Research Article

Jens Nothacker*, Zsolt Lavicza

Digital Didactic Objectives of Primary, Secondary, and Higher Education Curricula in the 21st Century Executable with a Single-board Computer

https://doi.org/10.1515/edu-2020-0135
received July 2, 2020; accepted December 17, 2020.

Abstract: This paper deals with the didactic objectives and content from the latest curricula of the different types of schools (schools, colleges, universities) in the D-A-CH regions. The aim of this paper is to provide an overview of the didactic goals of current and future curricula for primary, secondary, and high school, which are feasible with a single-board computer. For this purpose, the curricula are analysed according to digital terms and methods of information technology with a qualitative deductive meta-analysis and assigned to different categories. The results are presented in different diagrams for evaluation, from which the results can be interpreted. The results include a list of digital didactic goals, structured according to school type, competencies, and feasibility, which can be implemented with a single-board computer. All in all, it was found that an inexpensive single-board computer is quite sufficient for the acquisition and implementation of the digital goals and skills to be taught in the curricula. Furthermore, the paper concludes with a recommendation for further studies.

Keywords: 21st century skills; computational thinking; digital literacy; MINT/STEM Didactic; Education Tools.

1 Introduction

The increasing digitalisation of our world of life and work requires new competences and new qualification profiles of university graduates in order to enable them to participate actively in society (citizenship) and in the world of work employability (Stifterverband für die Deutsche Wirtschaft e.V., 2017). This also includes knowing how new ways of working or agile approaches can proactively promote change. “We need to teach people what they really need: critical thinking, basic technological skills, data analysis, learning to learn, working independently and entrepreneurial skills” (Daheim & Wintermann, 2018, p. 17). The largest part, 41 percent, is made up of those who keep up with the digital world, that is people, who occasionally move around the digital world and find their way around it to some extent. Hardly anyone masters programming languages or the design of web applications in the “age of digitalisation” and this also applies to the younger ones (Kantar TNS, 2018, p. 48). This raises the question of where this educational deficit in our society comes from and whether these skills are not adequately taught in our pre-university curricula, even though, at least in Germany, a corresponding curriculum reform has not taken place since 2015. Furthermore, the question arises to what extent the digital goals of the future are reflected in the pre-university curricula and what technical equipment is used to achieve this. What skills can be learned with an inexpensive single-board computer (SBC)? According to the curricula, what tools are available to learn these skills? Which programming languages are taught? In this context, it is also interesting to know whether the deficits mentioned above also apply to the neighbouring German-speaking countries: Austria and Switzerland.

*Corresponding author: Jens Nothacker, Johannes-Kepler-University Linz, School of Education, Austria, E-mail: jnothack@gmail.com
Zsolt Lavicza, Johannes-Kepler-University Linz, School of Education, Austria

Open Access. © 2020 Jens Nothacker, Zsolt Lavicza, published by De Gruyter. This work is licensed under the Creative Commons Attribution 4.0 Public License.
2 The Research

In order to answer the questions raised in the introduction, this study analyses the current computer science curricula of primary, secondary, high-school from the German-speaking countries, Germany, Austria, and Switzerland according to digital targets. For coding the documents and creating the graphs the Software MAXQDA 2020 Analytics Pro and Microsoft Excel was used. The citations were stored and referenced with the citations-software Citavi.

2.1 Data / Document collection

The curricula were gathered from the corresponding online platforms of the various ministries of the respective countries. The university curricula for bachelor’s degrees were picked at random and only one or two per region for comparison. A total of 378 documents were collected for analysis. All documents found were stored in the searchable portable document format (pdf) or were saved in this format. The collected documents were imported into the MAXQDA software and stored in the citation-software Citavi for further use.

2.1.1 Germany

In Germany, the education servers of the 16 different federal states provide the current curricula. All documents that could be relevant for the Mathematics, Informatics, Natural science, and Technic (MINT) department were considered.

The German school system is divided into primary, lower secondary, upper secondary and tertiary levels (Figure 1).

