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Tables and the Development of Computational Thinking in *Programming with Emil* for Primary School

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Abstract. Tables are fundamental tools for handling data and play a crucial role in developing both computational thinking (CT) and mathematical thinking (MT). Despite this, they receive limited attention in research and design. This study investigates pupils' attitudes toward and approaches to working with tables in informatics education, focusing on the systematic development of CT. Specifically, we examine how primary school pupils (aged 8–10) think and act when engaging with two-dimensional frequency tables integrated into *Programming with Emil*. Our objective is to deepen the understanding of pupils' cognitive processes when entering data into tables and interpreting their contents. Data were collected through individual semi-structured interviews and analysed using qualitative inductive coding. Identified codes were then iteratively consolidated into broader categories and final themes. Key findings include: (a) the opportunity to solve a problem by programming a character is highly motivating for pupils, and (b) the appropriate integration of different contexts and concepts, such as tables, into an engaging programming environment has the potential to foster advanced cognitive skills beyond CT.

Keywords: primary programming, structures, tables, computational thinking, mathematical thinking.

> *'It was more like I was moving Emil. But he was helping me sometimes; he knew somehow where to go, and when I told him where to go, that's where he went.'*
>
> - A 10-year-old pupil (an interviewee)

1. Introduction

Tables are essential tools for organising and presenting data and are utilised across a wide range of learning areas. Pupils encounter tables in their everyday lives right from the early stages of primary education. As representational structures, tables allow pupils to discover, organise and reflect on new information. They can serve as powerful cognitive tools that support problem-solving across diverse contexts. However, as noted by Marti (2009) and Marti *et al.* (2011), it is crucial to move beyond the common misconception that tables are simple structures that do not require thoughtful learning. Several studies have indicated that working with tables is neither easy nor intuitive for primary school pupils (see, e.g., Marti *et al.* 2011, Sabitzer *et al.*, 2014). In line with these findings, we believe it is essential to explore the cognitive complexity that tables present for pupils and to develop strategies that help them overcome these challenges. This will enable them to use tables more effectively as part of their broader cognitive development.

Our previous design research projects have provided valuable insights into how working with tables and other data structures can support the development of pupils' MT and CT. We have incorporated these insights into each component of our new informatics curriculum for primary education.[1] We believe that the thoughtful integration of tables into elementary programming and other areas of school informatics holds significant potential for fostering all aspects of CT (see, e.g. Cansu and Cansu, 2019), as discussed in Section 3.2. However, do our methods truly facilitate this development? Are the ways in which we incorporate tables into educational content genuinely effective? Do they promote deeper understanding and cognitive growth among pupils?

In our study, we aimed to investigate pupils' actual attitudes and practices when working with tables in informatics education, with a particular focus on the systematic and sustained development of CT. However, we also chose to consider the potential contribution of working with tables to the development of MT, given the close connection between informatics and mathematical concepts in our educational content. More specifically, we examined how primary school pupils (aged 8–10) approach solving tasks involving two-dimensional frequency tables, used as one of several representations integrated into programming-oriented activities. Our objective was to deepen the understanding of pupils' cognitive processes both when (a) entering data into the table and (b) interpreting its content. The central research question (RQ) guiding our study was:

RQ: *How do primary school pupils think and act when working with two-dimensional frequency tables within the context of* Programming with Emil*?*

In our research, we worked with 10-year-old pupils who were already familiar with the complete *Programming with Emil* educational content from previous years. Analysis of the collected data revealed several noteworthy findings and yielded practical implications for educators and informatics curriculum developers. Perhaps the most valuable insight is the confirmation that integrating various informatics concepts into programming-oriented tasks is not only feasible but also highly motivating and beneficial for pupils' learning.

[1] In Slovak educational system, this refers to Years 1–5, divided into Cycles 1 and 2, for pupils aged 6–11. By 'Year' we refer to pupils' academic level within a school year. In some other educational contexts the term 'grade' is used instead.

In the following section, we describe how tables are incorporated into the Slovak National Curriculum, specifically within the subjects of informatics and mathematics. In Section 3, we present the current state of knowledge from the research literature on tables. Section 3.2 summarises findings from our previous, closely related research (Čujdíková and Kalaš, 2025), in which we examined how other educators and researchers perceive the role of tables in the development of CT and MT. Section 4 introduces the educational content of *Informatics with Emil*, with a focus on *Programming with Emil* as a key component. We pay particular attention to how pupils work with various structures in Emil and explain how one specific set of tasks was used as a research instrument in this study. Section 5 outlines the research methods used, followed by Section 6, where we present the results of our analysis. Finally, we conclude with a discussion of the findings and some closing remarks.

2. Tables in the Slovak National Curriculum

In Slovakia, the new state curriculum for primary education is currently being piloted in schools (MSVVaS SR, 2023). This curriculum emphasises the importance of pupils developing skills to work with tables from the early years of primary education. Pupils progress from basic orientation and data manipulation to more advanced tasks such as interpretation and practical problem-solving. In the following sections, we specifically outline how tables are integrated into the Slovak informatics and mathematics curricula, as these subjects are central to our research on the educational use of tables.

2.1. *Tables in School Informatics*

In modern school informatics, which emphasises the development of CT, pupils are introduced to tables as one of the key data structures (Blaho and Salanci, 2011).

According to the curriculum, one of the learning objectives for Years 1–3 (Cycle 1, pupils aged 6–9) is to develop familiarity with basic linear and tabular representations of data. Pupils are expected to understand the concepts of sequences and tables, including rows and columns, as well as how to reference specific positions within a sequence or table. Learning activities include: (a) searching for and extracting information from simple structures based on specified criteria, (b) creating basic data structures in response to a given task and (c) manipulating data structures according to specific, simple rules.

In Years 4–5 (Cycle 2), one of the key learning objectives is to recognise the fundamental principles and concepts of informatics, including the representation of data in tables, trees and graphs. Building on previously acquired skills, pupils are expected to further develop their ability to interpret data from these structures and to use specific tools for working with various forms of data representation. The content standard in the domain of *data structures* focuses on the concepts of sequences and tables, including frequency tables, coding tables, dictionaries, grids, rows, columns, cells and cell addresses. It also addresses relationships such as the order of objects and their positions within a sequence, the cell address as a reference to an object's (cells) location in a table, and processes such as working with graph and tree structures and navigating within a structure. Required learning activities include: (a) organising information into structures, (b) interpreting data from a given structure and (c) inferring relationships from the data contained within a structure.

