a number of 78. The word “Modell” takes over the third place with a frequency of 37. 21 of 56 keywords are not mentioned at all.

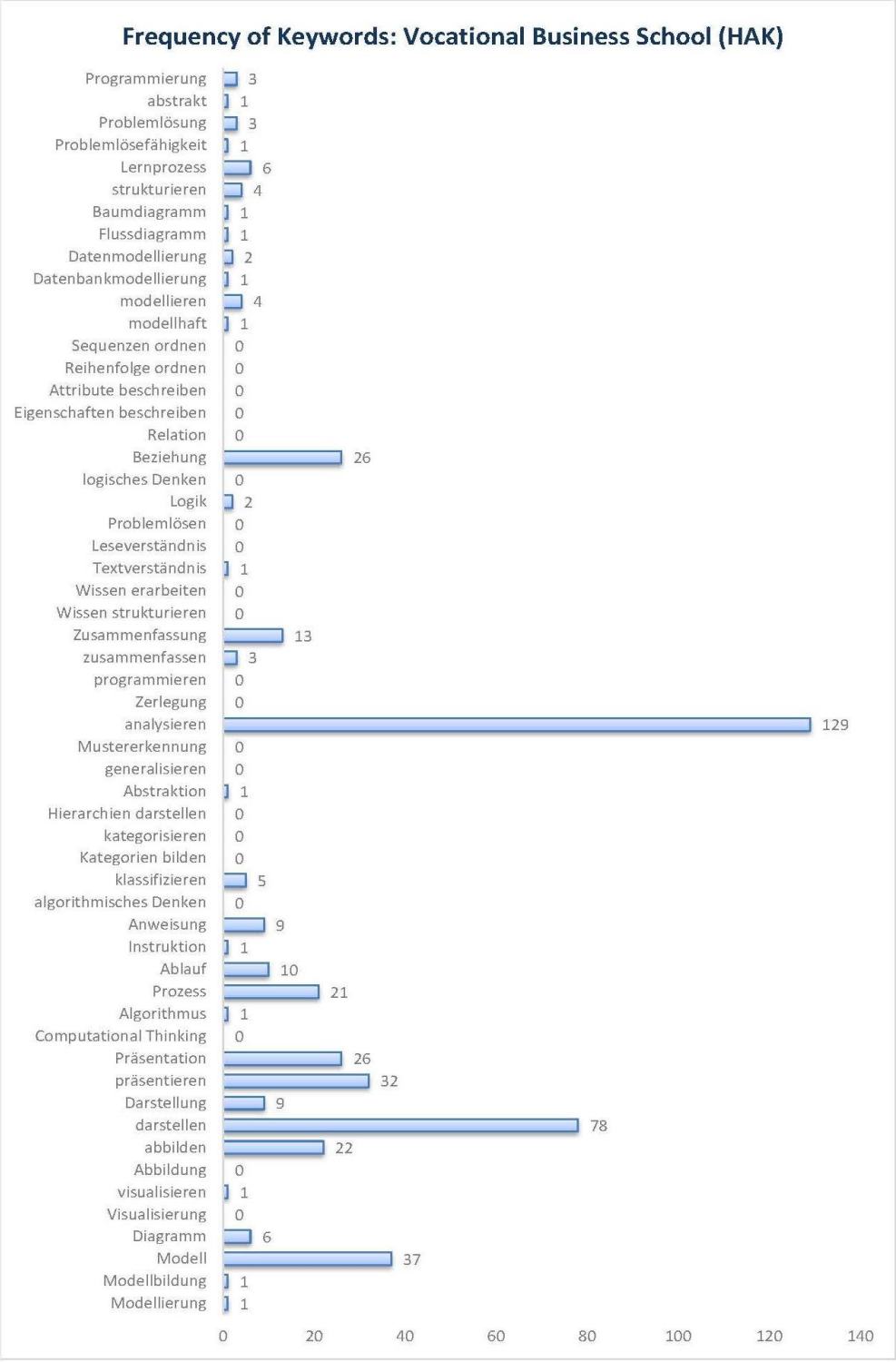


Figure 10: Vocational Business School - Frequency of Keywords

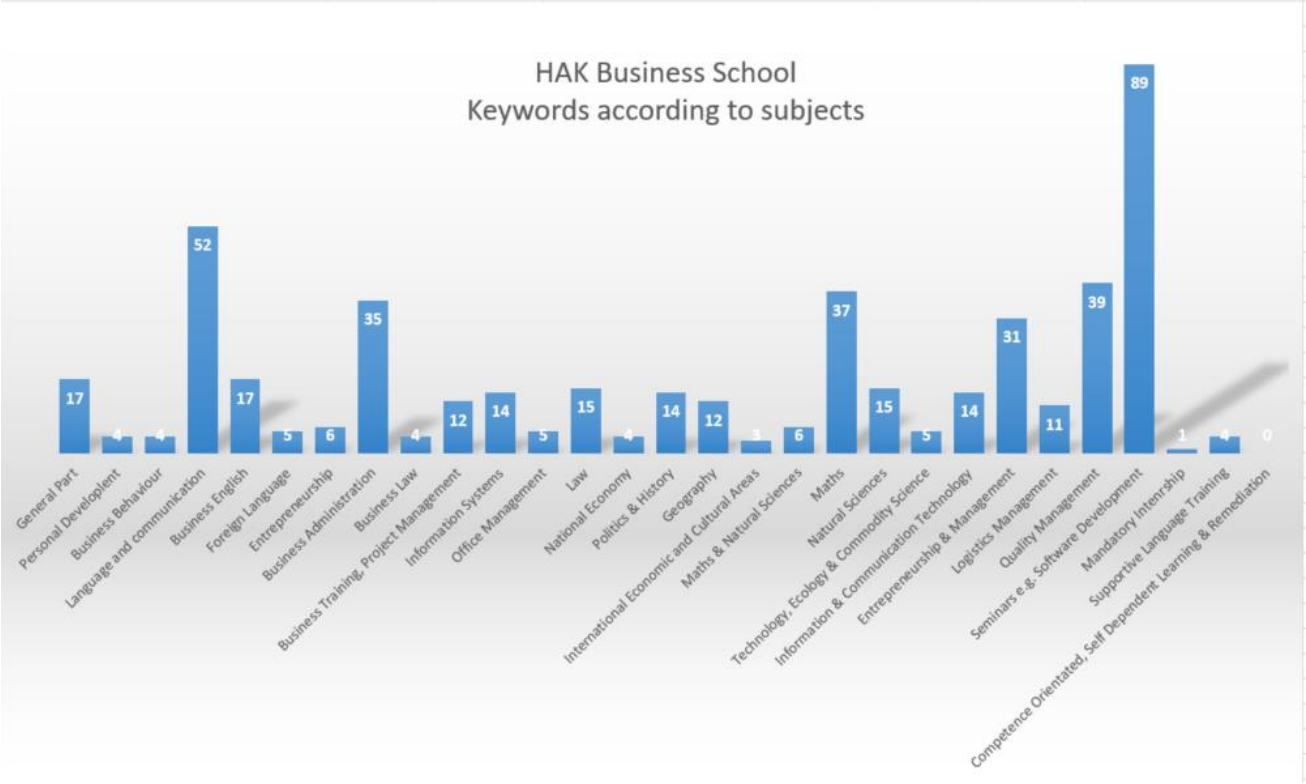


Figure 11: Vocational Business School - Frequency according to Subjects

The vocational business school offers a range of elective seminars. One of them is Software Development, which is responsible that the seminars contain the highest number of keywords with a frequency of 89. Surprisingly, the seminars are not followed by Maths, but by Language and Communication with a frequency of 52. Further subjects that are at the front rank are Quality Management, Maths, Business Administration and Entrepreneurship & Management.

2.1.2.6 (IT) HTL Technical Vocational School

Also in the curriculum of the vocational IT school, the keyword “analysieren” wins the ranking with a frequency of 72. Then, the occurrence halves. Even though the frequency significantly decreases, it is interesting to see, that the term “Modell” takes up the second place, followed by “darstellen”, “Präsentation” and “Algorithmus”.

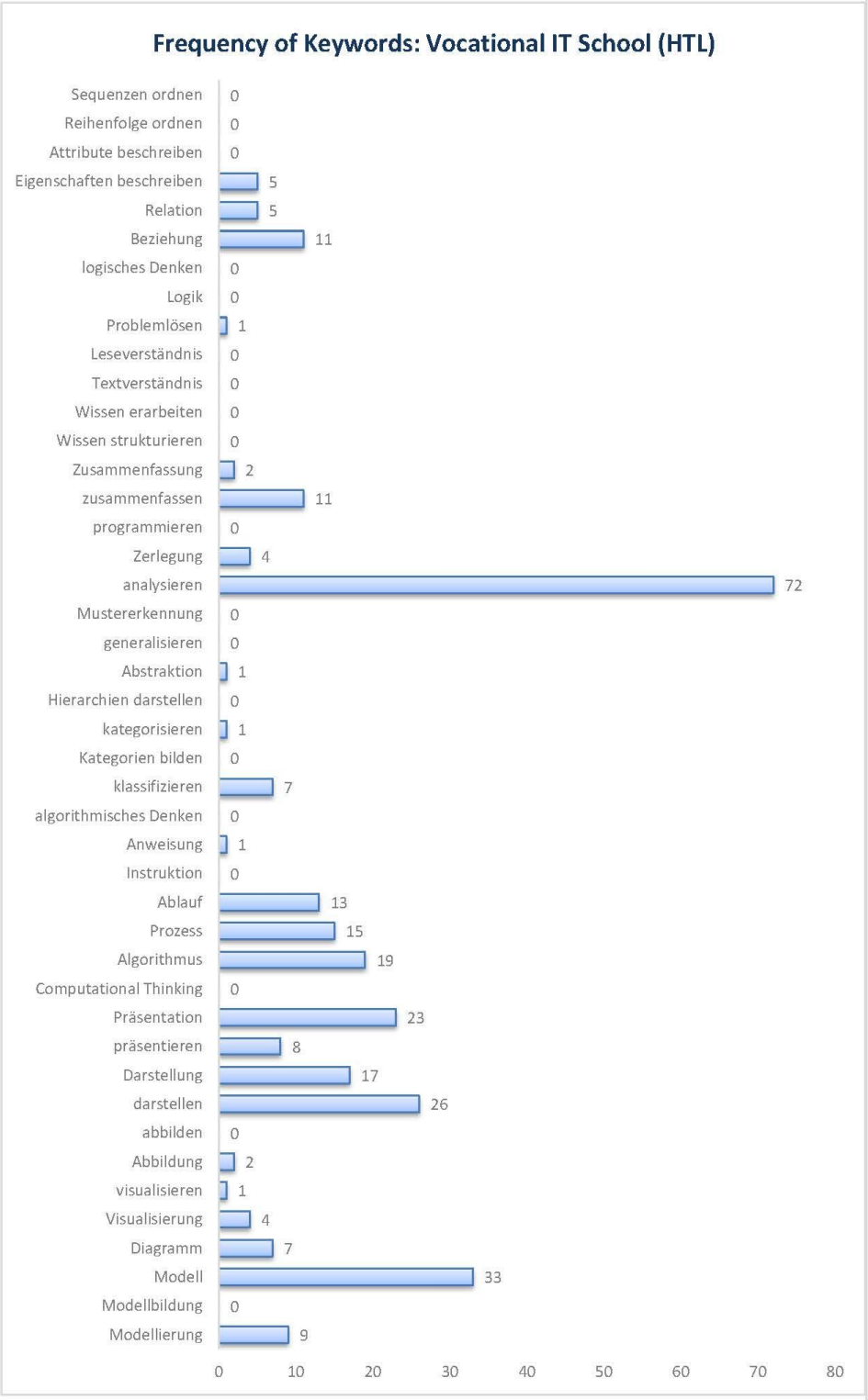


Figure 12: Vocational IT School - Frequency of Keywords

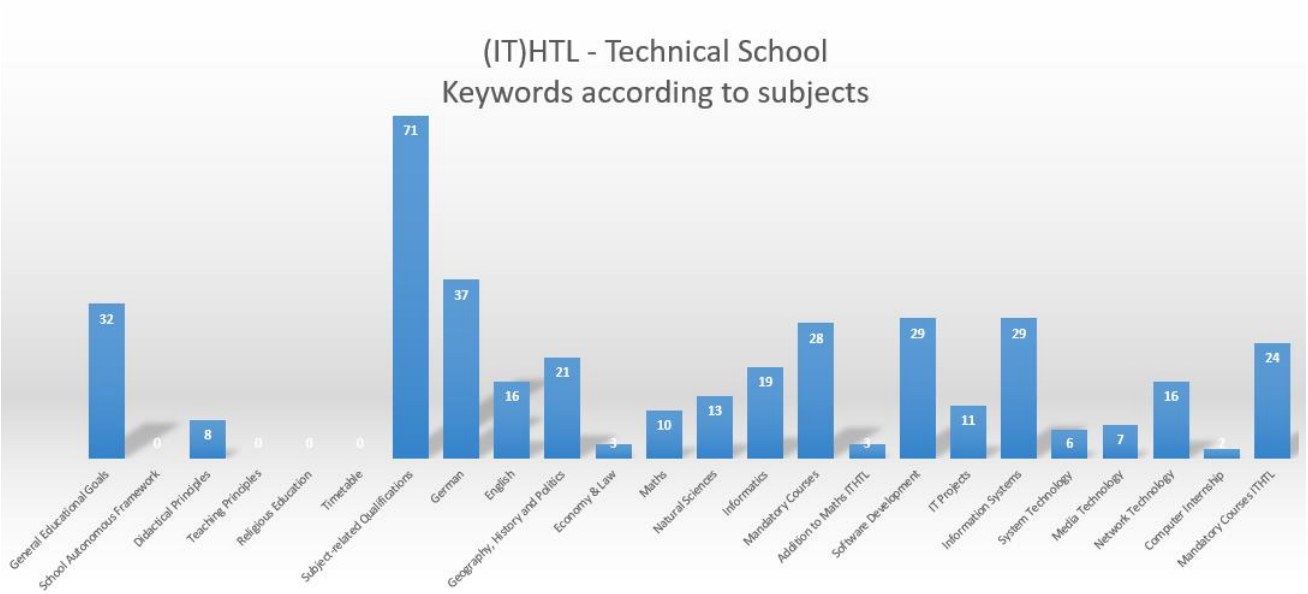


Figure 13: Vocational IT School - Keywords according to Subjects

The highest number of keywords can be found in the section “subject-related qualifications” (Fachbezogenes Qualifikationsprofil). As already mentioned in the introductory part of the report, the Austrian education system offers a wide range of vocational schools. When it comes to vocational technical schools, it is possible to choose schools that specialize in IT, mechatronics, engineering and many more. When it comes to the curriculum, there is one general curriculum for technical vocational schools and enclosures for each of the specializations, where also the section “subject-related qualifications” is presented. For the reason that we focus on an IT vocational school, the frequency of keywords in this chapter is significantly high with a number of 71. With almost half of the number, it is followed by German which closely goes before General Educational Goals, Software Development and Information Systems.

2.1.2.7 Summary

In summary, modeling itself is not always one of the leading keywords when it comes to its frequency. However, some of the keywords that are always at the frontline are “Beziehung” (relation), “darstellen” (to represent) and “Darstellung” (representation). According to its definition, a model is a simplified and reduced **representation** of reality. To **represent** concepts in a simplified manner is also one of the aims of “Modeling at School”. Furthermore, with UML diagrams it is not only possible to represent single pieces of information. Above that, it gives us the possibility to put information in **relation** to each other, **represent processes** and much more.

What is very interesting to see is that the term computational thinking did not occur in any of the curricula. However, keywords related to computational thinking are indeed essential elements. Especially “analysieren” (to analyse), “zusammenfassen” (to summarize), “Prozess” (process) and “Ablauf” (procedure). Even the term “Algorithmus” is slightly present in the new secondary school and secondary school and more strongly in the IT vocational school.

2.2 Finland

2.2.1 Education System

The first stage in the Finnish Education System is early childhood education and care (ages 0-5), which is followed by pre-primary education (age 6) as can be seen in Figure 14. Basic education is the focus of this curriculum analysis and therefore most of the text focuses on basic education. Basic education or Comprehensive school in Finland expands from years 7 to 16 and this ends the compulsory basic education offered in Finland. There is also an option for taking a voluntary additional year of basic education after the completion of the mandatory basic education. There are two levels of basic education: primary (grades 1-6) and secondary (7-9). In primary education grades 1-2 may be taught separate from grades 3-6, meaning that pupils are taught by different teachers or even in separate schools in these grade levels. However, in many schools pupils may be primarily taught by the same teachers in grades 1-6 and only change groups, when moving to secondary school. In all basic education level same core subjects are covered and new subjects are added at grades 3 and 7. The beginning of second national language and foreign languages have been in the past years changed, so pupils will be beginning to learn at least language other than their mother tongue already in grade 1. In the Finnish education system pupils learn at least three languages during basic education: mother tongue, second national language (Finnish or Swedish) and a foreign language.