For Germany, 326 documents were collected. Nine documents were found for Brandenburg (BB) (Bildungsserver Berlin Brandenburg), 16 documents for Berlin (BE) (Senatsverwaltung für Bildung, Jugend und Familie), 35 documents for Baden-Württemberg (BW) (Bildungsplan NaN – Bildungspläne 2016, 2016), 8 documents for Bayern (BY) (LehrplanPLUS 2020), 24 for Bremen (HB) (Landesinstitut für Schule Bremen 10.06.2020), 93 for Hessen (HE) (Hessisches Kultusministerium 2017), 14 for Hamburg (HH) (Bildungspläne Hamburg 10.06.2020, 2020), 11 for Mecklenburg-Vorpommern (MV) (Fächer und Rahmenpläne 2020), 6 for Niedersachsen (NI) (Curriculare Vorgaben für allgemein bildende 10.06.2020), 23 for Nord-Rhein-Westfalen (NW) (NRW, 2020), 4 for Rheinland-Pfalz (RP) (Lehrpläne: Lehrpläne 10.06.2020), 5 for Schleswig-Holstein (SH) (IQSH Lehrplanportal 2019), 10 for Saarland (SL) (Saarland, 2019), 39 for Sachsen (SN) (Lehrplanverzeichnis 2020), 3 for Sachsen-Anhalt (ST) (Bildungsserver Sachsen-Anhalt 2020), 26 for Thüringen (TH) (Thüringer Lehrpläne 2019, 2019).

2.1.2 Austria

The curricula for Austria were collected from the online sources of the “Bundesministerium Bildung Wirtschaft und Forschung” (BMBWF) in Vienna (Lehrpläne Austria). In Austria, the curricula are the same for all regions. They differ only in the type of school. These are the primary school, the new secondary school (NMS), the grammar school (AHS), the vocational secondary and higher school (BMS, BHS) and the polytechnic schools (Poly/PTS), as well as the universities of applied sciences, the universities, and the colleges of pedagogy. In addition, there are the special schools and the vocational colleges (Figure 2).

A total of 17 documents were found that have something to do with MINT topics. Parallel to the German system, the areas of primary level, secondary level I, secondary level II and tertiary level were assigned to the
corresponding class levels of the Anglo-American system of primary, secondary, high school, and undergraduate degrees.

2.1.3 Switzerland

The “Deutschschweizer Erziehungsdirektoren-Konferenz” (D-EDK) has for the first time revised the first common curriculum for schools in the “Lehrplan21” project for all German-speaking cantons between 2010 and 2014. This concerns the cantons of Aargau (AG), Appenzell Ausserrhoden (AR), Appenzell Innerrhoden (AI), Basel-Landschaft (BL), Basel-Stadt (BS), Bern (BE), Freiburg (FR), Glarus (GL), Graubünden (GR), Luzern (LU), Nidwalden (NI), Obwalden (OW), Schaffhausen (SH), Schwyz (SZ), Solothurn (SO), St. Gallen (SG), Thurgau (TG), Uri (UR), Wallis (WS), Zug (ZG), Zürich (ZH) and Fürstentum Liechtenstein (FL).

The curricula of Switzerland were collected from the online sources of the Swiss Confederation (Willkommen beim Lehrplan 21). Twenty-six documents were found for these cantons. Some cantons have further developed their curricula in MINT subjects, for example BS and AG.
Parallel to the German and Austria system, the primary, lower secondary, upper secondary and tertiary areas can be assigned to the corresponding class levels (Figure 3).

2.2 Data / Document assignment

For a better presentation of the evaluations, the documents were categorized to document-sets by country, region, year, and school level using a qualitative deductive method in a descriptive design (Mayring, 2014, p. 12). For Germany and Switzerland, the secondary level II and for Austria the upper level were assigned to the term “High School” to correspond to the Anglo-American designations. The documents were categorized according to the years from “2009” to “2021”, the school levels according to the groups “Undergraduate”, “High”, “Secondary” and “Primary”, the countries according to the groups “Germany” (DE), “Austria” (AU) and “Switzerland” (CH). The documents of the individual countries were combined according to the region codes with the individual country codes with a hyphen and grouped accordingly (e.g.: DE-BY for Bavaria, Germany or CH-ZH for Zurich, Switzerland). For Switzerland, a category CH-ALL was introduced, which contains all learning plans that apply to the German-speaking regions. The more detailed procedure is described in the next figure (Figure 4).

2.3 Data / Document – Coding / Analysis

After the documents were assigned to the document categories, the documents were encrypted with a code structure. Mayring (2014, p. 26) describes this process as “reprocessing the material using the category system to record the occurrence of categories”. This is a recurring process in which previously selected sources reflect the content to be analysed. Thus, the document pool was narrowed down by keywords such as “Lehrplan”. The results obtained were then searched again using a keyword, e.g. “Informatik” or “Informatik*”. The codes were implemented in the German language and therefore the graphics are also in German. In the continuous text the translations are provided in brackets.
In this way, after a few rounds, only those documents that are relevant for further research were obtained. The more detailed coding procedure is described in Figure 6. After this process, n=194 documents remained to be used in this study as shown in Figure 7.