2.2. *Tables in Mathematics Education*

Tables also play a significant role in primary mathematics education. Kirova (2018) asserts that working with *numerical data in tables and solving word problems involving such data are essential components of early mathematical learning*. In the Slovak curriculum, one of the learning objectives for mathematics education in Years 1–3 is to develop pupils' familiarity with simple tables and graphs and to apply them when solving contextual tasks. These tasks emphasise skills such as searching for, collecting, recording, sorting, organising and interpreting data. Within the content standards for Cycle 1, working with tables is included in the following subject domains:

- *Basic tools for working with simple dependencies and relationships.*
- *Basic tools for solving simple combinatorial situations.*
- *Basic tools for working with data.*

In Years 4–5, the learning objectives expand to include *collecting, recording, organising and sorting data; identifying appropriate methods for data organisation; creating simple frequency tables and graphs; and accurately interpreting results*. Within the content standards for this cycle, working with tables is integrated into the following subject domains:

- *Enhanced tools for working with dependencies and relationships* – completing or extending a table of direct proportion and representing its data as a set of points or a line in a coordinate system.
- *Enhanced combinatorial tools and techniques* – determining the number of possible outcomes in a combinatorial situation by manipulating objects, listing all possibilities, or using a table or graph.
- *Enhanced tools for working with data* **–** designing and creating simple tables and graphs based on a set of quantitative or qualitative data.

The Slovak example demonstrates that modern curricula provide explicit and sufficient attention to the use of tables. Naturally, this raises the question: what does the research literature say about their application in educational contexts?

3. Tables in the Literature

Several researchers highlight the importance of using tables, among other data structures, to teach various concepts in informatics. This is evident in numerous research projects analysing tasks from Bebras challenges conducted worldwide (see, e.g. Dagienė, 2025;

Vaníček *et al.*, 2021; Budinská *et al.*, 2017). Tables are also frequently used and studied in mathematics and other disciplines. This section focuses on research related to two key areas: how researchers and educators perceive the potential of tables in fostering the development of CT and MT.

3.1. *Research Related to Tables*

Contemporary approaches to teaching informatics, with an emphasis on developing CT, introduce pupils to tables as a fundamental data structure (Blaho and Salanci, 2011; Vaníček, 2013; Palts and Pedaste, 2015; Kabatova *et al.*, 2016). Pupils learn to navigate table structures, organise information within them and interpret data – whether individual values in cells or broader regions such as rows, columns or adjacent columns. They search for information based on specific criteria and develop an understanding that the contents of a table can be translated into alternative representations, such as graphs. This process enhances their comprehension of the relationships between various forms of data representation.

Tables also play a crucial role in information systems, where pupils in Years 5–9 learn to select and apply appropriate structures (including tables and spreadsheets) for recording larger volumes of data. They gain experience in sorting and filtering data within existing structures (Vaníček *et al.*, 2021). Naturally, the use of spreadsheets is closely related to informatics education. For example, Tort (2010) emphasises the need for purposeful curriculum design that supports pupils in understanding spreadsheet invariants, detecting errors and maintaining logical consistency. Similarly, Csernoch and Biró (2018) present a structured educational framework that defines spreadsheet-related competencies, highlighting the potential of spreadsheets to foster algorithmic thinking through progressively complex tasks. Torley *et al.* (2022) also argue that spreadsheets can serve as an effective bridge between data manipulation and programming. According to their findings, spreadsheets help develop essential programming skills by enabling learners to work with fundamental computational constructs, such as variables, conditionals, formulas and logic, within an accessible, visual framework.

In school mathematics, tables are used in arithmetic, algebra (Tanışlı, 2011; Carraher *et al.*, 2006), probability, statistics (Papancheva, 2017) and other areas. In the context of mathematical modelling, considered a key aspect of mathematical literacy (OECD[2], 2021), tables serve as valuable tools for analysing problems mathematically. They can also be used to represent the resulting models, providing a visual and structured representation of proposed solutions (Mousoulides *et al.,* 2010).

Tables are particularly useful for understanding mathematical functions. Several studies (e.g. Tanışlı, 2011; Schliemann *et al.,* 2001; Brizuela and Lara-Roth, 2001; Blanton and Kaput, 2004; Carraher *et al.,* 2006) have shown that lower primary pupils (Years 1–3 and 4–5) are already capable of using tables to explore functional relation-

[2] Organisation for Economic Co-operation and Development.

ships between variables. Brizuela *et al.* (2021) even reported such abilities in preschool children. Torres *et al.* (2022) investigated how Year 2 pupils engaged with linear functions through tasks involving blank or partially completed tables. Their findings indicate that pupils were able to identify regularities in the data and assign meaningful headings to columns and rows. The use of tables helped pupils recognise structures underlying the relationships between variables, thereby supporting the early development of functional thinking. Notably, more pupils were able to correctly identify these structures during the second interview than in the first, suggesting a learning effect resulting from continued engagement with tabular representations.

Although tables are effective tools for teaching concepts in informatics and mathematics, working with them can present significant cognitive challenges for pupils. Several studies (e.g., Sabitzer *et al.*, 2014; Marti, 2009; Brizuela and Lara-Roth, 2001) have shown that pupils often struggle to use tables and tend to avoid them when alternative problem-solving methods are available. For example, Sabitzer *et al.* (2014) conducted a study with 22 third-year pupils (aged 8–9), who were presented with five pictures depicting the stages of a simple action. These pictures were not in the correct order. The pupils' task was to recognise the sequence and present the story (event) in a logically coherent order, choosing one of three presentation formats: (a) cutting out and rearranging the pictures, (b) writing the correct order into a prepared table, stage by stage or (c) rewriting the story as a text. Although all pupils successfully completed the task, none chose the table as their final format. The authors hypothesised that pupils in this age group are not yet accustomed to using tables as a form of data representation.