After basic education, most pupils continue to either upper secondary or vocational education. Upper secondary school or High school takes commonly 3-4 years to complete and ends in the Matriculation examination. Vocational education usually take 3 years and provides the students with vocational qualifications to a profession. After this stage, students can apply to Higher education in Universities or Universities of Applied Sciences as can be seen in Figure 14.

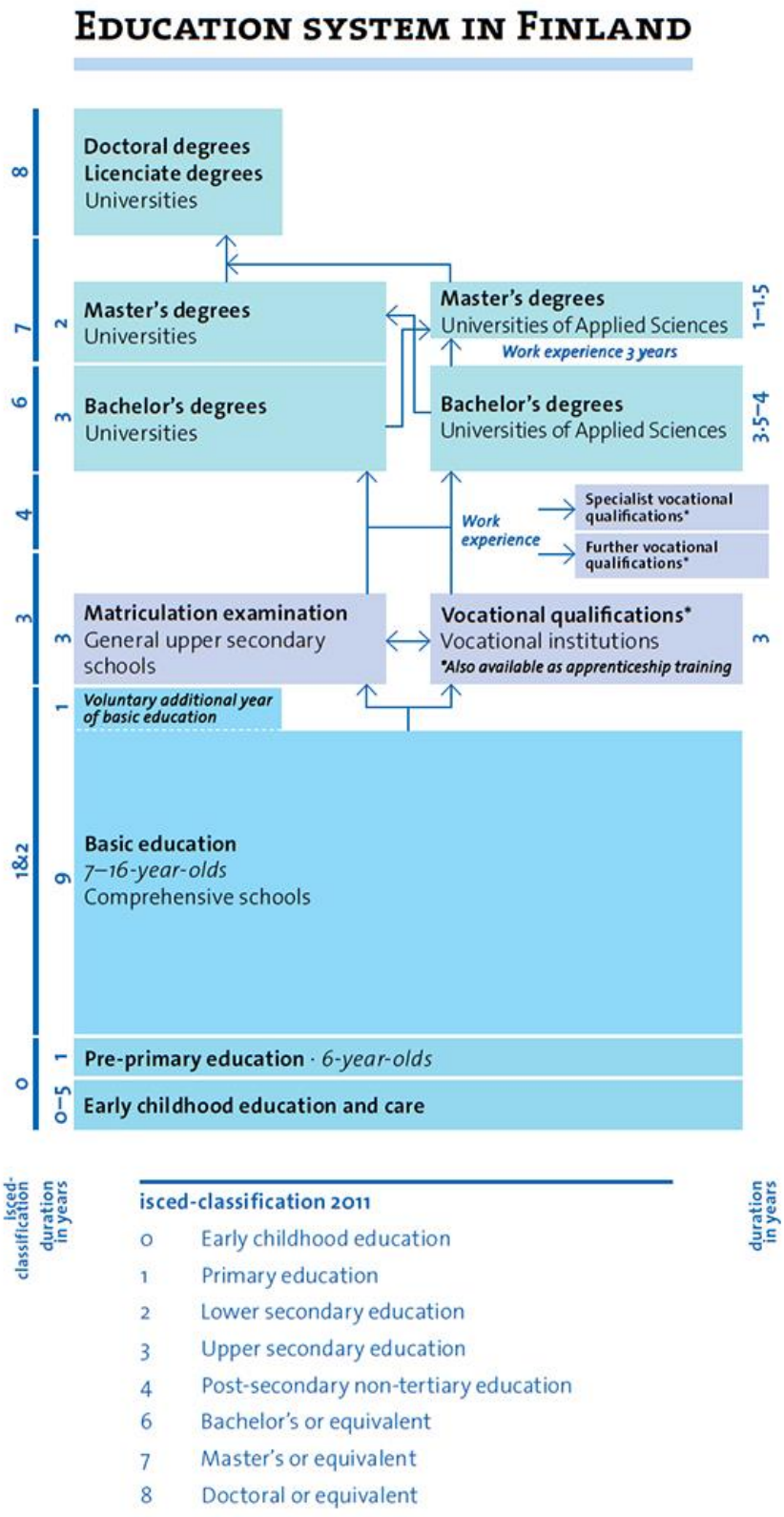


Figure 14: Finnish Education System

Source: https://www.oph.fi/english/education_system

The FNCC is based on the subjects specified in the Basic Education Act for all grades. The subjects taught in all levels of primary education can be seen in Table 3.

History and Social Studies are subjects that begin at grade 3 and home economics begins at grade 7. Environmental Studies is an integrated subject, which is taught in grades 1-6 and consists of learning content from Biology, Geography, Physics, Chemistry and Health Education. These five subjects are then taught as independent subjects in grades 7-9. In addition to the core subjects, schools can also offer elective subjects such as additional languages. The use of Information and Communication Technology (ICT) is considered to be a transversal skill and it is integrated in other subjects. The current FNCC introduced Coding on a national level to basic education, when the curriculum was enacted in fall 2017. However, some schools may have taught these skills prior to that, but at that point it was added to the national curriculum. Coding has been integrated into teaching of other subjects for example Mathematics, where algorithmic thinking is taught to pupils.

Table 3: Subjects taught in Finnish basic education schools

Grades 1-6	Grades 7-9
Mother tongue and literature	Mother tongue and literature
Second national language	Second national language
Foreign languages	Foreign languages
Mathematics	Mathematics
Environmental Studies	-
-	Biology
-	Geography
-	Physics
-	Chemistry
-	Health education
Religion	Religion
Ethics	Ethics
History (grades 3-6)	History
Social Studies (grades 3-6)	Social Studies
Music	Music
Visual arts	Visual arts
Crafts	Crafts
Physical education	Physical education
-	Home economics
Guidance counselling	Guidance counselling

2.2.2 Descriptive Curricula Analysis: Procedure & Results

The goal of this analysis is to examine the Finnish National Core Curriculum (FNCC) regarding the frequency of terms often used to describe the development computational and algorithmic thinking. This analysis utilized

the official English version of the FNCC as the basis for the keyword analysis and therefore the Finnish terms were not used in the analysis. However, for future reference these terms in both English and Finnish are provided in table 4.

Table 4: Keywords related to computational and algorithmic thinking in English and Finnish

Keywords in English	**Translated keywords in Finnish**
structured knowledge, structuring, structure	strukturoitu / jäsennelty tieto, jäsentäminen / organisointi, rakenne
process	prosessi
model, modeling	malli, mallintaminen
diagram	kaavio, diagrammi
visualize, visualization, visual(s)	visualisoida, visualisointi, ulkoasu / kuvat / kuvitus
illustrate, illustration, illustrative	havainnollistaa, kuvitus / esimerkki, havainnollinen
represent, representation	edustaa, representaation / esitys / esitysmuoto
develop, elaborate knowledge	kehittää / täsmentää / kehitellä tietoa
text comprehension	tekstin ymmärtäminen
reading comprehension	luetun ymmärtäminen
solve problems	ongelmien ratkaiseminen
logic	logiikka
logical thinking	looginen ajattelu
sequencing	sekvensointi
algorithms	algoritmit
computational thinking	laskennallinen ajattelu
procedure	proseduuri / toimintatapa / menetelmä
instructions	ohjeet
algorithmic thinking	algoritminen ajattelu
relationships	suhteet
classification	luokittelu
form, build categories	muodostaa / rakentaa kategorioita
represent hierarchies	edustaa hierarkioita
describe properties, attributes, characteristics	kuvata ominaisuuksia, attribuutteja, ominaispiirteitä

to abstract	abstrahoida / erottaa
abstraction	abstraktio / abstrahointi
generalization	yleistys
pattern recognition	hahmontunnistus
analyzing	analysointi
decomposition	erittely
coding	koodaus / ohjelmointi
summarizing	referointi / yhteenveto
summarize	referoida / tehdä yhteenveto
sum up	summautua
summary	tiivistelmä / yhteenveto

In the analysis the keywords were searched from all of the subjects. The only exclusion was made in the category of languages. In the case of Mother Tongue and Literature only the two official national languages of Finland, Finnish and Swedish has been taken into account. This was done due to the wide variety of languages presented in the curriculum and the repeating structure of the curricula framework and recommendations in the case of all the languages. No instances of the analysed terms were found in Physical Education and Guidance Counselling, therefore these subjects are left out from the analysis. Computer Science is not taught as a separate subject in Finnish primary and secondary education, but it is integrated into other subjects as ICT Competence is considered as one of the transversal skills of the Finnish National Core Curriculum.

In addition to subject and grade-level related observations there were also 38 occurrences of the keywords in the introductory text, which relates to the whole basic education system and cannot be connected to any specific grade-level or subject. Moreover, there were also 13 instances where the grade-level could be determined in the introductory texts, but the subject was not specified or the skill mentioned transcends subject borders, such as teaching and learning ICT skills and multiliteracy. In total, the keywords searched were found 217 times in the curriculum for primary education (grades 1-6) and 169 times in the curriculum for secondary education (grades 7-9). Out of the 35 keywords or term groups 12 were not used in the curriculum at all in this form and 8 terms were only used 1-2 times. Similar or synonymous uses of terms could in some cases be found, but in the analysis only the near match or perfect match terms were taken into consideration and were analysed further.

In the Primary School curriculum 'structured knowledge' and the terms related to structuring of knowledge and 'structures' were mentioned most often and the second most common term was 'process' (Figure 15). Some of the keywords directly linked to computer science, were mentioned only scarcely, for example algorithms was mentioned twice. Some of the central keywords for the Modeling at School Erasmus+ project such as 'modeling' or 'model' and 'solve problems' were used only occasionally in the Primary School curriculum.

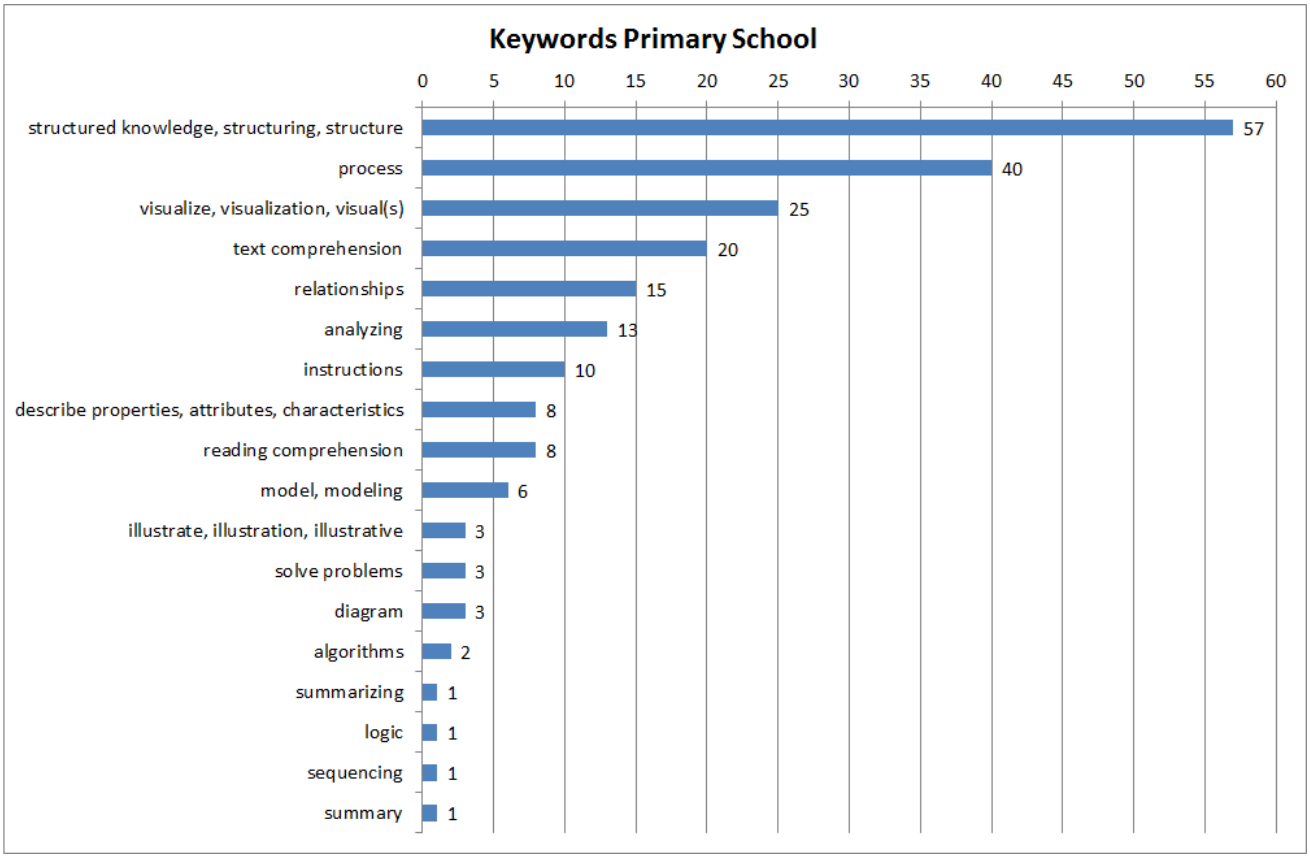


Figure 15: Keyword counts from Primary School curriculum

When looking at the keywords on subject level (Figure 16) in Primary School it can be observed that the subjects with the most occurrences of the keywords are languages (Mother Tongue and Second Language) and Environmental Studies. Furthermore, the keywords could be found also in mathematics, crafts and visual arts.

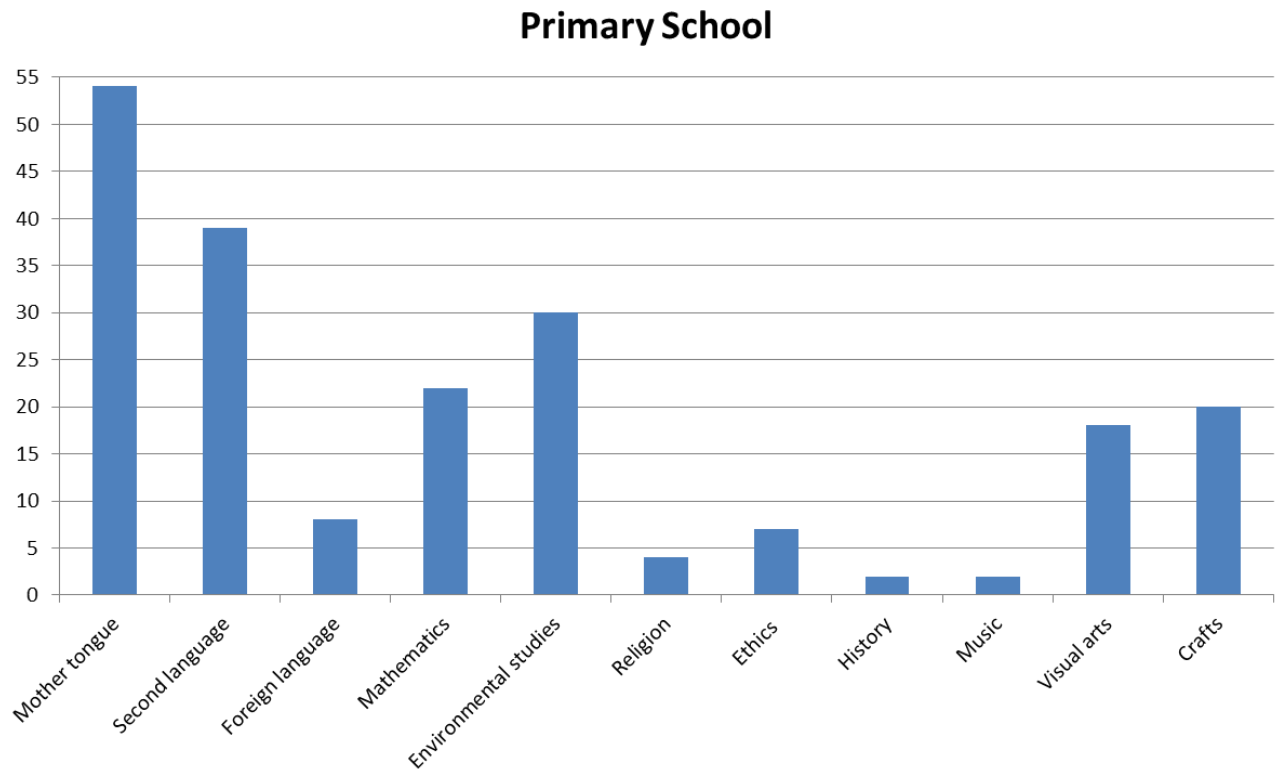


Figure 16: Keyword counts by subjects in Primary School

The results of the keyword analysis in Secondary School curriculum showed that the three most commonly used terms were the same in both Primary and Secondary school curriculums (Figure 17). However, the term 'model' or 'modeling' was used more commonly in the Secondary School curriculum than in the Primary School curriculum. The term 'algorithmic thinking' was used only in the Secondary School curriculum, and the term 'algorithm' was only used in Primary School curriculum. While many of the same keywords could be found in both Primary and Secondary School curriculum, some were only used in either Primary or Secondary curriculum. The keywords: 'algorithmic thinking', 'classification', 'to abstract' and 'to summarize' were used only in the Secondary curriculum and the keywords: 'algorithms', 'logic', 'sequencing' and 'summary' were used only in the Primary curriculum.