The data from Figure 7 were graphically presented in Figure 8 for better illustration. Figure 8 shows the distribution of the documents obtained with the document filter from Figure 5 with the document selection procedure of the document filter algorithm described in Figure 6 with the number of documents per region, which was described in advance in Figure 4.

The 194 documents were saved in a new content analysis project for further coding. Then the document filter was set up for different codes, which are shown in Figure 9. In order to develop the codes, the digital competence grid of the “Kultusministerkonferenz” (KMK) (KMK, 2016; KMK, 2017) was combined with the digital competences defined by the “Gesellschaft für Informatik” (GI) (Gesellschaft für Informatik e.V., 2016). The documents were examined according to process-related and content-related competencies. In addition, the documents were analysed specifically according to computer-related competences “Computational Thinking”, keywords from the field of Information Technology (IT) “Professional skills”, divided into “Modern Skills” and “Classic Skills”, and the older learning content “The Pupils ...”. “The pupils ...” competencies were restricted to programmatic skills. The “Classic skills” are those that have been taught in the upper school for several years and include hardware-knowledge as well as methodological content such as cryptology, PAP’s, or other program visualization models. Furthermore, contents about operating systems, networks and databases are examined. The “Modern Skills” are technical terms developed over the past two decades, which were taken from university curricula and professional journals. In order to be able to assign the documents to the individual school types, these were categorized according to the different school types, which were assigned to the different school levels according to the document sets shown in Figure 4 and Figure 9.

3 Findings

3.1 Document Frequency

The following chart (Figure 10) shows the document frequencies by year and region. From this chart, you can see the frequency of document changes over the years.

Accordingly, the first changes in the IT sector took place in 2009 in DE-SL and DE-HH and DE-HB, followed in 2010 by DE-HB, DE-BW. Austria followed in 2012 and Switzerland in 2013/14 in the cantons of Aargau and Basel. In fact, the biggest change will occur in DE-BW in 2016, which coincides with the transfer of learning content into competence areas and the integration of GI competences.
### Digital didactic objectives of primary, secondary, and higher education curricula in the 21st century...

|                 | Documents | Bildungsplan Lehrplan | Informations* | Informatik* | Informatiksysteme | Wahlpflichtfach Informatik | Informations- und Kommunikations-technologien | SUMME |
|-----------------|-----------|-----------------------|---------------|-------------|-------------------|---------------------------|-----------------------------------------------|-------|
| CH-AG           | 5         | 5                     | 5             | 2           | 1                 | 3                         | 11                                            | 21    |
| CH-ALL          | 2         | 2                     | 2             | 2           | 1                 | 0                         | 1                                             | 8     |
| CH-AR           | 1         | 1                     | 1             | 1           | 0                 | 1                         | 1                                             | 5     |
| CH-BE           | 4         | 4                     | 4             | 8           | 0                 | 1                         | 2                                             | 13    |
| CH-BS           | 1         | 1                     | 0             | 1           | 0                 | 0                         | 0                                             | 2     |
| CH-LU           | 1         | 1                     | 0             | 0           | 0                 | 0                         | 1                                             | 4     |
| CH-ZU           | 1         | 0                     | 1             | 0           | 0                 | 0                         | 0                                             | 2     |
| DE-BB           | 5         | 3                     | 3             | 1           | 1                 | 0                         | 0                                             | 8     |
| DE-BG           | 10        | 6                     | 8             | 5           | 3                 | 1                         | 0                                             | 23    |
| DE-BW           | 17        | 17                    | 14            | 13          | 8                 | 0                         | 2                                             | 54    |
| DE-BY           | 5         | 5                     | 2             | 4           | 0                 | 0                         | 0                                             | 11    |
| DE-HB           | 15        | 12                    | 12            | 6           | 1                 | 1                         | 1                                             | 55    |
| DE-HE           | 28        | 13                    | 15            | 25          | 9                 | 0                         | 8                                             | 68    |
| DE-HH           | 3         | 3                     | 0             | 3           | 3                 | 3                         | 2                                             | 11    |
| DE-MV           | 7         | 4                     | 7             | 7           | 6                 | 0                         | 1                                             | 25    |
| DE-MI           | 5         | 2                     | 4             | 5           | 4                 | 0                         | 1                                             | 16    |
| DE-MV           | 13        | 13                    | 10            | 10          | 5                 | 2                         | 5                                             | 41    |
| DE-BP           | 3         | 3                     | 3             | 3           | 2                 | 2                         | 2                                             | 14    |
| DE-SH           | 3         | 3                     | 3             | 3           | 2                 | 0                         | 1                                             | 12    |
| DE-SL           | 8         | 8                     | 2             | 5           | 0                 | 0                         | 0                                             | 25    |
| DE-SN           | 31        | 26                    | 28            | 24          | 11                | 0                         | 8                                             | 97    |
| DE-ST           | 2         | 2                     | 1             | 0           | 0                 | 0                         | 0                                             | 3     |
| DE-TN           | 21        | 21                    | 8             | 3           | 2                 | 0                         | 0                                             | 43    |
| SUMME           | 104       | 149                   | 136           | 137         | 61                | 9                         | 36                                            |       |