A similar result was observed in a study by Marti (2009), in which Year 1 and Year 5 pupils were asked to record the classification of objects into several categories on a sheet of paper. None of the pupils spontaneously used two-dimensional tables, even though this was the most appropriate format for the task. Among fifth-year pupils, the use of tables remained rare. Other studies (Brizuela and Lara-Roth, 2001; Marti *et al.,* 2011) have shown that even when pupils were explicitly instructed to produce a table as a solution, the formats they created often deviated significantly from conventional table structures. In another study, Reuter *et al.* (2015) found, contrary to their hypothesis, that providing external representations in the form of drawings and tables did not improve lower primary pupils' ability to solve non-routine word problems.

According to Marti (2009) and Marti *et al.* (2011), constructing a table is particularly challenging for pupils at this age, as it requires the integration of multiple cognitive and graphical skills. In examining the cognitive demands of creating a two-dimensional frequency table, the authors identified several potential difficulties for learners, including categorisation (arranging data into categories based on two criteria), graphical representation (spatially organising data into cells within rows and columns), abstraction of necessary information (filtering out irrelevant or redundant details) and frequency recording (counting items in each category and accurately documenting them).

Interpreting data from tables is also not straightforward for pupils. Gabucio *et al.* (2010) investigated the cognitive complexity of various tasks involving a table that dis-

Table 1
The table used in the research by Gabucio *et al.* (2010)

	Less than 25	From 25 to 34	From 35 to 44	Over 44
Boys	1	10	12	2
Girls	0	6	13	6
Together	1	16	25	8

played the number of boys and girls within specific weight intervals (Table 1). This table was introduced to a sample of Year 5 and Year 6 primary pupils, as well as pupils in Years 1 and 2 of secondary school.

Pupils were asked a series of questions about the table, which were categorised into four levels based on the cognitive actions required. Using pupils' responses, the researchers assessed the increasing cognitive demand of each task as follows:

Level 1: Direct reading of data from the table – *How many girls weigh 25 to 34 kg?*[3]

Level 2: Understanding the table structure – *What do the numbers inside the table indicate?*

Level 3: Inferring the data – *How many girls were weighed in total? How many children weighed less than 35 kg?*

Level 4: Interpreting with broader reasoning – *Do boys or girls weigh more?*

Similarly, Pallauta *et al.* (2021) investigated the abilities of pupils aged 14–16 to construct and interpret statistical tables. Their findings indicate that while most pupils were able to translate simpler graphical representations, such as pictograms, into one-dimensional frequency tables effectively, translating more complex representations – such as double bar graphs – into two-dimensional frequency tables proved significantly more challenging. Common difficulties included misinterpretation of pictogram icons and errors in calculating cumulative frequencies. Additionally, the authors observed that pupils' ability to reason and justify their conclusions based on data presented in tables was relatively weak, especially in tasks requiring broader contextual interpretation. Likewise, Sharma (2006) reported that upper secondary pupils experienced considerable difficulty interpreting tables compared to bar graphs. These pupils often relied on non-statistical reasoning, drawing on everyday experiences rather than engaging in explicit data-based interpretation.

3.2. *How Tables are Perceived by Specialists*

As researchers and designers of learning content for primary informatics, we have a clear understanding of the role tables play in developing CT. Drawing on our previous experience and research, we have well-defined expectations regarding the types of operations with tables that primary pupils can gradually learn and apply. However, during

[3] Examples of the questions used by the authors within each category are provided.

the preparation phase of the study presented in this section, we aimed to validate the extent to which our perspectives align with the broader views of educational specialists regarding the role of tables in relevant learning contexts. Since the existing literature does not offer comprehensive answers on this issue, we conducted a small pilot study. A detailed account of this study[4] is provided in Cujdikova and Kalas (2025). Here, we briefly outline our approach and summarise the key findings, which we consider significant for understanding the current state of knowledge on this topic.

To achieve our goal, we engaged 65 specialists in the fields of mathematics and/or informatics education. Using a purposeful sampling strategy, we aimed to capture a range of perspectives on the topic. The sample included: (a) academicians from several European universities, (b) experienced teachers from primary and secondary schools, and (c) a group of master's students at Comenius University specialising in teaching mathematics and informatics.[5] The academicians formed the largest subgroup within the sample.

We approached this specialists group with an anonymous, open-ended online questionnaire and successfully collected 29 responses. Through qualitative analysis, we gained a broad perspective on the perceived role of tables in developing CT and MT. However, distinguishing between CT- and MT-related themes in the responses proved challenging. Only a few participants explicitly linked tables to either CT or MT; we present these as the final two of the seven themes identified and summarised below. Quotations from the specialists' responses are presented in italics.

3.2.1. *Structure*

The importance of tables in developing CT lies primarily in their structural nature. Specialists emphasise that creating such structures, organising data within them, and developing the ability to navigate, interpret and utilise the structure are key aspects of CT. They highlight several specific skills, including understanding the correspondence between rows and columns, interpreting the data (whether a single item or a range), searching for relevant information and filtering this information based on one or more specific rules.

Several master's students view tables as a gateway to more complex data structures and programming concepts: *'It is a kind of precursor to more complex structures. Once pupils have mastered table navigation and understood its meaning, it is easier for them to move on to structures in programming languages.'*

Specialists also point to various structural features of tables that contribute to the development of both CT and MT. Organising data in tables is seen as valuable for modelling problem situations and systematically recording findings. As one respondent noted: *'Tables enable pupils to organise, analyse and manipulate data in a way that promotes logical thinking and problem-solving skills.'*

[4] The study was conducted by the same research team, as preparation for a deeper analysis of the data obtained from this study.

[5] Most of them are already part-time, non-qualified teachers in schools, gaining early experience in real-life settings.

3.2.2. *Data Representation*

Specialists consistently describe tables as a powerful tool for representing data.[6] They emphasise that tables offer a structured format for organising information: *'We can see the data arranged in a certain way, and we can work with them.'* In relation to MT, they note that tables can represent sets, categories, qualities, calculations in combinatorics and functional values such as logarithms. Some explicitly mention multiplication tables. Statistics is another domain they highlight, recognising the critical role of tables in effectively presenting real-world data.