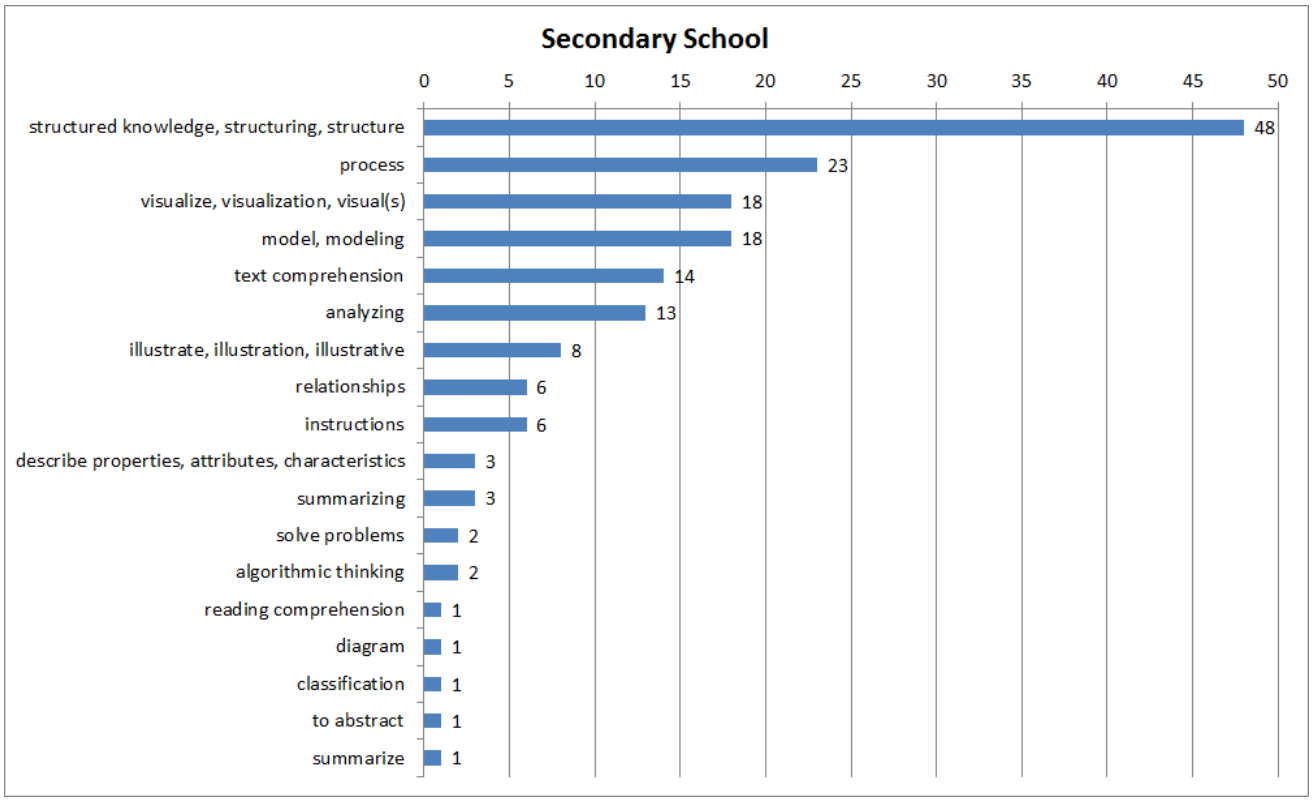


Figure 17: Keyword counts from Secondary School curriculum

The distribution of the keywords per subject in Secondary School is similar to Primary School (Figure 18). The subject of Environmental Studies in Primary School comprises of several subjects, which are taught as separate subjects in Secondary School including natural sciences (Biology, Geography, Physics, Chemistry) and Health Education. The major difference can be seen in the languages in that foreign languages had more instances of the keywords that Mother Tongue in Secondary School, while the situation was opposite in Primary School.

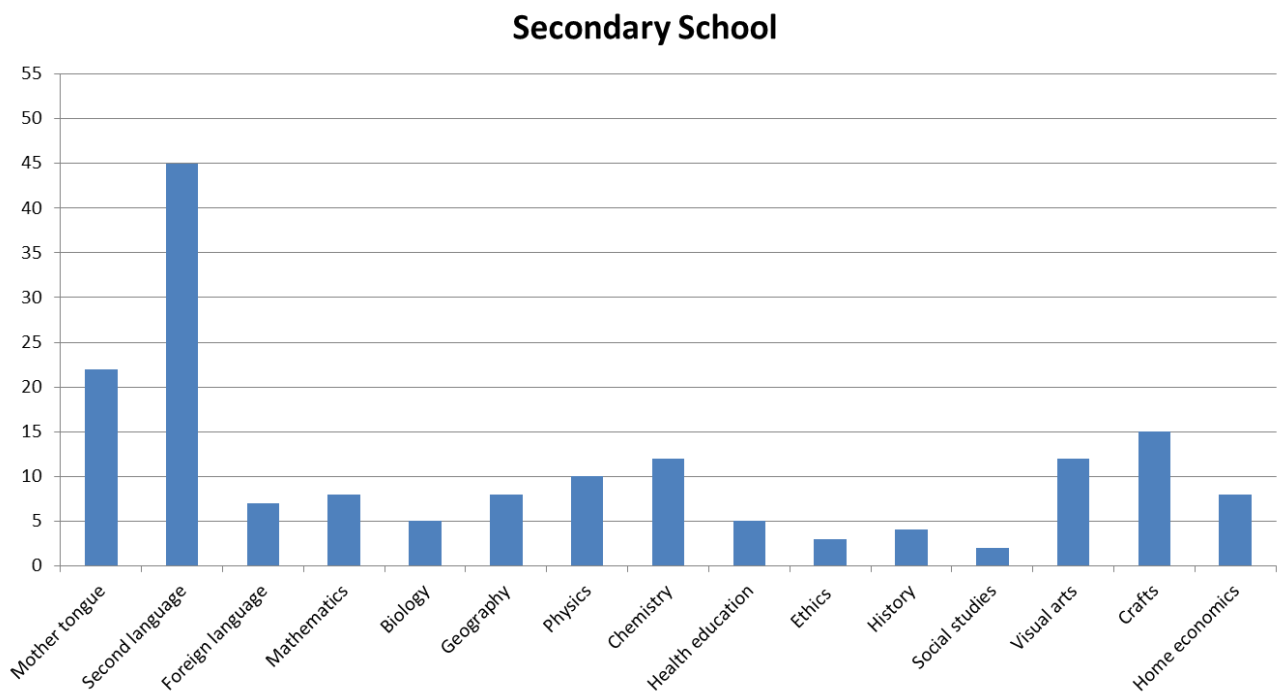


Figure 18: Keyword counts by subjects in Secondary School

Comparing the descriptions of the Key Competencies and the keyword analysis of the National Core Curriculum of Austria, Finland and Spain showed that there are many similarities. At the core of modeling is problem-solving, understanding of processes and structuring knowledge logically in visualisable models. Problem-solving skills are mentioned as part of Mathematical, Digital, Personal, social and learning to learn and Entrepreneurship competence. Process is used in various meanings in the Key Competences. In general, it is used to describe the learning process or in the context of the Literacy competence, the word 'process' refers to information processing. This was also the case in our curriculum analysis. In the cases of Mathematical competence and Competence in science, technology, engineering, the focus is on the processes relevant to mathematics and science. In Entrepreneurship and Cultural awareness and expression competences, the focus is on learning and understanding the creative process. In the Entrepreneurship competence there are also project related processes that pupils need to learn. In the case of Mathematical and Entrepreneurship competence there are structures that pupils should learn and these could be presented visually through modeling, which is in line with the aims of our Erasmus+ Modeling at School project.

2.3 Spain

2.3.1 Introduction

The main goal of IO1 is to assess the integration of modeling in the educational curriculum by country (Austria, Finland and Spain). Thus, this report shows a global analysis of modeling in Spanish Educational system. We began with an overview of the Spanish Education System, focusing in primary and secondary levels. For the analyses, we take into account the subjects in Spanish educational curriculum. The curriculum in Spain is a little complex, because of the content, methodologies and competences are divided the responsibility, Ministry of Education and "Comunidad Autónoma". In order to get a general analysis, we focused on official documents provided by the Ministry of Education, which establishes common guidelines for all levels of education.

2.3.2 Education System

The Spanish Education System adopted in 2006 the core competences provided by the European Union as elements of the curriculum and evaluation. Historically, two main laws have ruled the education system in Spain, these laws are: (1) LOE (Organic Law of Education) and (2) LOMCE-2013 (Organic Law for the Improvement of the Quality in Education). LOMCE is an amendment of the existing school reform LOE. LOMCE aims to follow and adheres to the European Union guidelines. A description of educational stages can be seen in Table 5, note that this table shows the common age range of students by level and we additionally provided a brief description of sub-levels by stage.

Table 5: Description of stages in Spanish Educational System

Stage	Age range in years	Description
Infant education	0-6	It is a non-compulsory education stage.
Primary education	6-12	It is compulsory and free in publicly-funded schools. It covers 6 academic years and organized by three cycles: 1st cycle - First and second of primary 2nd cycle - Third and fourth of primary 3rd cycle - Fifth and sixth of primary
Compulsory secondary education	12-16	It is compulsory and free in publicly-funded schools. Compulsory secondary education. At the end of this stage, students receive the first official certificate, the Lower Compulsory Secondary Education Certificate, which allows to access to upper secondary education level.
Post-compulsory secondary education (High-school)	16-18	Upper secondary education. It covers 2 academic years. It generally offers two modalities: (1)Bachillerato (general branch), which is offered in secondary schools; and (2) intermediate vocational training (professional branch), which is offered in secondary schools and vocational training integrated institutions.
University	>18	

In order to clarify the Spanish educational stages and complement the Table 5, we presented a representation in Figure 19, which summarizes the Spanish educational stages as well as the relationships between them. Note that compulsory basic education is up to 16 years and it ends with Obligatory Secondary Education.

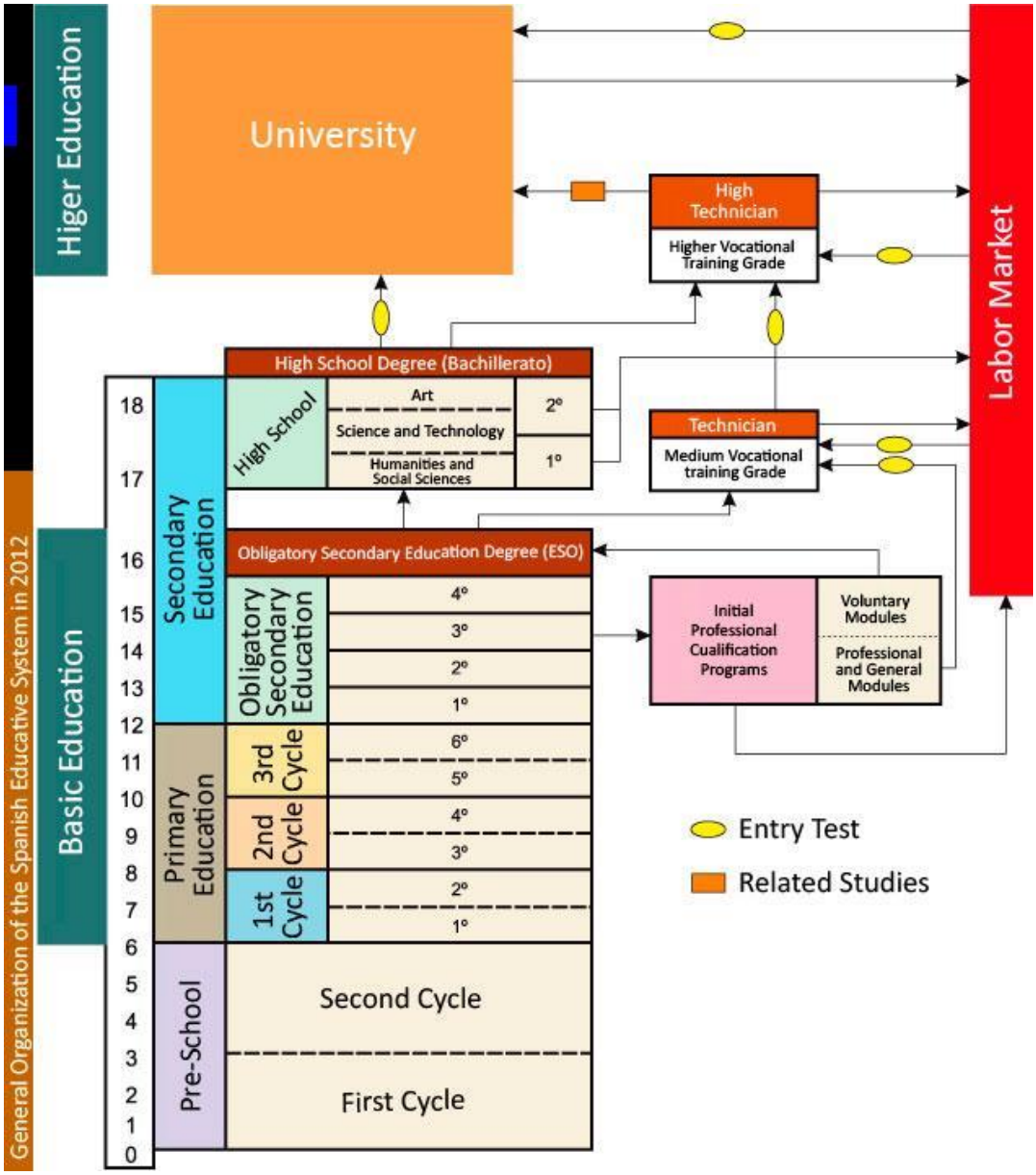


Figure 19: Spanish educational system

Source: https://www.boe.es/diario_boe/txt.php?id=BOE-A-2014-2222

As crucial element for the successive analysis in this document, all subjects taught in primary and secondary education were collected. In this line, we gathered all information linked to subjects taught in primary and secondary school levels in order to carry out the frequency analysis of keywords. According to [1, 2], which are official documents describing methodologies, contents, competences for primary and secondary education in

Spain, we selected the main subjects. These subjects are described in Table 6 and Table 7. Note that a category is provided, which shows the importance in the curriculum, core subjects are commonly compulsory and specific subjects are optional in some cases.

Table 6: Subjects taught in Primary Education

Asignatura	Subject	Category
Ciencias de la Naturaleza	Natural Sciences	Core
Ciencias Sociales	Social Sciences	Core
Lengua Castellana y Literatura	Spanish Language and Literature	Core
Matemáticas	Mathematics	Core
Primera Lengua Extranjera	First language	Core
Educación Física	Physical education	Specific
Religión o valores sociales cívicos	Religion and social and civil values	Specific
Educación Artística	Arts	Specific
Segunda Lengua Extranjera	Second language	Specific

Table 7: Subjects taught in Secondary Education

Asignatura	Subject	Category
Ciencias de la Naturaleza	Natural Sciences	Core
Ciencias Sociales	Social Sciences	Core
Lengua Castellana y Literatura	Spanish Language and Literature	Core
Matemáticas	Mathematics	Core
Primera Lengua Extranjera	First language	Core
Educación Física	Physical education	Specific
Religión o valores sociales cívicos	Religion and social and civil values	Specific
Educación Artística	Arts	Specific
Segunda Lengua Extranjera	Second language	Specific

2.3.3 Descriptive Curricula Analysis: Procedure & Results

In order to conduct a properly descriptive analysis of the educational curriculum in Spain, a set of terms related to *modeling, computational thinking and computer science* were chosen in prior meetings with all partners. These terms were called *keywords*. The selection of these keywords was carried out by using three major categories: (1) modeling, (2) computational thinking and (3) Computer Science. A list of these keywords and corresponding category can be seen in Table 8, note that spanish and english version of keywords are provided. As can be seen, there is a substantial difference among set of words belonging to modeling versus other fields, being the majority category, computational thinking.