**Figure 7:** Documents frequency – Regions, Author.

**Figure 8:** Document Distribution – Regions, Author.
Figure 9: Content-Based-Codes used in MAXQDA for analysis, Author.

Figure 10: Document Frequency – Regions chart, Author.
into the existing curricula (Gesellschaft für Informatik e. V., 2016). Austria recently updated its curricula in 2019 and the other German countries also adapted to the situation in the same year. The changes in the curricula are basically based on the introduction of modular competence areas and the inclusion of digital competences (KMK, 2016; KMK, 2017). Digital competences are examined in more detail below.

3.2 Content related skills

The digital competences identified by GI in 2016 (Gesellschaft für Informatik e. V., 2016) and KMK in 2016/17 (KMK, 2016; KMK, 2017) were divided into content-related and process-related skills. The content-related skills were divided into 4 main competences “Data and Coding” (“Daten u. Codierung”), “Algorithms” (“Algorithmen”), “Computers and Networks” (“Rechner u. Netze”), “Information Society and Data Security” (“Informationsgesellschaft u. Datensicherheit”). The visual representation of the data in Figure 11 shows that the generic terms “data and coding” (“Daten u. Codierung”) and “algorithms” (“Algorithmen”) are the most frequently taught skills.

In all regions the content of the curricula is based on algorithms. In DE-HE, DE-SN, DE-BW and DE-BW the emphasis is on “algorithms” (“Algorithmen”), in DE-BW the code “data and coding” (“Daten u. Codierung”) is the same. Computers and networks (“Rechner u. Netze”) and “Information society and data security” (“Informationsgesellschaft u. Datensicherheit”) are also a topic in DE-BW. In the other regions, the topic of “Information Society and Data Security” (“Informationsgesellschaft u. Datensicherheit”) is not an issue.

3.3 Process related skills

The content-related skills were divided into four main competences “Structuring and Networking”, “Modelling and Implementing”, “Communicating and Cooperating”, “Analysing and Evaluating”. The visual representation of the data in Figure 12 shows that the generic terms “modelling and implementing” and “structuring and networking” are the most frequently taught skills. According to this data, DE-BE is the leader in process-related skills, followed by DE-HE, DE-MV, with “modelling and implementation” taking the top position, as already mentioned. In DE-HH, however, the focus is on “analyse and evaluate”. In Switzerland, the focus is on the pioneer region CH-BE. In AU and CH-BE, however, the focus is equally on “modelling and implementing” and “analysing and evaluating”. However, not all countries have yet switched over to the new way of writing competences. For this reason, the documents were also examined for the old content descriptive notation “Die Schülerinnen und Schüler ...” (“The pupils ...”).
3.4 The pupils...

As a consequence of the change in the competence notation already mentioned in the previous section, this section will deal with the older content descriptive notation again. Because of the extremely high number of hits, the search expressions were reduced to special computer science search terms, that are only relevant for this study. These terms are, for example “Die Schülerinnen und Schüler nutzen” (“The pupils are using”), “Die Schülerinnen und Schüler analysieren” (“The pupils are analysing”), “Die Schülerinnen und Schüler implementieren” (“The pupils are implementing”) und “Die Schülerinnen und Schüler programmieren” (“The pupils are programming”). The results were graphically processed in figure 13 for better interpretation. As can be seen from figures 12 and 13, some countries use both the old and the new notation, especially in the regions DE-BW, DE-MV, DE-NW and DE-SN. There is no significant difference in the other German regions. In the Swiss regions, the old notation is still preferred according to the data, but in the canton of Basel this is currently being changed with the introduction of new curricula due to the visible differences in figures 12 and 13. An analysis of word frequencies has shown that the term “Computational Thinking” is also used in the newer curricula. The results according to this term are discussed in more detail in the following section “Computational Thinking”.