While all participants acknowledge the value of representing data through tables, some suggest that the key lies in the ability to select this form of representation when solving a problem. Additionally, specialists recognise the contribution of tables to CT through the translation between different forms of data representation. They highlight the importance of converting data from graphs, diagrams or unstructured text into tables, and vice versa. Connecting tables with other representations is also seen as beneficial for developing MT, particularly in fostering functional thinking: *'Understanding the abstract concept of a function, switching between different representations of a function, and using the one that is most appropriate in a given situation.'*

3.2.3. *Problem Solving*

Several specialists in our sample perceive tables as valuable tools for problem-solving, aligning with the views of Martí (2009). Regarding the development of CT, participants highlight several key procedures: *'An important prerequisite for successful problem-solving in different domains is the ability to organise data in tables, i.e. to model different problem situations, to interpret the data in tables… and to process them efficiently (to perform calculations, to search, to visualise the data, etc.).'* In this context, several participants also emphasise the potential of transitioning from simple tables to spreadsheets: *'Tables can make the problem-solving process clearer, which can be automated over time... and provide pupils with an alternative approach to problem-solving.'* They note that spreadsheets support learners in modelling different types of problem situations. One participant particularly underscores the connection between MT and CT through the use of spreadsheets: *'In higher grades, when working with mathematical modelling and when pupils start to use spreadsheets, the tables become even more important, and this is the moment when MT and CT clearly overlap.'*

In relation to the development of MT, participants further point out that spreadsheets are effective tools for solving word problems, exploring functions, working with algebraic equations and conducting statistical tasks. Additionally, *'by performing calculations with data, pupils can develop their ability to reason quantitatively and make informed decisions based on data.'*

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[6] Without commenting on how they perceive the difference between structure and representation.

3.2.4. *Data Analysis*

Another aspect emphasised by specialists in the development of both MT and CT is data analysis. Within the context of CT, the development of competencies related to data analysis using tables is considered essential. In contrast, within MT, tables are viewed as tools for analysing data to achieve specific mathematical objectives. Barr and Stephenson (2011) also highlight data analysis as a key concept of CT that is applicable across disciplines. In this context, participants identified a particular advantage of using tables in statistical data analysis, noting that tables help *'to get an overview of given or collected data and to make some predictions or characteristics of them.'*

3.2.5. *Patterns, Rules and Connections*

Tables allow us *'to understand the connections between different pieces of information, to look for patterns or to infer rules, and also to see patterns and trends that may not be obvious at first glance.'* In this sense, specialists recognise the value of tables in exploring a range of mathematical concepts. Among these, algebra is frequently highlighted as a key area. By using tables, learners can *'make generalisations*. [*Tables*] *are advantageous for generalisation tasks – when they clearly display specific values (or pairs of values), pupils can "see" a dependency, which they can then express symbolically.'* The connection between the use of tables and the development of understanding in algebraic contexts is also supported by prior research (Carraher *et al.,* 2006; Csizmadia *et al.,* 2015).

Some participants also refer to the development of MT through the exploration of patterns and connections in multiplication tables. They explain that *'Tables mean the learning of sets of multiplication and division facts that embed ideas of factors, prime numbers (the missing numbers in the multiplication grid), interrelated sequences (visible through rows and columns) and other patterns (such as diagonals representing square numbers).'* They further emphasise: *'It is not the rote learning of tables as a set of number facts! The ideas are fundamental to developing number sense and are of significant importance to developing learners' mathematical understanding.'*

3.2.6. *Components of CT*

There is a strong connection between working with tables and the development of specific components of CT. Specialists frequently refer to elements from frameworks such as that of Cansu and Cansu (2019), which categorise CT into abstraction, decomposition, algorithmic thinking, automation and generalisation (sometimes also including evaluation; see Csizmadia *et al.,* 2015). *'In the context of CT, we can think about logic (e.g. drawing conclusions, deducing the initial state, inferring rules), decomposition (e.g. splitting data into smaller, easier-to-process parts), pattern search (identifying similar data), abstraction (e.g. abstracting relations from specific cases) and evaluation (e.g. assessing data accuracy, suggesting criteria for evaluation).'*

3.2.7. *Components of MT*

Participants refer to various forms of reasoning that contribute to the development of MT, including functional, algebraic, logical, statistical, quantitative, abstract, number sense, combinatorial and probabilistic reasoning. They also recognise the role of tables in supporting MT through opportunities to explore diverse mathematical concepts. As one participant observed, *'Tables contribute to the clarity, efficiency and understanding of mathematical concepts.'* Another added that *'by using tables and spreadsheets to explore mathematical concepts, pupils can develop their abstract and quantitative reasoning skills, which are key components of mathematical thinking.'* Furthermore, the use of tables was seen as a way to support the understanding of more complex ideas: *'It prepares for the concept of function, one of the most important mathematical concepts.'*

The findings presented above offer a detailed and structured view of how specialists perceive the use of tables in education. They highlight the broad relevance of tables from both CT and MT perspectives. Moreover, we consider these results to support our central premise: that programming at the lower primary level can support the development of pupils' structural understanding of data and processes. In addition, modern school informatics and programming can effectively align their learning objectives with those of other subjects, particularly mathematics, at the primary level. We also find that a validated, curriculum-embedded and comprehensive understanding of the value of working with tables in programming allows for a more informed analysis of the data collected for the central focus of this study.

4. *Informatics with Emil*: Curriculum and Pedagogy Design

Informatics with Emil is ongoing research and development project that we have been conducting since 2017, aimed at teaching informatics in a way that supports pupils' long-term, systematic cognitive development.[7] To achieve this goal, we have gradually developed and tested educational content that aligns with the requirements of the Slovak and Czech national curricula for informatics in Cycles 1 and 2 of primary school (Years 1–5). The content consists of three interrelated components: (a) *Programming with Emil*, (b) *Robotics with Ema* and (c) the *Living Workbook*, designed to build the informatics foundation of digital literacy. This content is currently used in approximately 700 primary schools across several countries, primarily in the Czech Republic and Slovakia.