Table 8: List of keywords used for frequency analysis

The keywords are located in three main categories: (1) modeling; (2) computational thinking; and (3) computer science. Note that spanish and english translation of keywords are provided.

Palabras clave	Key words	Category
resumen	abstract	Computational thinking
abstracción	abstraction	Computational thinking
algoritmo	algorithm	Computational thinking
algorítmico	algorithmic	Computational thinking
pensamiento algorítmico	algorithmic thinking	Computational thinking
analizar	analyzing	Computational thinking
atributo/atributos	attributes	Computational thinking
construir	build	Computational thinking
construir categorías	build categories	Computational thinking
categoría	category	Computational thinking
características	characteristics	Computational thinking
clasificación	classification	Computational thinking
codificación	coding	Computational thinking
comprensión	comprehension	Computational thinking
computacional	computational	Computational thinking
pensamiento computacional	computational thinking	Computational thinking
descomposición	decomposition	Computational thinking

describir	describe	Computer Science
describir atributos	describe attributes	Computer Science
describir característica	describe characteristics	Computer Science
describir propiedades	describe properties	Computer Science
desarrollar	develop	Computer Science
desarrollar conocimiento	develop knowledge	Computer Science
diagrama/diagramar	diagram	Modeling
generalización	generalization	Computational thinking
jerarquías	hierarchies	Modeling
ilustrar	illustrate	Modeling
ilustración	illustration	Modeling
instrucción/instrucciones	instructions	Computational thinking
conocimiento	knowledge	Computational thinking
lógica/lógico	logic	Computer Science
pensamiento lógico	logical thinking	Computer Science
modelo	model	Modeling
modelado	modeling	Modeling
patrón/patrones	pattern	Computational thinking
reconocimiento de patrones	pattern recognition	Computational thinking
procedimiento	procedure	Modeling

proceso	process	Modeling
propiedad/propiedades	properties	Computational thinking
lectora	reading	Computational thinking
comprensión lectora	reading comprehension	Computer Science
reconocimiento	recognition	Computational thinking
relación/relaciones	relationships	Computer Science
representar	represent	Modeling
representar jerarquías	represent hierarchies	Computational thinking
representación	representation	Modeling
secuenciación	sequencing	Computer Science
resolviendo problemas	solve problems	Computer Science
resolver/resolviendo	solving	Computational thinking
estructurar/estructura	structure	Computer Science
estructurar conocimiento	structure knowledge	Computer Science
resumir	sum up	Computational thinking
sintetizar	summarize	Computational thinking
resumiendo	summarizing	Computational thinking
recopilación	summary	Computational thinking
comprensión de texto	text comprehension	Computer Science
pensamiento	thinking	Computational thinking

visualización	visualization	Modeling
visualizar	visualize	Modeling

Once distinguished these keywords, we proceed to count the occurrence of these keywords in all subjects. This was carried out for educational curriculum of primary and secondary schools. The most detailed frequency analysis of keywords for primary and secondary schools can be seen in Table 9 and Table 10, respectively.

Table 9: Frequency analysis of keywords for primary subjects

		Core subjects					Specific subjects		
Palabras clave	Key words	Natural Sciences	Social Sciences	Spanish language and literature	Maths	First foreign language	Arts	Physical education	Social and civic values
resumen	abstract	0	0	2	0	0	0	0	1
abstracción	abstraction	0	0	0	0	0	0	0	0
algoritmo	algorithm	0	0	0	7	0	0	0	0
algorítmico	algorithmic	0	0	0	0	0	0	0	0
pensamiento algorítmico	algorithmic thinking	0	0	0	0	0	0	0	0
analizar	analyzing	1	1	1	14	0	1	2	6
atributo/atributos	attributes	0	0	0	0	0	0	0	0
construir	build	0	0	1	8	0	0	0	1
construir categorías	build categories	0	0	0	0	0	0	0	0
categoría	category	0	0	4	0	0	0	0	0
características	characteristics	18	19	10	8	0	10	6	6
clasificación	classification	4	1	1	8	0	0	0	0
codificación	coding	0	0	0	0	0	0	0	0
comprensión	comprehension	0	6	15	3	0	0	0	1
computacional	computational	0	0	0	0	0	0	0	0
pensamiento computacional	computational thinking	0	0	0	0	0	0	0	0
descomposición	decomposition	0	0	0	3	0	0	0	0

describir	describe	0	2	1	4	2	3	1	0
describir atributos	describe attributes	0	0	0	0	0	0	0	0
describir característica	describe characteristics	0	0	0	0	0	0	0	0
describir propiedades	describe properties	0	0	0	0	0	0	0	0
desarrollar	develop	5	2	3	6	4	0	11	7
desarrollar conocimiento	develop knowledge	0	0	0	0	0	0	0	0
diagrama/diagramar	diagram	0	0	0	3	0	0	0	0
generalización	generalization	0	0	0	0	0	0	0	0
jerarquías	hierarchies	0	0	0	3	0	0	0	0
ilustrar	illustrate	0	0	3	0	1	1	0	0
ilustración	illustration	0	0	0	0	0	1	0	0
instrucción/instrucciones	instructions	0	0	1	0	9	0	0	0
conocimiento	knowledge	5	9	23	15	8	7	6	1
lógica/lógico	logic	8	6	1	9	7	2	2	3
pensamiento lógico	logical thinking	0	0	0	0	0	0	0	0
modelo	model	0	1	9	1	2	0	2	0
modelado	modeling	0	0	0	0	0	0	0	0
patrón/patrones	pattern	0	0	0	5	7	2	0	0
reconocimiento de patrones	pattern recognition	0	0	0	0	0	0	0	0
procedimiento	procedure	5	1	1	7	1	2	2	0
proceso	process	5	9	9	33	1	7	3	4
propiedad/propiedades	properties	8	4	0	10	0	1	0	0
lectora	reading	0	0	3	0	0	0	0	0
comprensión lectora	reading comprehension	0	0	2	0	0	0	0	0
reconocimiento	recognition	0	0	0	5	0	0	0	1
relación/relaciones	relationships	8	3	7	21	8	0	7	15
representar	represent	1	10	1	9	0	5	1	1
representar jerarquías	represent hierarchies	0	0	0	0	0	0	0	0
representación	representation	0	3	0	3	0	0	0	1
secuenciación	sequencing	0	0	0	0	0	0	0	0
resolviendo problemas	solve problems	0	0	0	15	0	0	0	0
resolver/resolviendo	solving	2	4	1	24	0	0	3	3
estructurar/estructura	structure	7	3	11	4	13	0	4	7

estructurar conocimiento	structure knowledge	0	0	0	0	0	0	0	0
resumir	sum up	0	0	0	0	0	0	0	0
sintetizar	summarize	0	0	0	0	0	0	0	0
resumiendo	summarizing	0	0	1	0	0	0	0	0
recopilación	summary	0	0	0	0	0	0	0	0
comprensión de texto	text comprehension	0	0	10	0	0	0	0	0
pensamiento	thinking	2	0	3	2	0	1	0	15
visualización	visualization	0	0	0	0	0	0	0	0
visualizar	visualize	0	0	0	0	0	0	0	0

In the Primary school curriculum, the keywords 'characteristics', 'knowledge', 'represent', 'relationships', 'structure' were the terms more mentioned (Figure 20). Some of these keywords are close to computer science ('relationships' and 'structure'), although to a minor extent with modeling. Modeling word 'model' reached a low value (15 times) by comparing with others. Some words strongly related to computational thinking also reached low values ('algorithmic', 'abstraction', 'solve problems'). No instances of the terms: 'logical thinking', 'modeling', 'pattern recognition' were found. The latest pointed out a reasonable insight of the lack of use of keywords in the curriculum of Primary Schools.

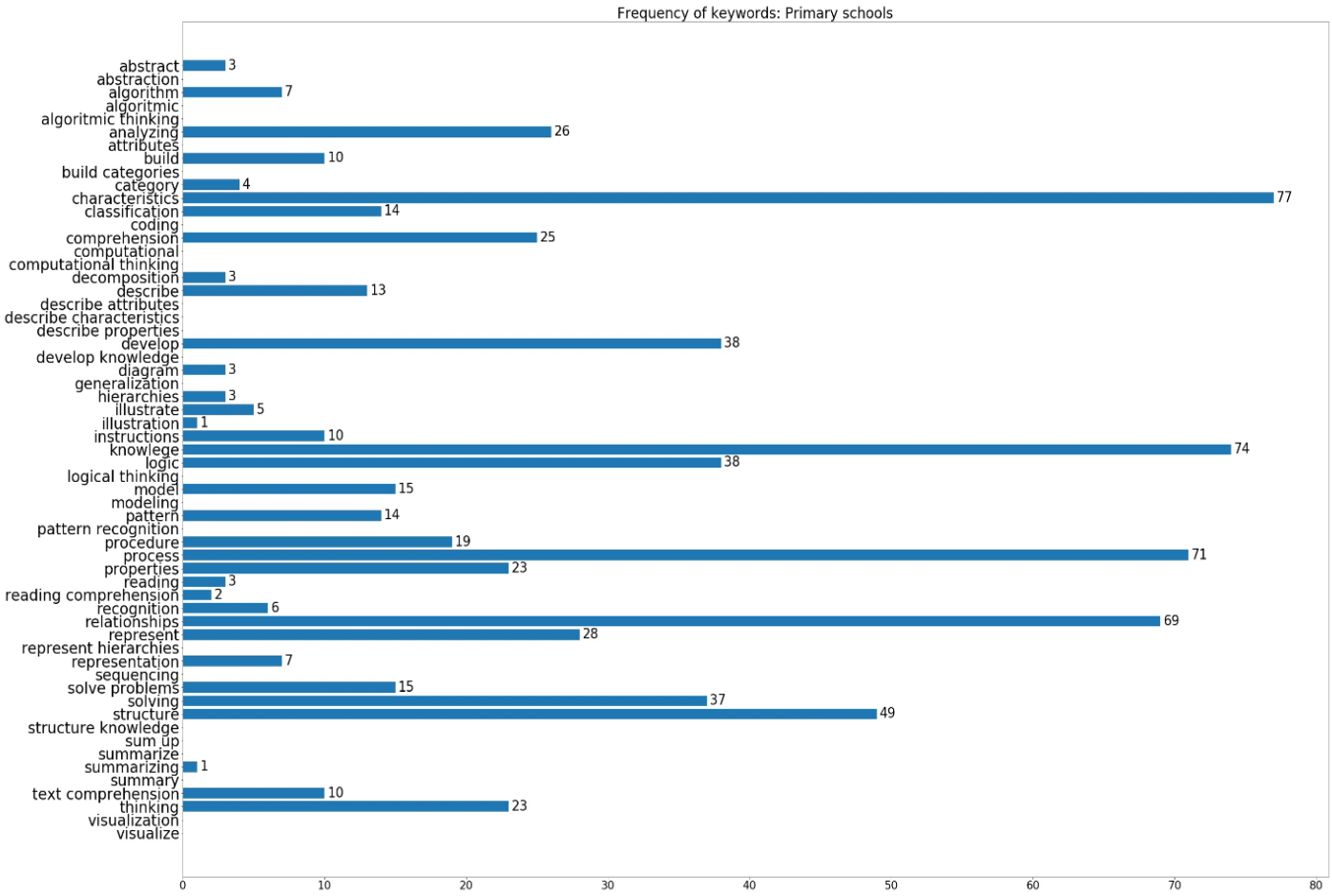


Figure 20: Frequency analysis of keywords in primary school curriculum

We provided a frequency analysis of keywords by subjects of primary education, this analysis can be seen in Figure 21. There are substantial differences considering only the distribution of the keywords per subject. In Spain, Computer Science is not a subject, but it is integrated to the curriculum through two competences (described in next section): Competence in Mathematics, Science and Technology and Digital Competence. Broadly speaking, Computer Science might be considered as transversal if we consider that the curriculum establishes the development of the latest competences in almost all subjects.

For Primary education, Maths, Spanish Language and Literature reached the highest values (230 and 124, respectively), which is comprehensible for Maths (one of the STEM subjects) due to the strong relationship of terms with Computer Science. However, in the case of Spanish Language subject (124) the result was notorious. The subjects with low occurrences were Arts and Physical Education (43 and 50 respectively).

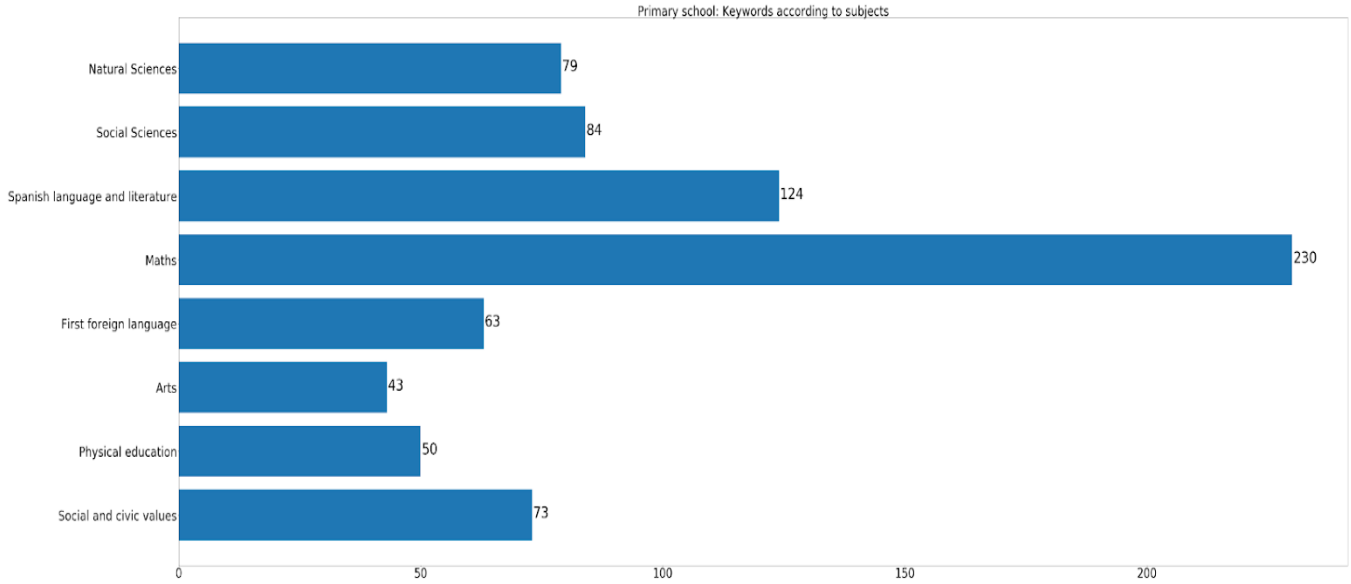


Figure 21: Frequency analysis of keywords. Summary by subjects for primary schools

The same frequency analysis of keywords was carried out for educational curriculum of Secondary schools. The results can be seen in Table 10 and Figure 22.