3.5 Computational Thinking

Al Aho from Columbia University, Jan Cuny from the National Science Foundation and Lary Snyder from the University of Washington define the term “Computational Thinking” as follows: “Computational thinking is the thought processes involved in formulating a problem and expressing its solution(s) in such a way that a computer—human or machine—can effectively carry out.” (Wing, 2017, p. 8)

Yadav uses “Computational Thinking” defined as “understanding how computers work”, “involves thinking logically to solve problems”, “involves using computers to solve problems”, “involves abstracting general principles and applying them to other situations” (Yadav et al., 2014). Wing classified computational thinking into five main competences. Computational thinking “requires thinking at multiple levels of abstraction”, which refers to the competence of “Abstraction”. Computational thinking “is a way human-beings solve problems”, which corresponds to the competence of “Problem Solving”. Wing also states that “Computational thinking” is a “fundamental, not rote skill”. That relates to the competence of “Creativity, Innovation, Individuality and Flexibility”. “The constraints of the underlying computing device force computer scientists to think computationally, not just mathematically”, corresponds to “Algorithmizing by Pattern Recognition”. “Computational thinking for everyone, everywhere”, relates to “Integration by
reflection and evaluation” (Wing, 2006). Figure 14 shows how Computational Thinking was adapted to the curricula.

According to Austrian curricula, the term “computational thinking” includes “working with algorithms” and “the creative use of programming languages”, which can be related to the categories of “Problem Solving” (“Problemlosung”), “Algorithmizing” (“Algorithmisierung”) and “Reflection and Evaluation” (“Reflexion und Bewertung”). In Germany, the term “Computational Thinking” is associated with the definition of content- and process-related competencies. The two terms have already been described in the sections “Content Related Skills” (Figure 11) and “Process Related Skills” (Figure 12) above. The Swiss cantons do not use the term Computational Thinking at all, but the terms “Problem solving” and “Abstraction” appear in the curricula of Switzerland. The following section deals with the question of what skills are taught in higher education.

### 3.6 Professional Skills

Further education, such as a degree in computer science, nowadays requires prior mastery of digital skills. In contrast to Computational Thinking, curricula are specifically examined for computer science content to identify overlaps. The terms were taken from the bachelor courses of study at randomly selected universities, but at least one university per region was selected from the D-A-CH regions. For better visualisation, the results were split to the categories “Classic Skills” and “Modern Skills”. The “Classic Skills” are the skills that have been taught for several years and are shown in Figure 15. “Modern Skills” are those skills previously taken from university curricula, as described above, which are not part of the “Classic Skills” and are shown in Figure 16.

In Figure 15, most of the “Classic Skills” that are studied in depth at universities are already mastered at lower secondary level in the individual countries. The focus in all countries is on the topic of software, which also reflects the topic of algorithms and software development.
**Figure 14:** Computational Thinking by School Levels and Countries, Author.

**Figure 15:** Classic Skills by School Levels and Countries, Author.
In Austria, the subject of “Hardware” is introduced at the Polytechnic School and in Austria at the lower secondary school level, i.e. at the secondary level according to the Anglo-American division of school levels. The topics of “operating systems”, “networks”, “databases”, “programming” are covered at all school levels and all countries. In Figure 16, the “Modern Skills” are examined. The skills are also from the bachelor courses of study at randomly selected universities, but at least one university per region was selected from the D-A-CH regions. Figure 16 shows that 3D-Printing (“3D-Druck”) has entered secondary education in Austria and Germany. The topics of “robotics” (“Robotik”) and “Artificial intelligence” (“Künstliche Intelligenz” ) are represented at all school levels and in all countries. However, the subject of “Deep Learning” and “Simulation” is only dealt with in secondary schools in Germany. “Sensor technology” (“Sensorik”) and “actuator technology” (“Aktorik”) belong to the topic of “robotics”, whereby “sensor technology” is only mentioned in Switzerland and Germany and “actuator technology” only in Germany.