One of the key design principles of our approach is *informatics for every learner in the classroom*, aligning with the perspectives of Caspersen *et al.* (2019) and Sentance (2019). We share Sentance's (2019, p. 1) perspective that we must *'challenge stereotypes around who is capable of studying computing. We must prepare all young*

[7] One of the authors of this paper is the co-author of *Informatics with Emil*'s content and pedagogy. Other co-authors of the curriculum are A. Blaho and M. Moravcik.

people for a world full of technology that does not yet exist.' Our strategy is grounded in constructionist pedagogy, drawing on Papert's (1980) view of programming as a means for learners to engage with powerful ideas. In our research, we first aim to identify powerful informatics ideas that pupils of a given age can meaningfully explore as they engage with basic programming concepts and related procedures. To support this inclusive exploration, we also examine the cognitive complexity of these concepts and how pupils interact with them, while identifying appropriate small steps in the progression of activities that foster deep understanding (Kalas *et al.,* 2018; Kalas and Horvathova, 2022).

Another fundamental design principle of *Emil* is collaborative learning among pupils, based on Vygotsky's theory of social constructivism (see, e.g. Saleem *et al.,* 2021). Pupils work in pairs on a single tablet or computer, each using their own workbook. They then discuss their progress as a whole class. These discussions, scaffolded by the teacher, also serve as a form of indirect feedback for the pupils.

Emil also incorporates learning principles that, according to Gee (2003), are characteristic of many video games. These include, for example, *active and critical learning* (pupils actively move around the environment, discover relationships and rules, test their ideas, evaluate them critically and explore new strategies); *the psychosocial moratorium principle* (pupils can make mistakes safely – nothing serious happens, and they are encouraged to try a different approach); *the identity principle* (pupils adopt the identity of Emil); *the amplified input principle* (a small action, such as clicking on a space, triggers a strong response – for instance, Emil moves to that space and collects all objects along the way); *the exploration principle* (pupils observe and investigate Emil's reactions and those of the environment); and *the situated meaning principle* (everything that happens in the environment is meaningful and fits the context).

In addition to fostering CT, we aim to encourage pupils to view programming as a tool for reasoning and exploring various domains through diverse problem-solving tasks. To support this goal, we consider it essential to establish strong connections with other subjects. Our approach follows the 5E pedagogical framework from the ScratchMaths project (Benton *et al.,* 2017), designing activities that motivate pupils to explore problems,[8] explain processes and discoveries to one another, reflect, share and relate their learning to other subject areas.

The *Programming with Emil* component forms the backbone of our informatics curriculum for primary education and features a structured progression through four *worlds* (Fig. 1).[9] Task sets increase in complexity and are denoted by the letters **A**, **B**, **C**, etc. Most tasks are designed for pupils to engage with both Emil's software environment and the accompanying workbook simultaneously. In addition, some problem sets in the workbook are followed by a section labelled *Without Computer*, in which pupils solve problems using only paper. Solving a task involves developing a procedure to address a

[8] 5E in ScratchMaths comprises Explore, Explain, Express, Exchange and bridgE.

[9] Due to our long Logo educational tradition, we use *world* in reference to Papert's *microworld* (1980). However, our worlds are not micro in scope. For instance, the second world consists of more than 60 tasks, and pupils spend about eight lessons on it. Hence, *world* is used instead of *microworld*.

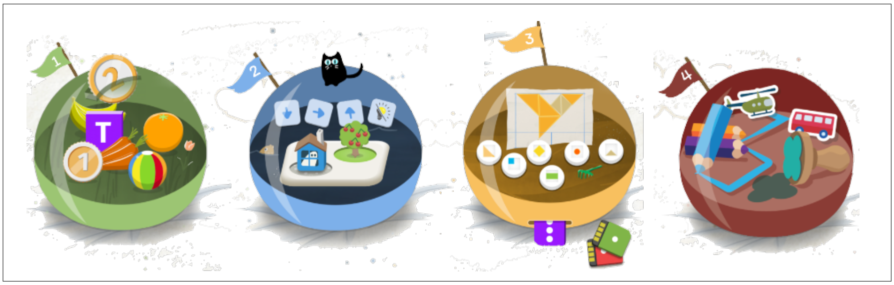


Fig. 1. The four worlds of *Programming with Emil*, illustrating increasing cognitive demand along with higher levels of control and representation.

given problem, either by directly controlling Emil or by programming it, executing the procedure, refining the solution, comparing different approaches, simplifying the procedure and making any necessary corrections.

Throughout the learning content, some tasks have clear and unambiguous solutions, while others have none. A task with no solution is considered correctly solved only when pupils can justify why it is unsolvable. Some tasks allow for multiple solutions, but the aim is not necessarily to find them all – instead, it is to recognise their variations, similarities and differences. In all four worlds, certain tasks are intentionally left incomplete to encourage pupils to clarify rules, set constraints or agree on interpretations. Another consistently popular activity involves pupils designing similar tasks for their classmates within the same context.[10] Table 2 outlines the focus and content of each world.

4.1. *Emil and Working with Structures*

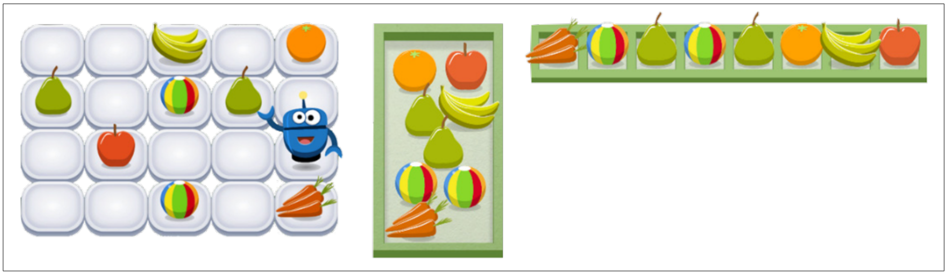
Our goal in this project was to investigate how pupils think and act when working with two-dimensional frequency tables integrated into the programming activities of Emil's second world, *Emil the Keeper*. However, the development of skills related to working with structures and understanding tables is gradual, beginning with the very first activity in the first world. Therefore, we briefly introduce the simpler structures that pupils encounter before engaging with two-dimensional frequency tables.