Table 10: Frequency analysis of keywords for secondary subjects

	Core subjects						Specific subjects			
Key words	Biology and geology	Physics and chemistry	Geography and history	Spanish language and literature	Maths	First foreign language	Physical education	Religion and social and civil values	Arts	Second language
abstract	0	0	0	0	0	2	0	2	0	0
abstraction	0	0	0	0	0	0	0	0	0	0
algorithm	0	0	0	0	3	0	0	0	0	0
algorithmic	0	0	0	0	0	0	0	0	0	0
algorithmic thinking	0	0	0	0	0	0	0	0	0	0
analyzing	0	9	2	3	7	0	2	1	3	0
attributes	0	0	0	3	0	0	0	2	0	0
build	3	0	0	0	0	0	0	0	2	1
build categories	0	0	0	0	0	0	0	0	0	0
categorías	0	0	0	12	0	0	0	1	0	0

characteristics	17	8	23	4	14	2	4	6	1	1
classification	3	1	0	0	1	0	0	1	1	0
coding	0	0	0	0	0	0	0	0	0	0
comprehension	0	0	2	12	4	19	1	4	0	4
computational	0	0	0	0	0	0	0	0	0	0
computational thinking	0	0	0	0	0	0	0	0	0	0
decomposition	0	0	0	0	1	0	0	0	0	0
describe	0	11	5	1	2	5	0	0	0	0
describe attributes	0	0	0	0	0	0	0	0	0	0
describe characteristics	0	0	0	0	0	0	0	0	0	0
describe properties	0	0	0	0	0	0	0	0	0	0
develop	0	0	0	1	1	0	2	2	0	2
develop knowledge	0	0	0	0	0	0	0	0	0	0
diagram	0	1	0	1	2	0	0	0	0	0
generalization	0	0	0	0	1	0	0	0	0	0
hierarchies	0	0	4	0	3	0	0	1	0	0
illustrate	0	0	0	0	0	0	0	0	0	0
illustration	0	0	0	0	0	0	0	0	0	2
instructions	0	0	0	1	0	4	0	0	0	4
knowledge	2	3	3	23	2	9	1	2	2	1
logic	40	8	11	2	27	14	1	0	0	0
logical thinking	0	0	0	0	0	0	0	0	0	0
model	7	7	1	0	4	3	1	3	0	0
modeling	0	0	0	2	0	0	0	0	0	0
pattern	0	0	0	0	1	6	1	1	0	5
pattern recognition	0	0	0	0	0	0	0	0	0	0
procedure	3	5	0	6	2	2	0	1	1	2
process	38	7	24	3	33	0	6	2	8	0
properties	4	12	0	2	60	0	0	0	5	2
reading	0	0	0	2	0	0	0	0	0	0
reading comprehension	0	0	0	0	0	0	0	0	0	0
recognition	0	0	0	0	0	0	0	1	0	0
relationships	5	16	11	9	16	21	4	12	3	7
represent	3	2	4	0	9	0	0	2	1	0

represent hierarchies	0	0	0	0	0	0	0	0	0	0
representation	0	6	2	1	5	0	0	0	3	0
sequencing	0	0	0	0	0	2	0	0	0	0
solve problems	0	0	0	0	14	0	0	0	0	0
solving	1	2	0	6	19	0	2	0	0	0
structure	20	4	1	12	5	28	1	3	2	5
structure knowledge	0	0	0	0	0	0	0	0	0	0
sum up	0	0	0	0	0	2	0	0	0	0
summarize	0	0	0	0	0	0	0	0	0	0
summarizing	0	0	0	4	0	0	0	0	0	0
summary	0	0	0	0	0	0	0	0	0	0
text comprehension	0	0	0	0	0	0	0	0	0	0
thinking	0	0	0	1	0	0	0	2	0	0
visualization	0	0	0	0	0	0	0	0	0	0
visualize	0	0	0	0	0	0	0	0	0	0

The results of the keyword analysis in educational curriculum for secondary schools showed that most common keywords used were ‘process’, ‘relationships’, ‘logic’, ‘properties’, ‘structure’. The term ‘process’ led the ranking with an occurrence of 121. In contrast to primary schools, terms related to modeling (‘model’, ‘modeling’) reflected slightly higher values (26 and 2, respectively). No instances for ‘algorithmic thinking’, ‘computational thinking’ were found. 21 keywords were not used in the secondary school curriculum.

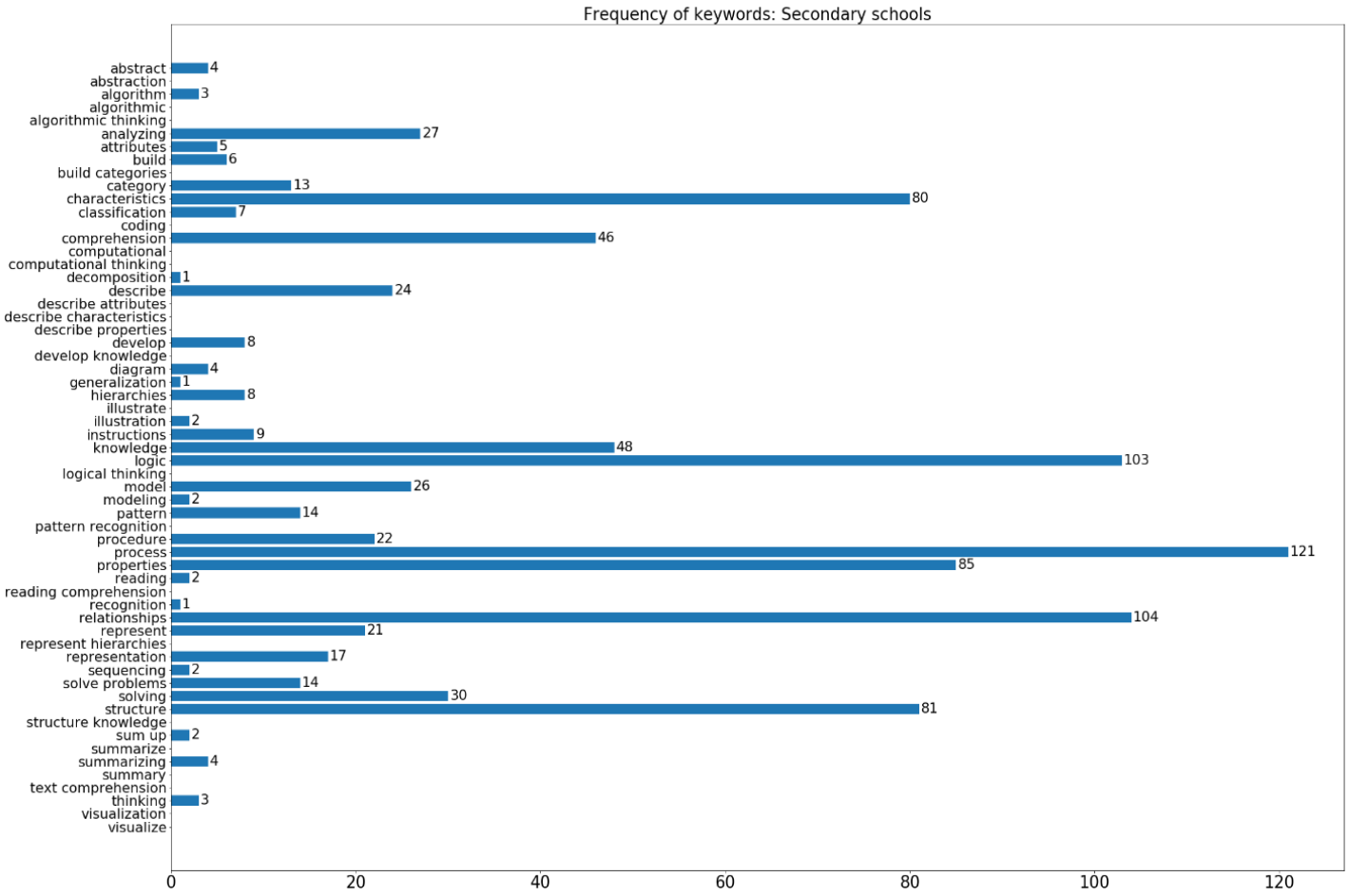


Figure 22: Frequency analysis of keywords in secondary schools

Taking into account the frequency of keywords according to subjects of Secondary Education (see Figure 23), Maths, Biology and Geology and First foreign languages reached the highest values of occurrence (236, 146 and 119 respectively). Maths was the subject with more occurrences, which is in line with Primary schools. The subjects with low occurrences of keywords were Arts and Physical Education, as occurred in Primary schools.

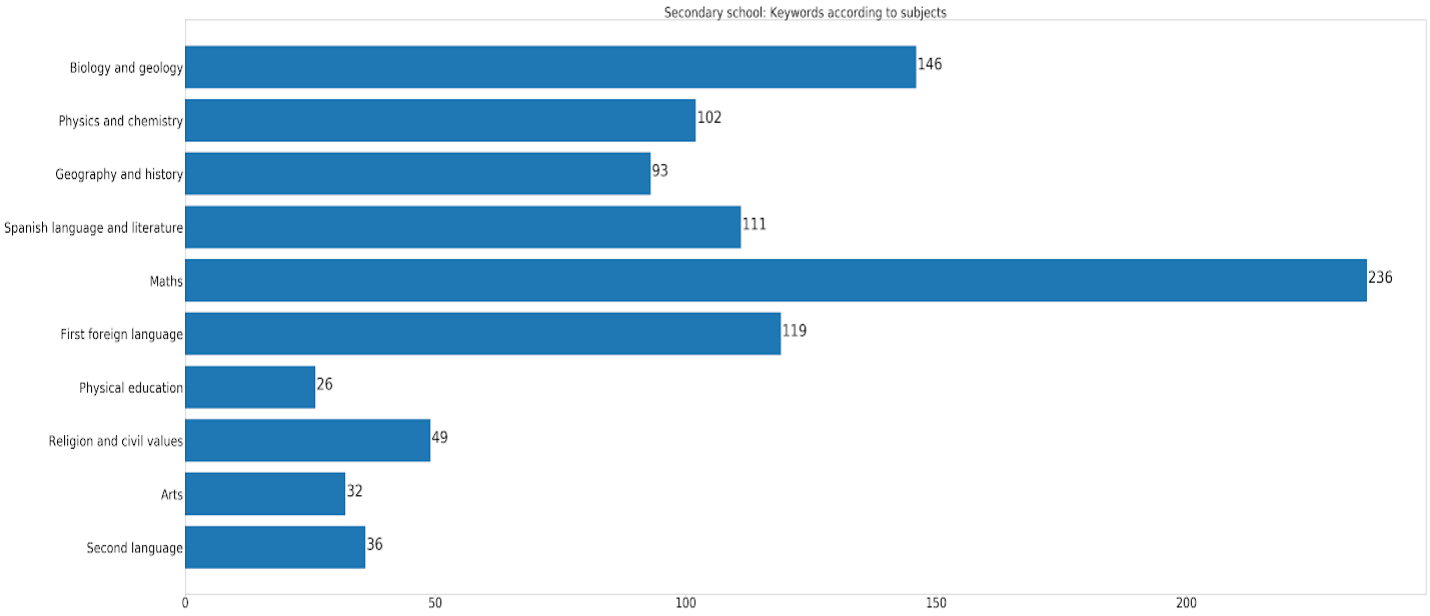


Figure 23: Frequency analysis of keywords according to secondary subjects

3 Analysis of Key Competencies

3.1 European Competence Framework

According to European Commission's educational policy on key-competences, education in the European Union continue to move towards a competence-oriented approach in education. This direction is clearly reflected in the *Proposal for a COUNCIL RECOMMENDATION on Key Competences for LifeLong Learning* (2018). Reforms are affecting both the structure of European curricula and the organization of learning. Teachers are more and more expected to be recognized in a new role in learning guidance, as well as new approaches are transforming the traditional assessment. Cross-curricular approaches, increasing interactive learning and teaching styles, combinations of formal with informal learning approaches are slowly taking place, by following the tendencies outlined by the *Recommendation on Key Competences for Lifelong Learning* (2006). This document also defines key competences as dynamic combinations of skills, knowledge and attitudes, which the learners need to develop from an early age onwards throughout their life. The European Union Key Competences for Lifelong Learning Reference Framework sets out eight key competences (Proposal for a Council Recommendation, p. 38.), as it is also represented in Figure 24:

1. Literacy competence,
2. Multilingual competence,
3. Mathematical competence and competence in science, technology and engineering,
4. Digital competence,
5. Personal, social and learning to learn competence,
6. Citizenship competence,
7. Entrepreneurship competence,
8. Cultural awareness and expression competence.

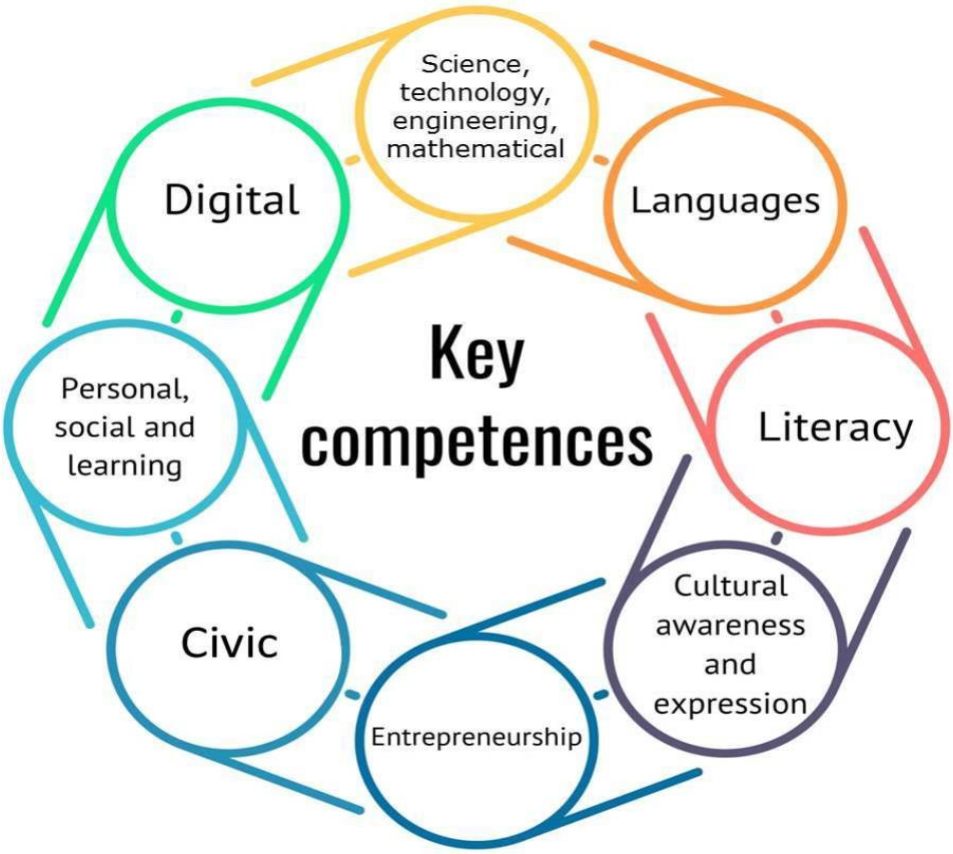


Figure 24: European Framework of Key Competences

Source: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018SC0014&from=EN

The *Council Recommendation on Key Competences for Lifelong Learning* (2018) is summarizing the content of the key competences, as follows:

Literacy competence is the ability to understand written and oral (reading, writing, listening, speaking) communication, communicate effectively and creatively with others both orally and in writing in various situations and being able to adapt one's way of communication to suit the situation. Positive attitude towards literacy includes skills for constructive and critical dialogue, which entails understanding of the effect language has on others and using language in a positive and socially responsible manner.

Multilingual competence shares the main skill dimension with literacy and expands that to understanding and communicating effectively in foreign languages, while respecting and understanding the cultural and societal aspects of language use in other languages. The competence also includes creating understanding of the main types of verbal interaction and registers in languages. Positive attitude towards multilinguality ingrains appreciation towards cultural diversity and curiosity towards about intercultural communication and languages.

Mathematical competence and competence in science, technology, engineering has two components. Mathematical competence is aimed towards creating individual's mathematical models, thinking and reasoning, and problem solving skills. Positive attitude towards mathematics includes an appreciation for truth and the interest towards seeking reasons and assessing their validity. Competence in science, technology and engineering is focused on developing individual's skills and ability to make observations and questions to draw evidence-based conclusions about the natural world. Skills include understanding of science as a process for investigation and the ability to use scientific tools and data to achieve an evidence-based decision or conclusion. The competence includes also a critical appreciation and curiosity towards ethical issues, safety and environmental issues on an individual, local and global level in scientific and technological progress.

Digital competence focuses on attaining critical, confident and responsible ways of engaging with digital technologies and understanding the logic behind their operation. Digital competence also includes skills such as digital literacy, communication and collaboration, safety and intellectual property rights. Attitude towards digital technologies should be open-ended and curious, but also critical and reflective.

Personal, social and learning to learn competence includes skills of self-reflection, managing time, information, one's own learning and career, ability to work constructively in cooperation with others and to remain resilient (coping with uncertainty and complexity). The competence also includes learning to learn skills and the ability to maintain one's mental and physical well-being. The competence is based on a positive attitude towards one's personal and other's well-being and lifelong learning. Problem-solving attitude helps one to overcome challenges and obstacles in life while remaining resilient and curious towards learning from life experiences.