However, all three subjects are introduced at the primary level. In Germany, the topics “Industry 4.0” (“Industrie 4.0”) and “Big Data” are also dealt with from the primary level onwards, and even “Deep Learning” and “Simulation” are handled at the secondary level. The term “data mining” can be found in secondary and high schools. Nevertheless, the topics of “Machine Learning”, “High Performance Computing”, “Blockchain” and “Data Mining” are currently reserved for students of computer science courses.

**What are the digital goals in the curricula from primary school to high school in the 21st century that can be achieved with a single-board computer in the D-A-CH Regions?**

To answer this question, the feasibility of the different skills that can be realized with a single board computer must be checked. From the above sections we can infer that there are different meanings of competences and terminology used to describe them also varies. In this way, the individual competencies were arranged into different groups, which were collectively referred to before and combined with the skills of the future.

**Competencies taught with a single-board computer**

Single-board computers (SBCs) can run standard operation systems and mainstream workloads. An SBC has been described as “a complete computer built on a single circuit board, with microprocessor(s), memory, Input/Output (I/O) and other features required of a functional computer” (Johnston, et al., 2018, p. 202). SBCs are among the cheapest computers, around $100 or less depending on the model, and are therefore predestined for use in education. Not only the low price, but also the compact size similar to that of a credit card speaks for the use in this area instead of having expensive PCs, laptops, or tablets in schools. Another advantage is that
it can also be used to control other components, such as
motors or cameras in robots or automation treadmills,
cranes, or other automatic machines. They impress
with their wide range of possible applications and this
makes them particularly interesting in the educational
sector across all school levels and countries to promote
creativity, innovation, individuality, and flexibility.
Figure 17 below summarises the competences that can be
covered by an SBC. The extract is not to be understood
as exhaustive.

Figure 17 also shows which programming languages
are preferably used at which school levels and countries.
Almost at all school levels and countries, these are:
Scratch, Java, Python, C / C++ and Basic. The visual
programming languages Lego and NEPO are currently
only used in Germany at the primary and secondary level.

4 Conclusion and Outlook

The aim of this study was to get an overview of the
didactic goals of current and future curricula for primary,
secondary, and high school level, which are feasible with
an SBC and answer the questions raised by the author.
To answer these questions in section 2 “The Research”
the research procedure was described. In section “Data/
Document Collection”’, the individual school systems
of the D-A-CH countries were presented again in order to
maintain the allocation to the levels of primary, secondary
and grammar school in accordance with international
language usage and to be able to trace the categorisation
or allocation of the documents to the individual regions
of the countries. In section “Data / Document – Coding /
Analysis” the qualitative deductive text coding according
to Mayring (2014) was described and how the coding of the documents was done and which filter algorithm was used to filter out the finally relevant documents. In section 3, the findings were presented, where the findings were visualized in graphs and discussed. After looking at the development of the documents by years and subdivided by regions, first the content, then the operational and professional skills were examined, which resulted from word analyses of the curricula. In this way, the various skills, structured by country and school level, could be presented, and discussed in figures. The results allowed the following initial questions to be clarified: What digital knowledge and common didactic goals can be taught with digital devices according to current and future curricula? What skills can be learned with an inexpensive single-board computer? According to the curricula, what tools are available to learn these skills? Which programming languages are taught?

In Figure 17, the answer to the question is given in the form of a graph. The breakdown is more detailed and corresponds to the contents of the skills discussed in section 3: “Content-related skills”, “Process-related skills”, “The Pupils ...” restricted to programmatic processes, “Computational Thinking” and the “Professional Skills”, which were divided into the “Classic Skills” and the “Modern Skills”. It was also possible to analyse the programming languages used in the different countries and at different school levels. However, this analysis does not claim to be complete, as the different programming languages are only compulsory in the undergraduate university curricula, but the most important ones were discussed in this study.

All in all, it can be said that a low-cost single-board computer is quite sufficient for the acquisition and implementation of the above-mentioned digital goals and capabilities. Of course, there are differences in performance, which limits the application, but with such a device, there are no limits to students’ creativity. And students could also dedicate the “computational thinking” skills mentioned by Wing to generating ideas and self-realisation, which in turns encourages individuality and flexibility (Wing, 2006).