In the first world of Emil, pupils are introduced to simple data structures in the form of a scene, a box and a shelf (Fig. 2). The scene (part 2a in the figure) is Emil's fixed-grid workspace, typically organised into four rows and five columns of spaces. The scene represents the current state of the task, which pupils can alter by clicking on individual spaces – always aligned with Emil's current row or column. Emil then moves to the selected space, collecting all objects along the way.

[10] In this research project, we included such activities in the entire classwork, as well as in the interviews (presented in Section 5). However, the results were so compelling that we decided to present them additionally in a separate publication.

Table 2
Curriculum, content and concepts of the worlds of *Programming with Emil*

World	Curriculum	Computing Content and Concepts
Emil the Collector  Letters **A–H** with 56 tasks	• Perceiving the order of items and actions • Selecting items based on various conditions and constraints • Recording the path of the solution • Reading and interpreting the recorded path • Reconstructing the initial state • Solving problems with various constraints and obstacles • Planning/programming the solution path in advance	• Controlling Emil by clicking the spaces on the stage • Navigating Emil with arrows (absolute frame for navigation) • Collecting to the tray and to the shelf • Initial state and end state on the shelf and on the stage • Planning a solution prior to running the moves; plan of moves represented on the stage • Running a plan; considering different properties of a programme
Emil the Keeper  Letters **A–H** with 61 tasks	• Taking record of commands in direct control • Recognising repeating commands, repeating pairs or groups of commands • Perceiving multiple representations of the state, translating between them • Considering multiple or no solutions • Programming solution in advance; reading, analysing, comparing and running programmes	• Commands to move Emil with arrows • Commands as tools to change the state of the spaces on the stage • Commands recorded on the panel • Stacking repeating commands to one position in the panel • Programming solution in advance • Exploring programmes with repeating pairs and triples of commands; merging pairs and triples into double and triple cards
Emil the Artist  Letters **A–H** with 82 tasks	• Controlling the actor in an absolute frame for navigation • Recognising repetitive patterns, considering the order of placing tiles • Exploiting rotations of tiles • Programming the solution incrementally in parts, completing the programme • Working with a compound command as a symbol of a small group of basic commands	• Placing and rotating tiles on the stage • Analysing and creating patterns of tiles • Using 'memories' as shortcuts to groups of commands • Controlling Emil using simple commands and memories; memories that place tiles and make Emil move • Reading and running programmes with memories • Completing then defining memories, solving tasks using our own memories
Emil the Painter  Letters **A–K** with 93 tasks	• Controlling the actor in a relative frame for navigation • Using basic commands for moving forward and turning left/right within a square grid • Programming 'turtle style' drawings • Setting pen colour and pen size • Filling the polygons • Drawing diagonal lines in the square grid • Using premade compound commands, modifying and programming compound commands	• Basic 'turtle style' commands to control Emil within the square grid • Constant 1-square distance for move and 90° turns left or right • Moving with the pen down or pen up; commands for setting the pen colour and size; random pen colour • Drawing polygons and filling them • Using premade compound commands • Repeating compound command • Debugging, modifying, creating and using compound commands for solving problems by programming



(a) (b) (c)

Fig. 2. In the scene from the first world of Emil, we see (a) the initial state before pupils begin directing Emil to collect objects either into a box (b) or onto a shelf (c). Parts (b) and (c) show the resulting states of these structures.

The box and the shelf serve as records of the objects (data) Emil collects as pupils direct him around the scene. In Fig. 2a we see the initial state of the scene. The box (Fig. 2b) functions as a set, displaying the objects Emil has collected, regardless of the order in which they were gathered. In contrast, the shelf (Fig. 2c) functions as a list, preserving the sequence of collection – for example, first the carrot was collected, followed by the ball, the pear, etc.

In the second world of Emil, *Emil the Keeper*, another important structure is introduced: a blue panel displaying, above the scene, the individual steps of the pupil's progress (Fig. 3). This panel becomes an integral part of all subsequent tasks and, depending on the level of representation (Kalas *et al.*, 2018), reflects either the current record of steps taken or a plan for future steps, a programme, to control Emil. In both cases, this structure enables learners to reflect on and discuss the sequence of commands, as well as to analyse or debug their solutions. The range of data structures that pupils engage with throughout the *Informatics with Emil* curriculum gradually expands to include images, texts, tables, concept maps, sounds, animations and more – typically

Fig. 3. The blue panel displays a record of the steps taken to solve a task in *Emil the Keeper*. The scene shows the final state of the task. To the right of the scene, the available commands for the learner are displayed.

introduced through concrete, hands-on experiences in the context of problem-solving, with developmentally appropriate operations linked to each structure.

Tables hold a special place among the various representations and structures in *Informatics with Emil*, as they appear in multiple components, such as:

- In *Programming with Emil*, tables serve as auxiliary structures in the form of one- or two-dimensional frequency tables.
- In *Robotics with Ema*, tables function as symbolic representations of physical mats for Blue-Bots – for example, for recording or specifying a path. Some mats directly represent a table, with various methods of marking rows, columns and spaces (cells). These allow for alternative encodings of the robot's path on the mat, such as **8 9 6 5 2 1 4** or **B1 C1 C2 B2 B3 A3 A2**, etc.
- In the *Living Workbook*, tables are central to two distinct groups of tasks, where working with tables is the primary learning objective.

By implementing various structures, we pursue two key objectives in our content. The first is to familiarise learners with these structures and enable them to use them effectively. The second, and even more significant, objective is to use different structures and translations between them to present multiple representations of the same situation, data or procedure. This approach promotes deeper conceptual understanding within the context of informatics (Bers, 2020; Lesh and Zawojewski, 2007).