Citizenship competence is the ability to act responsibly as a citizen and to participate in civic and social life, which entails understanding social, political, legal and economic structures and concepts. Citizenship competence includes the ability to engage effectively with others in common and public interest and critical understanding and interaction with traditional and new forms of media. In the core of the responsible and constructive attitude lay on respect for basic human rights as a basis for democracy.

Entrepreneurship competence is the capacity to act upon ideas and opportunities in a way that produces value for others. At the core of this competence are creativity, problem-solving, critical thinking, taking initiative, collaboration and perseverance. Entrepreneurial attitude includes the sense of initiative and agency and proactive and forward-looking courage to achieving objectives. It also includes valuing others ideas and the desire to motivate them and the empathy to take care of others and the world by adopting ethically responsible approaches during the process.

Cultural awareness and expression competence skills include the ability to empathetically express and interpret abstract ideas in various art and other cultural forms. This requires knowledge of local, national, regional, European and global cultures and expression and how they influence each other and individual's. Positive attitude includes curiosity towards the world, openness to imagine new possibilities and participation in cultural experiences.

3.2 Digital Competence Development in the European Union

Supporting initiatives and research on the development of computational thinking are among the main priorities in the European Union's digital competence development. The *ET2020 Working Group on Digital Skills and Competences* has been focusing on coding and computational thinking, teacher skill and training, the gender gap, open educational resources (OER), device provision (such as Bring Your Own Device, BYOD), infrastructure, the use of data in education (learning analytics) or digital assessment and aims to touch on upcoming technologies and approaches, such as open badges, blockchain or makerspaces (see: https://ec.europa.eu/jrc/en/computational-thinking).

According to comprehensive studies and reports focusing on the computational thinking (CT) initiatives in the European Union integration of CT in compulsory education is represented in multiple ways in the European education (see Figure 25), however it is still facing with multiple challenges (Bocconi et al., 2016). The definition, main characteristics of CT, CT-related teacher training and teaching practices, curricula integration, assessment-related questions are still to be addressed on European level in order to foster a comprehensive strategy for the development of computational thinking in education.

As Bocconi et al. (2016, p. 8-9.) describe, several European countries, including Austria and Finland aim to develop students' logical thinking skills and problem-solving skills through CT. The importance of CT and Computer Science is raising in European compulsory education in general, as it is reflected by curricula reforms as well. Finland is already concluded a reform process that includes CT and related concepts. Austria is integrating CT mainly in upper secondary schools by building on their long-standing tradition in Computer Science (CS) education as well as in lower secondary school and new secondary school with the implementation of the new curriculum "digital education", which was launched in autumn 2018. As Bocconi et al. (Ibid.) points out, Spain, where curricula development is managed at regional level, the integration of CT in school varies from region to region. Regarding the positioning of CT in the curricula, it is usually situated along two axes: educational levels and subjects. As Bocconi et al. (2016) is summarizing the current state of the art in Europe as follows: "Most countries integrate CT in secondary school. However, there is a growing trend towards primary school integration as well. Several countries embed CT across subject areas, particularly at primary level, while at secondary level CT is mostly included as a computing subject in its own right.

However, a combination of approaches is also present. Some countries (e.g. Wales and Austria) consider CT and related concepts as part of their digital competence (DC) curriculum" (Bocconi et al. 2016, p. 9.).

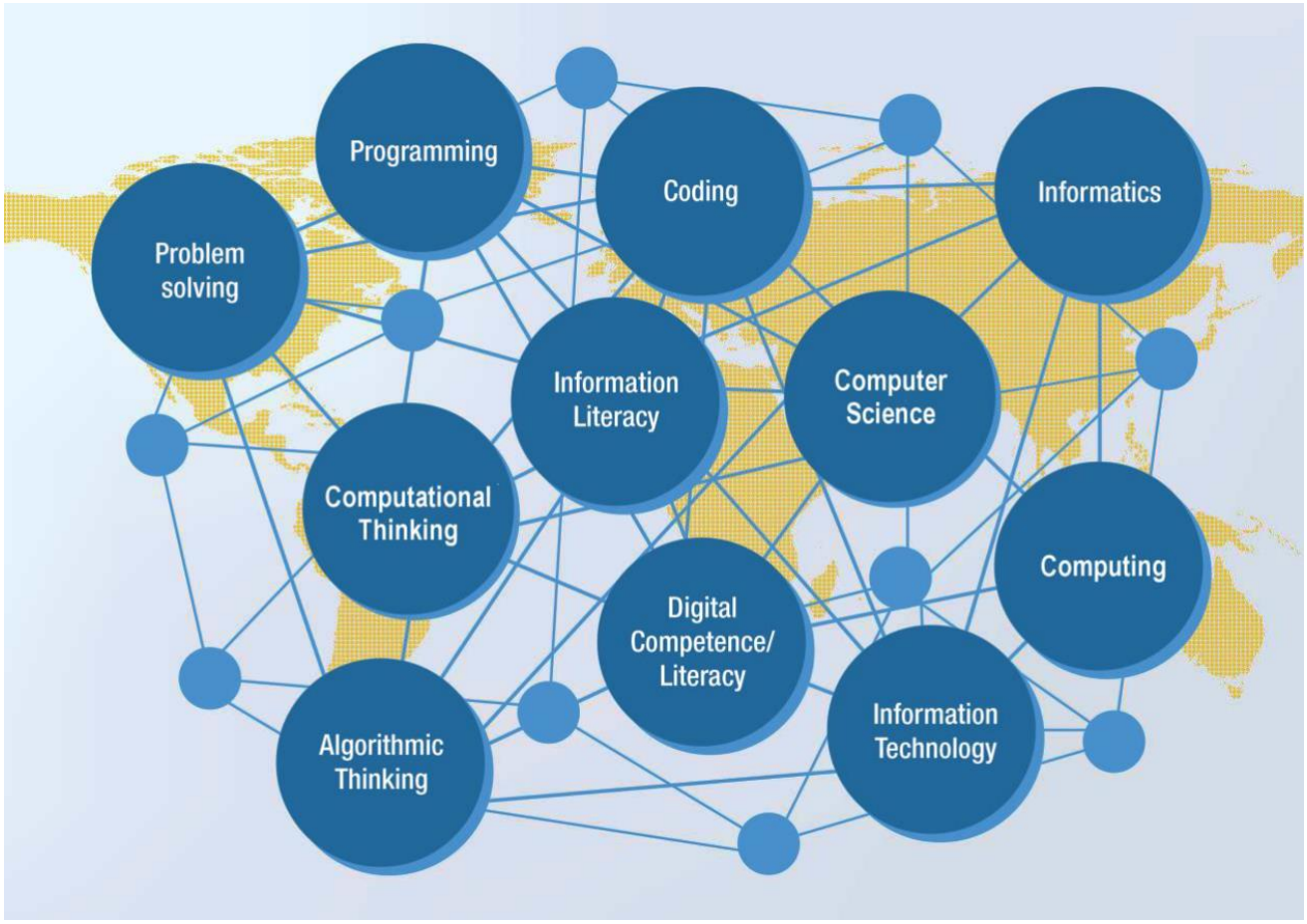


Figure 25: Set of CT-related terms to capture major trends in the field

Source: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC104188/jrc104188_computhinkreport.pdf

3.3 Spain

3.3.1 Description of relevant competencies in Spanish Education System

In Spain, the curriculum associated to primary and secondary education is organized by competences. The Spanish Education System establishes a competency-based learning approach. A competence is defined as: "The ability to integrate knowledge, skills and attitudes in a practical way to solve problems and react appropriately in a variety of context and situations". The latest means the integration and application of theoretical and practical knowledge in settings outside the academic context. The 7 key competences for lifelong learning defined in the Spanish curriculum are shown in Table 11. How competences are related with curriculum? The Spanish curriculum is defined as series of objectives, key competences, contents, methodology and evaluation criteria.

Table 11: Key competences in Spanish curriculum by considering European Reference Framework

Abbreviation	Competence	Description
KC1-CLC	Competence in Linguistic Communication	The ability to express and interpret concepts, thoughts, feelings, facts and opinions in both oral and written form.
KC2-CMST	Competence in Mathematics, Science and Technology	The ability to use and relate numbers, basic operations, symbols and forms of mathematical expression and reasoning. Also involves the ability to apply mathematical thinking and mathematical tools to describe, interpret and predict different phenomena in context.
KC3-DC	Digital Competence	It involves a creative, critical and safe use of information and communication technologies, in order to achieve objectives related to work, employability, learning, use of free time and inclusion and participation in society.
KC4-L2L	Learning to learn	The ability to feel motivated to learn, and the need to foster organization and learning management. This competence is characterized by the ability to start, organized and persist in learning.
KC5-SCC	Social and Civic Competences	*(1) Social competences* include personal, interpersonal and intercultural skills. *(2) Civil competences* are based on knowledge of next concepts: democracy, justice, equality, citizenship and civil rights
KC6-SIE	Sense of Initiative and Entrepreneurship	The ability to transform ideas into actions, becoming aware of the situation to be solved, know how to choose, plan and manage their knowledge and the necessary skills or abilities and attitudes with self-criteria, in order to achieve the desired objective.
KC7-CAE	Cultural Awareness and Expression	Knowing, understanding, appreciating and valuing the different cultural and artistic demonstrations, using them as source of enrichment and personal enjoyment, and considering them as part of people's wealth and heritage.

Note that we can relate competences of Spanish curriculum with 21st century competencies (shown in parentheses), following a similar approach of [2]. KC1-CLC (Effective oral and written communication, critical thinking); KC2-CMST (Problem solving and resolution); KC3-DC (Accessing and analyzing information); KC4-L2L (Critical thinking); KC5-SCC (Collaboration and leadership); KC6-SIE (Flexibility and adaptability, initiative and entrepreneurialism); KC7-CAE (Creativity). Following a same approach of the authors [1], we did an approximation of grid, which key competences and subjects are related. These approaches were done for primary and secondary school and they can be shown in Table 12 and Table 13, respectively.

Table 12: Relationships between key competences and subjects for Primary Education

Competencies and areas	Natural Sciences	Social Sciences	Spanish language and literature	Maths	First foreign language	Arts	Physical education	Social and civil values
KC1-CLC	X	X	X	X	X			X
KC2-CMST				X				
KC3-DC	X	X	X		X	X		
KC4-L2L	X	X	X	X	X	X	X	X
KC5-SCC								
KC6-SIE								
KC7-CAE	X	X	X	X	X	X	X	X

Table 13: Relationships between key competences and subjects for Secondary Education

Competencies and areas	Biology and Geology	Physics and Chemistry	Geography and history	Spanish language and literature	Maths	First foreign language	Physical Education	Religion and Social civil values	Arts	Second language
KC1-CLC	X	X	X	X	X	X		X		X
KC2-CMST				X	X					
KC3-DC	X	X	X	X						
KC4-L2L	X	X	X	X	X	X	X		X	X
KC5-SCC								X		
KC6-SIE								X		
KC7-CAE	X	X	X	X	X	X	X	X	X	X

3.4 Finland

3.4.1 The current National Core Curriculum for Basic Education in Finland

The Finnish National Agency for Education introduced the National Core Curriculum for Basic Education in 2014. It was introduced for grades 1–6 in all schools beginning on 1 August 2016 (FNCC). The curriculum was introduced to the higher grades of basic education in the following steps: the new curriculum was adapted by grades 7 on 1 August 2017, by grades 8 in 2018 and by grades 9 in 2019. For now, education providers have drawn up their own local curricula based on the National Core Curriculum.

FNCC's main aim to provide active and flexible support for teaching and school activities and to enhance equality in education throughout whole Finland. It serves as a uniform foundation for local curricula, which are developed by each municipality and school by taking local needs and perspectives into consideration (FNCC, p. 9-14.). Issues subject to local decision are defined in each chapter of the FNCC.

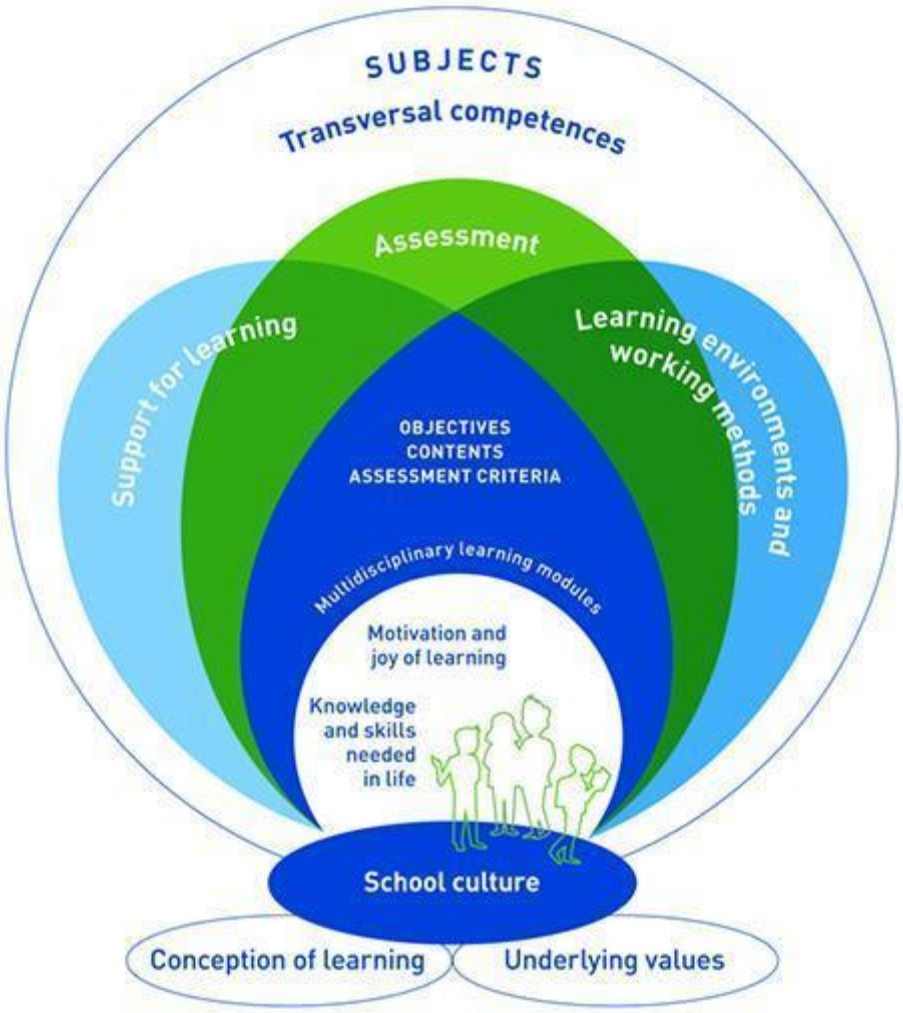


Figure 26: Learning and assessment in the Finnish curriculum

Source: https://www.oph.fi/english

As it is represented by Figure 26, FNCC's description of the policies on underlying values, conception of learning and school culture provides a general basis, while the development of transversal competences is the main target for all local curricula's objectives of learning (FNCC, p. 14-103.).

The FNCC describes the preferences and content for different subjects as well, and introduce the concept of multidisciplinary learning modules (MLs). MLs are supposed to set the scene for phenomenon- / theme- or topic-based learning in schools, which is primarily defined and organized by the learners interests, and go beyond the subject-based education by integrative, holistic approaches both in instruction and in the learning processes. MLs promote active learning (learning-by-doing) and encourage the exploration of possible links between the individual schools and surrounding local societies, and the creative implementation of resources, which can be involved as potential learning opportunities (FNCC, p. 32-34.). In each school year every school must have at least one clearly-defined theme, project or course that combines the content of different subjects and deals with the selected theme from the perspective of several subjects. These are called multidisciplinary learning modules. Schools plan and implement the multidisciplinary learning modules. The topics and duration may vary based on local needs and interests. Pupils participate in planning the modules. The assessment of learning is based on the objectives of the different subjects. MLs' background and structure is introduced in Figure 27.