In addition, it was also possible to clarify things that were not the subject of the questions asked at the beginning and that came to light incidentally through the analysis. From Figure 10, it can be shown that the introduction of curriculum changes in Germany is a gradual process. The pioneers of digitalisation in Germany are DE-BW, DE-SN and DE-TH, other states adopted them later, e.g. DE-BB and DE-SH. In Austria, information technology content was included in the 2009 curricula and adapted for 2018/2019. Switzerland started to follow in the cantons CH-BS in 2014 and 2019.

For the future there are still some things to be investigated, which could not be clarified in this article. This concerns, for example, the following open questions: Which equipment is used at the different school levels, and which single-board computer is the best for widespread use in the educational sector? Which single-board computers exists on the market and meet the requirements of the educational sector in the future across all school levels?

Notes

The original source documents are all written in German. Therefore, the key words were not translated but left in the original wording so that the study remains reproducible. The key words have been explained and translated in the text. Please translate them into your own language if necessary. For German Image citations Figure 1, Figure 2 and Figure 3, the terms used in the graphs have been translated into English below for a better understanding:

1. Additional Information to Figure 1 “The German Education System”
   Mindestalter – Minimum Age;
   Bildungsjahr – Eduactional Year;
   Vorschulische Einrichtungen – Pre-School facilities, Kindergarten;
   Primärbereich – Primary Level; Grundschule – Primary School;
   Sekundarbereich I – Secondary Level I;
   Gesamtschule – Comprehensive School;
   Orientierungsstufe – Orientation Level;
   Gymnasium – Grammar School;
   Realschule – Secondary School;
   Hauptschule – Main School;
   Schule mit mehreren Bildungsgängen – School with several courses;
   Sonderschulen – Special Schools;
   Sekundarbereich II – Secondary Level II;
   Gymnasiale Oberstufe – Upper secondary School;
   Berufliche Vollzeitschulen – Full-time vocational Schools;
   Berufliche Teilzeitschulen – Part-time vocational Schools;
Duales System – Dual System; Lehre – apprenticeship; Tertiärer Bereich – Tertiary Level; Wissenschaftliche Hochschulen – Scientific Universities; Fachhochschulen – Universities of Applied Sciences; Weiterbildung – Further education.

2. Additional Information to Figure 2 “The Austrian School System”
Alter – Age; ISCED – International Standard Classification of Education; Kindergarten – Pre-School facilities (ISCED0); Volksschule – Primary School (ISCED1); Allgemeinbildende höhere Schule Unterstufe – Lower secondary school; Neue Mittelschule – New Secondary School; Hauptschule – Main School (ISCED2); Sonderschule – Special School (ISCED1 – 2); Allgemeinbildende höhere Schule Oberstufe – General secondary school (ISCED 3G); Berufsbildende höhere Schule – Vocational Secondary School (ISCED 3V/5V); Berufsbildende mittlere Schule bis 4 Jahre – Vocational Secondary School up to 4 years (ISCED 3V); Ausbildungen des Gesundheitswesens – Health care training courses up to 3 years (ISCED 3V/4V); Berufsschule (Lehre) bis 4 Jahre – Vocational school Apprenticeship up to 4 years (ISCED 3V); Polytechnische Schule – Polytechnic school (ISCED 3G); Reife- (und Diplom) Prüfung (Matura) – high-school leaving exam; Studienberechtigungsprüfung, Berufsreifeprüfung – University Entrance Qualification Examination; Werkmeister-, Meister- und Bauhandwerksschulen (2 Jahre) – Master craftsmen’s and building trade schools (2 years) (ISCED 5V); Kolleg 4 Semester – College 4 Semesters (ISCED 5V); Lehrgänge an tertiären Bildungs-einrichtungen – Courses at tertiary educational institutions (ISCED 5V); Bachelorstudium (6-8 Sem.) – Bachelor’s degree programme (ISCED 6); Diplomstudium (8-12) – Diploma course (ISCED 7); Masterstudium (2-4 Sem.) – Master’s degree programme (ISCED 7); Doktoratsstudium (min. 6 Semester) – Doctoral studies (min. 6 semesters) (ISCED 8); Universitäten – Universities; Fachhochschulen – University of Applied Science; Pädagogische Hochschulen – Universities of education.