4.2. Emil the Keeper *and Working with Tables*

In Group **C** of tasks within this second world of Emil, the focus is on translating between programmes, tables, and representations through text or images (Fig. 4). Tasks **C1** to **C4** begin with the same short instruction in the software environment: *Follow the task in the workbook.* In these cases, pupils first shift their attention to their workbooks to read the task instructions. They then solve the task in pairs at the computer by controlling Emil. Finally, they answer related questions (text) in the workbook, recording their responses or plotting their solution according to the task requirements, such as colouring uncoloured houses red, blue or green. Fig. 6 illustrates all Group **C** assignments as presented in the workbook.

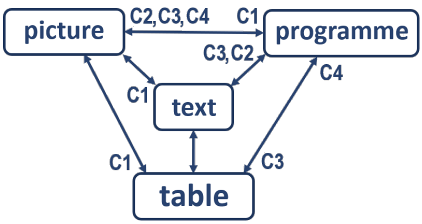


Fig. 4: Multiple representations and corresponding translations in tasks **C** of *Emil the Keeper*. All edges are bidirectional, with labels such as **C1**, **C2**, etc., placed at one of the two connected nodes. For example, the label **C1** on the leftmost edge indicates that task **C1** involves translating the situation depicted in the picture into the corresponding table.

In task **C1** (Fig. 5 and Fig. 6), pupils must control Emil on the screen to colour the houses according to the picture in the workbook. Fig. 5 illustrates the initial state of task **C1** within the software environment: two houses are already coloured, and five remain to be filled in. When a command to colour a house blue, red or green is entered, Emil executes it immediately,[11] and a corresponding command icon appears on the blue panel above the desktop.[12] Since this panel has limited space, pupils must carefully plan Emil's sequence of actions for colouring the houses. After completing the task on the computer, pupils answer questions in their workbooks and fill out a frequency table with two rows and two columns. In terms of Fig. 4, task **C1** involves multiple translations: from picture to programme (as pupils guide Emil using a limited number of steps), from picture to text (as they respond to questions about the final scene) and from picture to table (as they complete the frequency table based on the colours and positions of the houses).

In addition to programming, task **C2** introduces a combinatorial challenge. The objective is to help Emil colour the houses so that the number of red houses is equal in both the top and bottom rows. Some houses are already coloured, and pupils are encouraged to explore multiple possible solutions. Although this task does not directly involve working with tables, it serves as valuable preparation for understanding and solving later tasks. Task **C2** involves translating a logical condition expressed in text into a programme and then translating the programme into a picture by colouring the houses in the workbook.

In **C3**, pupils are asked to use Emil to colour the houses in a way that satisfies a compound condition involving both the number of red and green houses. This task requires

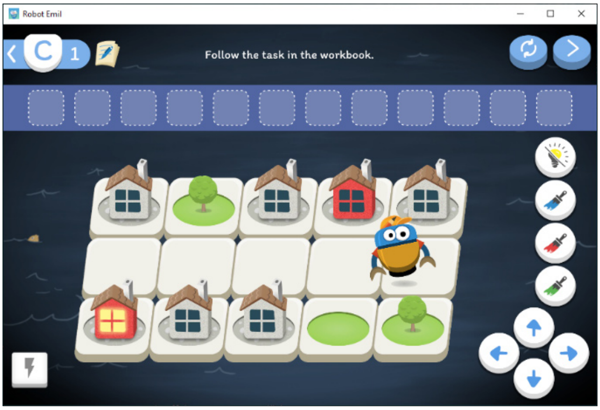


Fig. 5. *Emil the Keeper*, task **C1** in its initial state within the software environment. The available command buttons for this task are displayed on the right side of the screen.

[11] However, Emil executes a command only if it is possible to do so.

[12] When the same command is entered repeatedly in succession, these steps are automatically merged into a single stack of icons on the panel, displaying the number of repetitions. For example, in Fig. 3, Emil first moves left three times from the starting position. Later, after executing other commands, Emil moves down twice and then right twice.