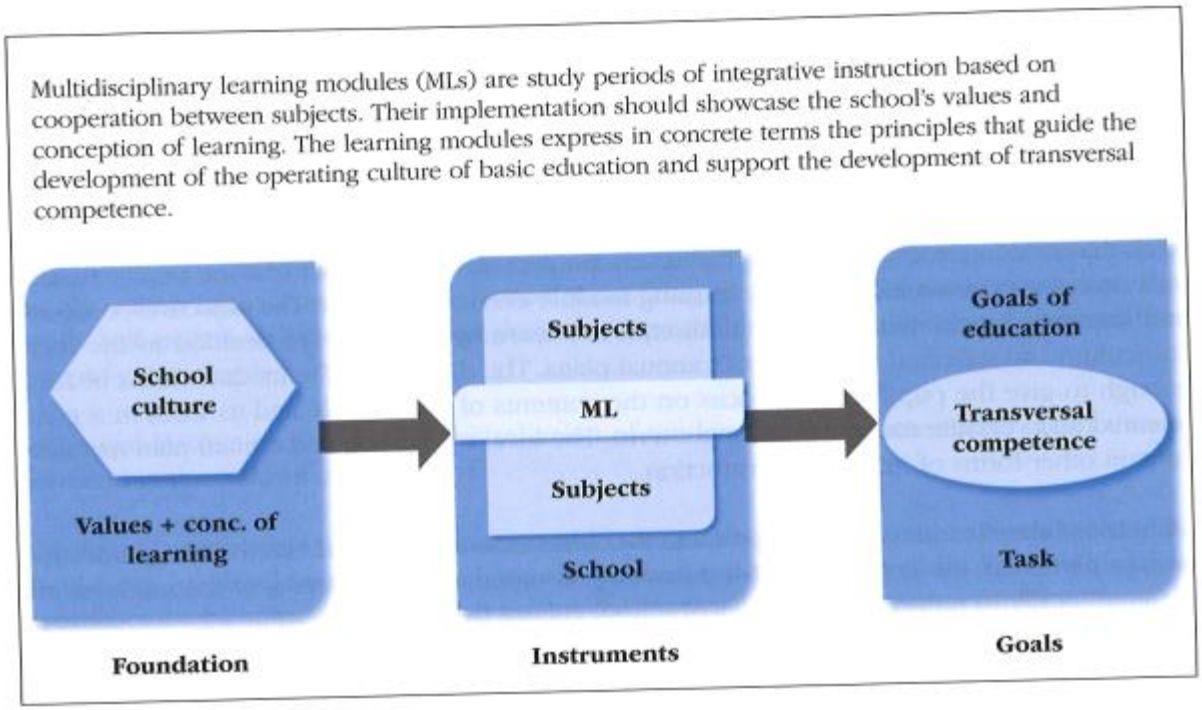


Figure 27: Multidisciplinary Learning Modules

The structure and basic components of Multidisciplinary learning modules (MLs) in the learning process (FNCC, p. 34.)

The current FNCC's most important innovations are focused on: (1) securing the necessary knowledge and skills, as well as encourage learning by increasing students' interest and motivation; (2) renewing subjects; (3) developing transversal competences as part of every subject; (4) changing the ways schools operate; (5) providing at least one multidisciplinary learning module a year; and (6) enhancing diversity in pupil assessment, as it is shown on Figure 29.

The set of aims for transversal competences (FNCC, p. 21-25.) include: "thinking and learning to learn"; "cultural competence, interaction and self-expression"; "taking care of oneself and managing daily life"; "multiliteracy"; "ICT competence"; "working life competence and entrepreneurship"; "participation, involvement and building a sustainable future" (Figure 28).

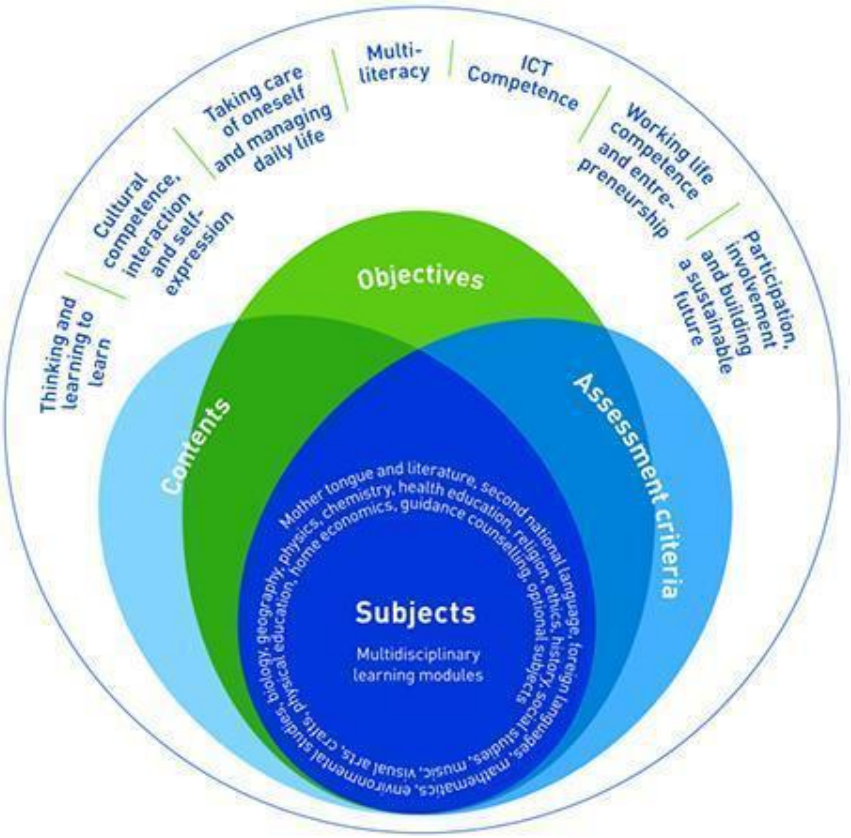


Figure 28: Transversal competences and subjects in the Finnish curriculum

Source: https://www.oph.fi/english

The principle of developing transversal competences (Figure 28) as part of MLs offer several opportunities to introduce computational thinking and modelling, both as topics and approaches in the learning process.

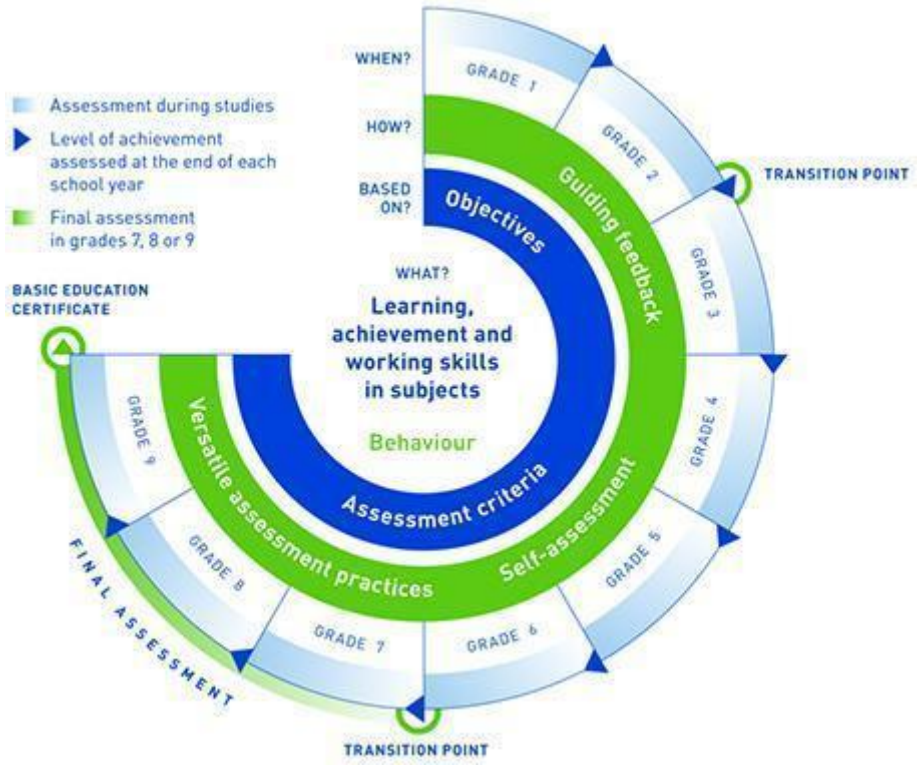


Figure 29: Assessment in the Finnish curriculum

Source: https://www.oph.fi/english

3.4.2 Key Competencies in the Finnish National Core Curriculum

According to the monitoring and analysis of national competence frameworks, the European Framework of Key Competences has been used as an inspiration, but national circumstances are affecting the local definitions and the usage of the competence concepts. Table 14 shows as an example, how the main components of the European Key Competences Framework are reflected in the Finnish Curriculum.

Table 14: Comptetences of the European Key Competences Framework and the FNC Curriculum (2014)

European Key Competences Framework	**Finnish National Core Curriculum's Competence Framework**
Digital competence	ICT competence
Learning to learn	Thinking and learning to learn Multiliteracy (critical thinking and learning skills)
Social and civic competence	Participation, involvement and building a sustainable future Taking care of oneself and managing daily life (incl. well-being, health and safety)

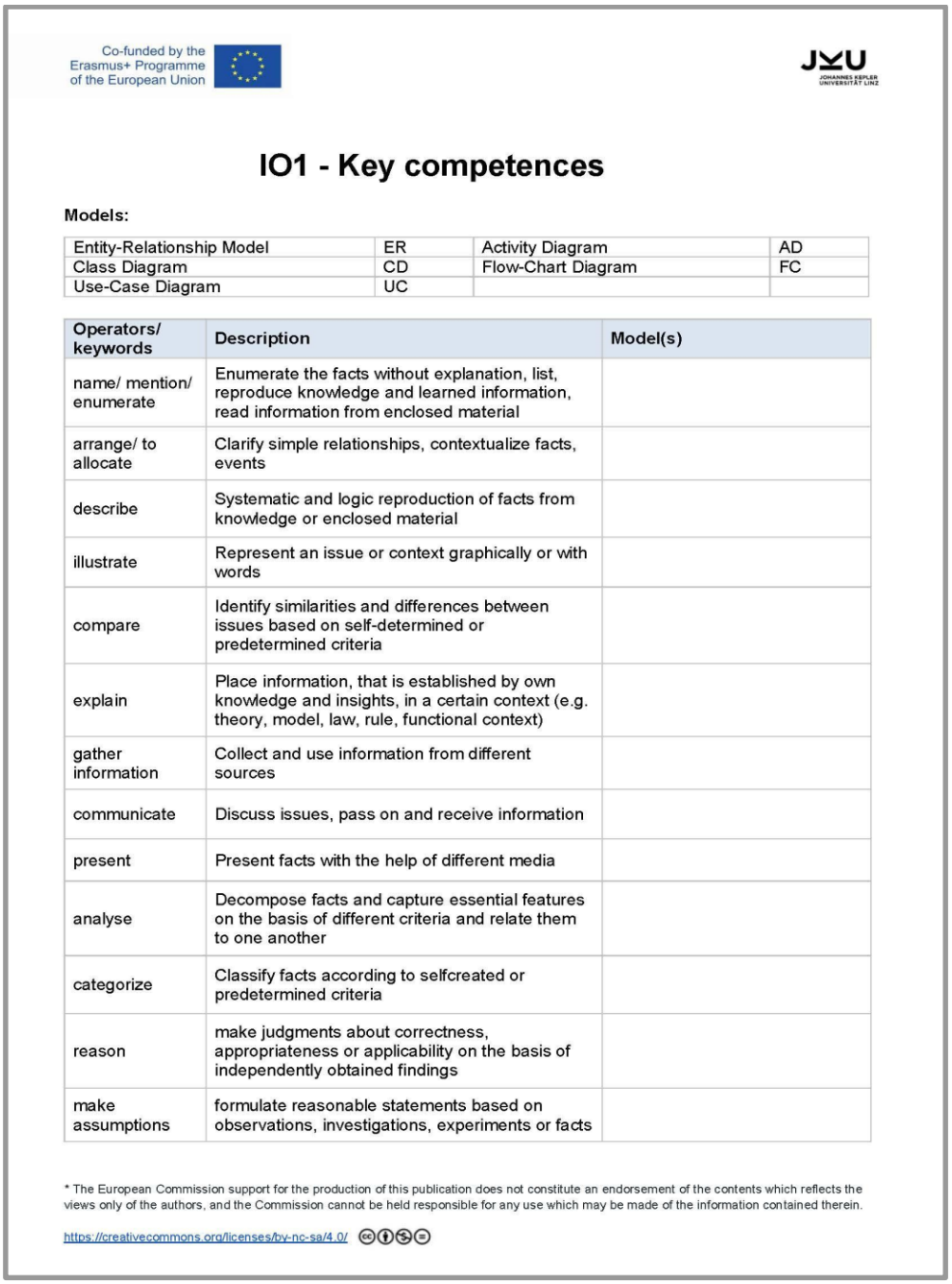
Sense of initiative and entrepreneurship	Working life competence and entrepreneurship
Cultural awareness and expression	Cultural competence, interaction and self-expression
Other competences / skills	Taking care of oneself and managing daily life (incl. using technology responsibly; consumer and personal finance skills) Working life competence

3.5 Austria

3.5.1 Procedure – Analysis of Key Competencies

In the next step of intellectual output 1, our aim was to find out in which subjects and contexts an integration of modeling is possible and useful. After taking into consideration different approaches, we came to the conclusion that it would be useful to focus on key competencies that are relevant for every subject. The new core curriculum of Finland presents the so-called transversal competences and also the curricula of the Spanish primary and secondary schools do follow a competence-based learning approach. In Austria, on the other hand, such key competencies are still not officially designed. However, the Federal Ministry of Education and Research published a “map of competencies” (BMBWF 2019a) that contains numerous competencies with detailed descriptions. Added to this, the Ministry of Education has published an amendment to the map of competencies, which is called “list of operators and its definitions” (BMBWF 2019b). After taking into consideration various approaches, we decided to use the list of operators as the foundation for the following reason: our aim is to provide teachers an overview where they can easily see where modeling can be a useful tool. It is important that this overview is comprehensible, convincing, not too overloaded and suitable for all subjects and teachers with or without computer science background. For the reason that the “map of competencies” is very detailed, the list of operators seemed to be more appropriate.

The next step was to adapt this list and assign the different diagrams accordingly to each of the operators. To achieve valuable results, we involved six experts from computer science in this procedure who had to match the diagrams to the different competencies independently. The following images show the English version of the expert survey.