3. Additional Information to Figure 3 “The Swiss Education System”
Üblicher Weg – usual route; Möglicher Weg – viable route; Obligatorische Schule – compulsory school; Brückenangebote – Bridging offers; Weiterbildung – Further Education; Sekundarstufe II – Secondary Level; Berufliche Grundbildung – basic professional training; Betriebe, Berufsfachschulen, Überbetriebliche Kurse – Companies, vocational schools, inter-company courses; Eidgenössisches Berufsattest – Swiss Federal Vocational Certificate; Eidgenössisches Fähigkeitszeugnis – Federal certificate of proficiency; Berufsmaturität – Vocational baccalaureate; Allgemeinbildende Schulen – General education schools; Fachmittelschulen – Secondary technical colleges, Secondary vocational schools; FMS Ausweis – FMS ID card; Fachmaturität – Specialised baccalaureate; Gymnasien – Grammar Schools; Gymnasiale Maturität – Grammar school baccalaureate; Tertiärstufe – Tertiary level; Berufs- und höhere Fachprüfungen – Professional and higher professional examinations; Höhere Fachschulen – Higher technical colleges, Colleges of Higher Education, Advanced technical colleges; Fachhochschule – University of Applied Sciences; Pädagogische Hochschulen – Universities of education; Universitäten – Universities; ETH – Swiss Federal Institute of Technology Zurich; Eidgenössisches Diplom / Fachausweis – Swiss Federal Diploma; Bachelor, Master, PhD/Doktorat – Bachelor, Master, PhD/Doctorate.

References
Bildungspläne BW 2016. (2016). Retrieved June 10, 2020, from http://www.bildungsplaene-bw.de/Lde/LS/BP2016BW/ALLG Bildungspläne Hamburg. (2020). Retrieved June 10, 2020, from https://www.hamburg.de/bildungsplaene/
Lehrpläne: Lehrpläne: Bildungsserver Rheinland-Pfalz. (2020).
Retrieved June 10, 2020, from https://lehrplaene.bildung-rt.de/
LehrplanPLUS. (2020). Retrieved May 11, 2020, from https://www.lehrplanplus.bayern.de/suche/lehrplan/filter/add/jgs/11
Lehrplanverzeichnis. (2020). Retrieved June 10, 2020, from https://www.schule.sachsen.de/lpdb/
Mayring, P. (2014). Qualitative Content Analysis: theoretical foundation, basic procedures and software solution. Retrieved from https://nbn-resolving.org/urn:nbn:de:0168-ssoar-395173
NRW, Q.-L. (2020). Schulentwicklung NRW – Lehrplannavigator – Richtlinien und Lehrpläne für die Grundschule. Retrieved June 10, 2020, from https://www.schulentwicklung.nrw.de/lehrplaene/lehrplannavigator-grundschule/
Saarland. (2019). Lehrpläne und Handreichungen | Saarland.de.
(Saarland, Producer) Retrieved June 10, 2020, from https://www.saarland.de/lehrplaeue.htm
Senatsverwaltung für Bildung, Jugend und Familie (Ed.). (2020). Rahmenlehrpläne – Berlin.de. Retrieved June 10, 2020, from http://www.berlin.de/sen/bildung/unterricht/faecher-rahmenlehrplaene/rahmenlehrplaene/
Staatsssekretariat für Bildung, Forschung und Innovation SBFI. (2019). Bildungssystem Schweiz. Retrieved June 26, 2020, from https://www.sbs.admin.ch/sbs/de/home/bildung/bildungsraum-schweiz/bildungssystem-schweiz.html
Stifterverband für die Deutsche Wirtschaft e.V. (2017, April 13). Curriculum 4.0: Konsequenzen der Digitalisierung für Studiengangsreformen an deutschen Hochschulen. (D. S. e.V., Editor) Retrieved September 7, 2020, from https://www.stifterverband.org/curriculum-4-0
Thüringer Lehrpläne · Thüringer Schulportal. (2019). Retrieved June 10, 2020, from https://www.schulportal-thueringen.de/lehrplaeue
Willkommen bei Lehrplan 21. (2020). Retrieved June 11, 2020, from https://www.lehrplan21.ch/
Wing, J. M. (2006). Computational Thinking. Communications of the ACM, 49(3), March 2006, 33–35.
Wing, J. M. (2017). Computational thinking’s influence on research and education for all. Italian Journal of Educational Technology, 25(2), 7-14. doi:10.17471/2499-4324/922
Yadav, A., Mayfield, C., Zhou, N., Hambrusch, S., & Korb, J. T. (2014). Computational Thinking in Elementary and Secondary Teacher Education. ACM Transactions on Computing Education, 14(1), 1–16.