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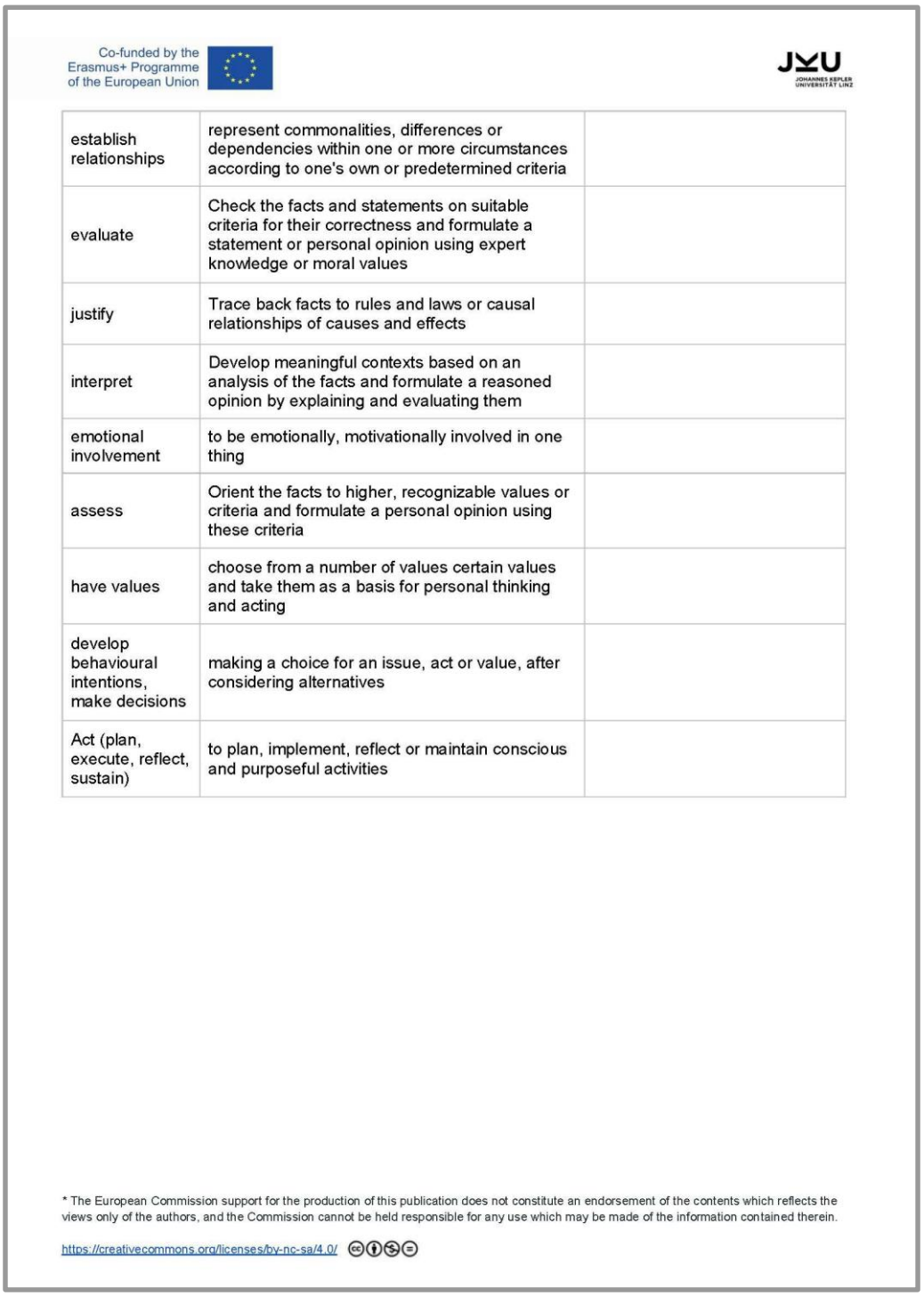
IO1 - Key competences

Models:

Entity-Relationship Model	ER	Activity Diagram	AD
Class Diagram	CD	Flow-Chart Diagram	FC
Use-Case Diagram	UC		

Operators/ keywords	Description	Model(s)
name/ mention/ enumerate	Enumerate the facts without explanation, list, reproduce knowledge and learned information, read information from enclosed material	
arrange/ to allocate	Clarify simple relationships, contextualize facts, events	
describe	Systematic and logic reproduction of facts from knowledge or enclosed material	
illustrate	Represent an issue or context graphically or with words	
compare	Identify similarities and differences between issues based on self-determined or predetermined criteria	
explain	Place information, that is established by own knowledge and insights, in a certain context (e.g. theory, model, law, rule, functional context)	
gather information	Collect and use information from different sources	
communicate	Discuss issues, pass on and receive information	
present	Present facts with the help of different media	
analyse	Decompose facts and capture essential features on the basis of different criteria and relate them to one another	
categorize	Classify facts according to selfcreated or predetermined criteria	
reason	make judgments about correctness, appropriateness or applicability on the basis of independently obtained findings	
make assumptions	formulate reasonable statements based on observations, investigations, experiments or facts	

Figure 30: Expert Survey - Page 1



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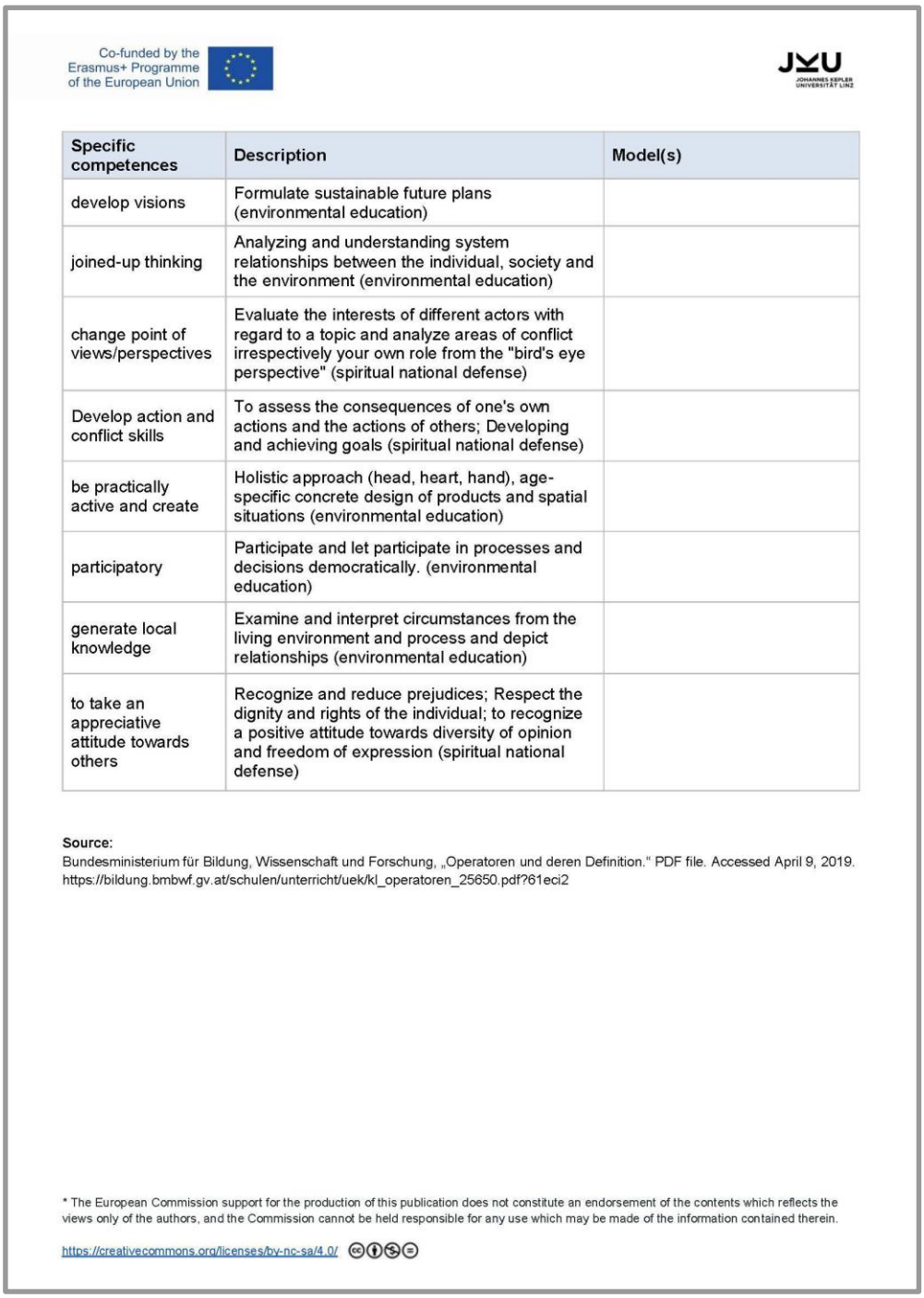
establish relationships	represent commonalities, differences or dependencies within one or more circumstances according to one's own or predetermined criteria	
evaluate	Check the facts and statements on suitable criteria for their correctness and formulate a statement or personal opinion using expert knowledge or moral values	
justify	Trace back facts to rules and laws or causal relationships of causes and effects	
interpret	Develop meaningful contexts based on an analysis of the facts and formulate a reasoned opinion by explaining and evaluating them	
emotional involvement	to be emotionally, motivationally involved in one thing	
assess	Orient the facts to higher, recognizable values or criteria and formulate a personal opinion using these criteria	
have values	choose from a number of values certain values and take them as a basis for personal thinking and acting	
develop behavioural intentions, make decisions	making a choice for an issue, act or value, after considering alternatives	
Act (plan, execute, reflect, sustain)	to plan, implement, reflect or maintain conscious and purposeful activities	

Figure 31: Expert Survey - Page 2



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Specific competences	Description	Model(s)
develop visions	Formulate sustainable future plans (environmental education)	
joined-up thinking	Analyzing and understanding system relationships between the individual, society and the environment (environmental education)	
change point of views/perspectives	Evaluate the interests of different actors with regard to a topic and analyze areas of conflict irrespectively your own role from the "bird's eye perspective" (spiritual national defense)	
Develop action and conflict skills	To assess the consequences of one's own actions and the actions of others; Developing and achieving goals (spiritual national defense)	
be practically active and create	Holistic approach (head, heart, hand), age-specific concrete design of products and spatial situations (environmental education)	
participatory	Participate and let participate in processes and decisions democratically. (environmental education)	
generate local knowledge	Examine and interpret circumstances from the living environment and process and depict relationships (environmental education)	
to take an appreciative attitude towards others	Recognize and reduce prejudices; Respect the dignity and rights of the individual; to recognize a positive attitude towards diversity of opinion and freedom of expression (spiritual national defense)	

Source:
Bundesministerium für Bildung, Wissenschaft und Forschung, „Operatoren und deren Definition." PDF file. Accessed April 9, 2019. https://bildung.bmbwf.gv.at/schulen/unterricht/uek/kl_operatoren_25650.pdf?61eci2

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Figure 32: Expert Survey - Page 3

The results of this approach were rather disillusioning. For the reason that the single operators and its descriptions are quite vague, even for experts, the assignment of the diagrams was not perfectly viable. However, this process was very important and useful for the final outcome. As we already stated earlier, the benefit for the teacher is of utmost importance and so we continued to search for a more appropriate solution.

3.6 Summary & Final Outcome

To summarize the whole process of the descriptive curricula analysis, a table, with a ranking of the four most common keywords in every curriculum is provided below.

Table 15: Ranking - Keyword Analysis

	1	2	3	4
ESP Primary School	characteristics	knowledge	process	relationship
ESP Secondary School	process	relationship	logic	properties
FIN Primary School	structure	process	visualize	text comprehension
FIN Secondary School	structure	process	visualize	model, modeling
AUT Primary School	represent	relationship	procedure	decompose/representation
AUT New Secondary School	relationship	represent	representation	model
AUT AHS Secondary School	analyse	represent	relationship	process
AUT HAK Vocational School	analyse	represent	model	present
AUT HTL Vocational School	analyse	model	represent	presentation

As it can be seen in the table above, some keywords appear repeatedly across the borders. One term, that occurs in at least one of the curricula of all three countries is “process”. The keyword “relationship” occurs several times in Spain and Austria. In the Austrian curricula, the terms “analyse” and “represent(ation) /present(ation)” are the most crucial ones. In Finland, “structure”, “process”, and “visualize” share the same ranking in primary and secondary school and also in Spain, “process” (as well as “relationship”) occurs in both of the curricula. Interestingly, also the terms “model/modeling” are positioned under the top 4 twice. To summarize, we are positively surprised, that the keywords related to modeling, computational thinking and computer science in general, are already strongly established in all the curricula. Furthermore, the result shows, that modeling is the ideal instrument to put these terms into practice.

During the process of the key competence analysis, we focused on competences on national level, as well as on European level. Interestingly, two out of three partner countries’ education systems do already follow a competence orientated approach. The Finnish National Core Curriculum for basic education, for instance, focuses on the so-called traversal competences as part of every subject. Similarly, the Spanish curriculum is also organized by competences. At the time of research, the Austrian Ministry of Education has still not published reports on official interdisciplinary key competences, anyway the lessons in Austrians schools are competence-oriented. However, the Ministry proposes a so-called “map of competences” and a “list of operators” as a guideline for teachers. On European level, the *Council Recommendation on Key Competences*

for Lifelong Learning (2018) proposes 8 key competences. In the following table, a comparison of the official key competences of Spain, Finland, and the European Union is presented.

Table 16: Comparison Key Competences

Council Recommendation on Key Competences for Lifelong Learning (2018)	**Finnish Curriculum**	**Spanish Curriculum**
Literacy competence	Multiliteracy	Competence in linguistic communication
Multilingual competence		
Mathematical competence and competence in science, technology and engineering		Competence in mathematics, science and technology
Digital competence	ICT competence	Digital competence
Personal, social and learning to learn competence	thinking and learning to learn	Learning to learn
	taking care of oneself and managing daily life	
Citizenship competence	participation, involvement and building a sustainable future	Social and civic competences
Entrepreneurship competence	working life competence and entrepreneurship	Sense of initiative and entrepreneurship
Cultural awareness and expression competence	cultural competence, interaction and self-expression	Cultural awareness and expression

The table above shows, that the competences of the Spanish and Finnish curricula are almost identical with the version provided by the European Union. This implies, that the two countries took note of the recommendation on European level and adapted it respectively.

As already mentioned earlier in the report, the result of Intellectual Output 1 should be a table that lists the key competencies and topics in different curricula and appropriate diagram types that may help to train them. During the second project meeting in Finland, all the members of the consortium intensively discussed in small focus groups their results and tried to find a perfect solution. The focal point of the final table should lie on the practicability. In other words, this table should serve as an overview helping teachers to quickly decide which diagram serves best for a specific purpose and also provide the foundation for the development of teaching material, workshops, as well as the online tool. Similar to the results of the Austrian expert survey, it was soon clear that building on the interdisciplinary competencies, provided by the European Council is not the ideal solution, because also in this case, depending on the specific task or interest, all the diagrams could be used.

Therefore, another approach had to be found. Fortunately, intensive discussions led to a final result and in agreement with the consortium the following table has been developed:

Table 17: Diagram Overview

Structures & Categories	Rules & Procedures	Situations & States
+ class diagrams + object diagrams + graphs	+ activity diagrams + flow charts + graphs	+ use case diagrams + entity relationship diagrams + state diagrams

Thinking of different subjects, we came to the conclusion, that these are the three crucial categories, that are interdisciplinary relevant. This diagram should serve as an overview, which helps the teacher to quickly decide which diagram serves best for a specific purpose:

- Structure & Categories
    - e.g. elaborating vocabulary, representing hierarchies, demonstrate relations,...
- Rules & Procedures
    - e.g. grammar rules, mathematical rules, experiments in chemistry or physics,...
- Situations & States
    - e.g. text work, dialogues,...

To conclude, most of the tasks or activities of a certain lesson can be assigned to one of the three categories. In our point of view, these three pillars are the perfect foundation of intellectual output 2, as well as the other outputs that follow.

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5 List of Tables

Table 1: School Types of Partner Schools 4
Table 2: List of Keywords 5
Table 3: Subjects taught in Finnish basic education schools 22
Table 4: Keywords related to computational and algorithmic thinking in English and Finnish 23
Table 5: Description of stages in Spanish Educational System 29
Table 6: Subjects taught in Primary Education 31
Table 7: Subjects taught in Secondary Education 31
Table 8: List of keywords used for frequency analysis 32
Table 9: Frequency analysis of keywords for primary subjects 35
Table 10: Frequency analysis of keywords for secondary subjects 39
Table 11: Key competences in Spanish curriculum by considering European Reference Framework 49
Table 12: Relationships between key competences and subjects for Primary Education 50
Table 13: Relationships between key competences and subjects for Secondary Education 50
Table 14: Comptetences of the European Key Competences Framework and the FNC Curriculum (2014) 54
Table 15: Ranking - Keyword Analysis 59
Table 16: Comparison Key Competences 60
Table 17: Diagram Overview 61

6 List of Figures

Figure 1: Austrian Education System 3
Figure 2: Total Keywords per School 7
Figure 3: Comparison - Frequency of Keywords 8
Figure 4: Frequency of Keywords - Pre- & Primary School 9
Figure 5: Pre- & Primary School - Keywords according to Subjects 10
Figure 6: Frequency of Keywords – New Secondary School 11
Figure 7: New Secondary School - Keywords according to Subjects 12
Figure 8: Secondary School LG and UG - Frequency of Keywords 13
Figure 9: Secondary School LG & UG - Keywords according to Subjects 14
Figure 10: Vocational Business School - Frequency of Keywords 15
Figure 11: Vocational Business School - Frequency according to Subjects 16
Figure 12: Vocational IT School - Frequency of Keywords 17
Figure 13: Vocational IT School - Keywords according to Subjects 18

Figure 14: Finnish Education System 21
Figure 15: Keyword counts from Primary School curriculum 25
Figure 16: Keyword counts by subjects in Primary School 26
Figure 17: Keyword counts from Secondary School curriculum 27
Figure 18: Keyword counts by subjects in Secondary School 28
Figure 19: Spanish educational system 30
Figure 20: Frequency analysis of keywords in primary school curriculum 38
Figure 21: Frequency analysis of keywords. Summary by subjects for primary schools 39
Figure 22: Frequency analysis of keywords in secondary schools 42
Figure 23: Frequency analysis of keywords according to secondary subjects 43
Figure 24: European Framework of Key Competences 45
Figure 25: Set of CT-related terms to capture major trends in the field 48
Figure 26: Learning and assessment in the Finnish curriculum 51
Figure 27: Multidisciplinary Learning Modules 52
Figure 28: Transversal competences and subjects in the Finnish curriculum 53
Figure 29: Assessment in the Finnish curriculum 54
Figure 30: Expert Survey - Page 1 56
Figure 31: Expert Survey - Page 2 57
Figure 32: Expert Survey - Page 3 58