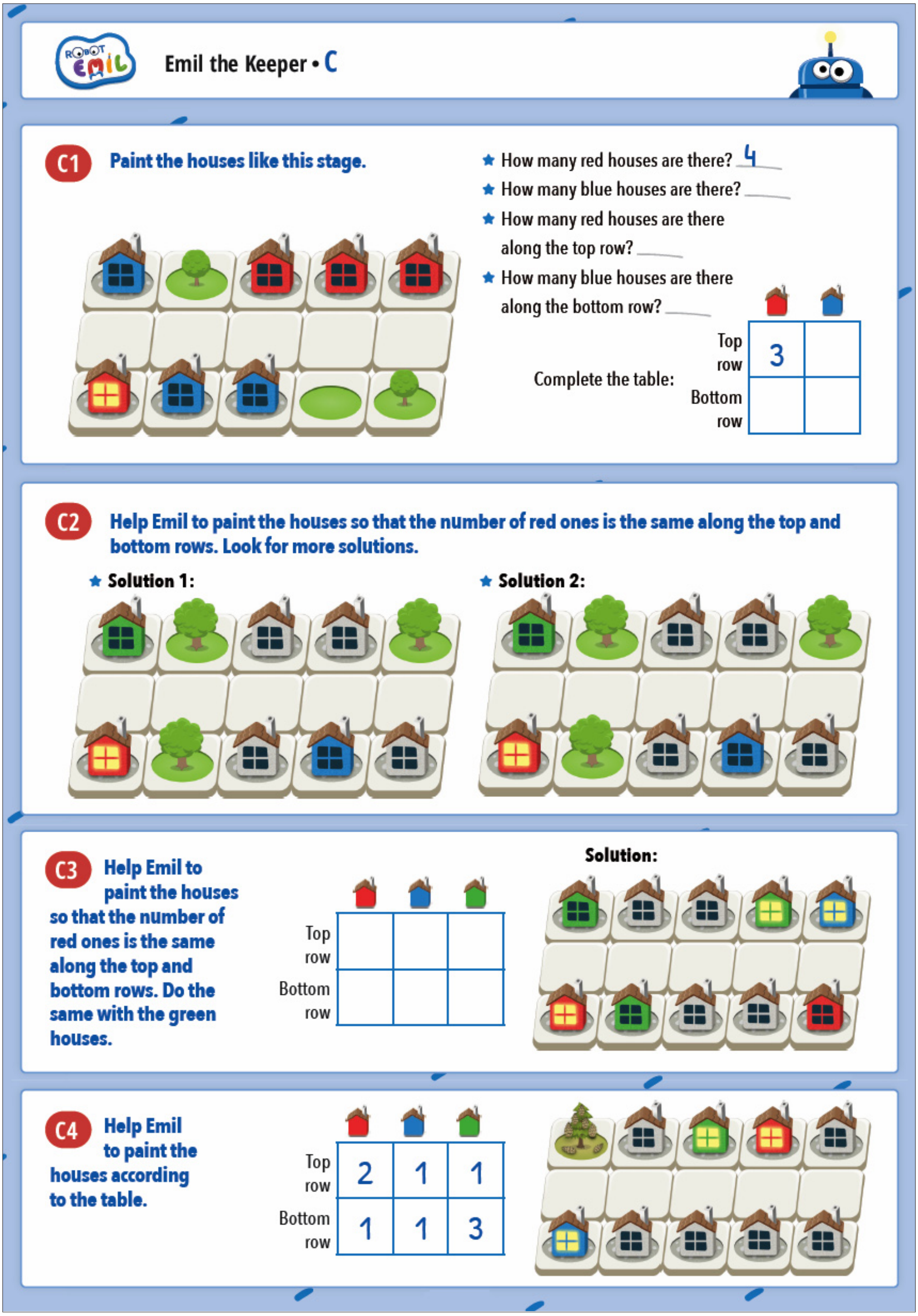


Fig. 6. *Emil the Keeper*, the second world of Emil – tasks **C1** to **C4,** as presented in the workbook.

them to apply combinatorial reasoning in conjunction with their programming skills. After completing the task, pupils record their solution by colouring the houses in their workbook and filling in the corresponding two-dimensional frequency table.

Compared to the previous task, an additional colour is introduced in **C3**, resulting in a table with three columns. In this task, pupils translate a compound condition expressed in words into a programme, and then from the programme to both a table and picture.

In **C4**, pupils do not complete the table themselves; instead, they interpret its values and use them to control Emil, ensuring that the final state on the stage satisfies the task requirements. Some houses are already coloured at the start and must be considered during reasoning. Pupils then record their final solution, of which there are multiple possible versions, in their workbooks. This process involves interpreting the table's values and translating from table to programme, and then from programme to picture.

5. Aims and Structure of the Research

The primary objective of this study was to address the following **RQ:** *How do primary school pupils think and act when working with two-dimensional frequency tables within the context of* Programming with Emil*?* To explore this, we formulated three specific RQs:

- **RQ1:** How do pupils perceive working with tables?
- **RQ2:** How do pupils think and proceed when entering data into a table?
- **RQ3:** How do pupils think and proceed when interpreting data from the table?

Our research was conducted at a primary school with which we have a long-standing collaboration on various research and development projects. The school is a large state institution located in a small town outside the capital. The participants were Year 5 pupils from a single class who had previously engaged with all four worlds of *Programming with Emil* during Years 3 and 4. As part of this study, the pupils once again tackled problems involving two-dimensional frequency tables from Emil's second world, during a lesson specifically reserved for our research. The activities were carried out in pairs, with each pair using one tablet running *Emil*. To refresh their memory after more than a year, the entire class first revisited a familiar set of tasks (**C1** to **C4**) using the software environment along with a corresponding paper worksheet. This review was followed by a whole-class discussion in which the pupils reflected on their observations, procedures and completed tasks, as is typical in their informatics lessons. Subsequently, within the same lesson, we introduced three additional paper-based tasks, **C5**, **C6** and **C7**, which are described in this section. These tasks were new to the pupils.

After the lesson, we conducted individual semi-structured interviews with six selected pupils from the class, which we audio-recorded. The group consisted of three girls and three boys who, based on the teacher's selection, representing three different levels of learning achievement within the class. At the beginning of each interview, we asked the pupils how they liked the lesson and how they felt about the tasks they had completed. We were also interested in their general views on the usefulness of tables and the other subjects, beyond informatics, in which they had encountered them. In the next part of the interview, pupils were asked to solve and comment on slightly modified versions of tasks **C5**, **C6** and **C7** from the lesson, completing them again in our presence. The modifications were minor, such as changing the colours of some houses in the picture or reordering the columns in the frequency table. These slight changes were introduced to minimise the likelihood that pupils would simply recall their previous solutions. We refer to these modified tasks as **C5i**, **C6i** and **C7i**, where the suffix 'i' stands for 'interview'. After solving each task, we further developed the conversation by exploring the pupils' perceptions of the differences between the modified tasks and the versions completed in class. These interviews formed the core of our analysis, the results of which we present in Section 6 as the key findings of our research. Therefore, we consider it essential to describe the modified interview tasks in detail here.

Through task **C5i** (Fig. 7), we investigated how pupils approached and reasoned through the process of entering data into a table. In this task, the interviewees were asked to complete a frequency table based on a picture, where each cell represented the number of houses of a particular colour in a given row. The in-class version of this task **C5**, differed only in the colouring of the houses.

Task **C6i** (Fig. 8) focused on how pupils acted and reasoned when interpreting data from a table. In this task, the table was already completed and displayed the number of houses of each colour in each row. Pupils were asked to use this data to answer three

Fig. 7: Task **C5i** (without a computer): 'Complete the table based on Emil's stage.' The column order differs from that used in tasks **C1** to **C4.**

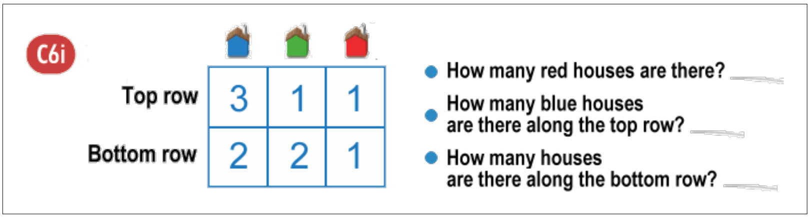


Fig. 8. Task **C6i** without a computer: 'The table shows how Emil coloured in the houses. Answer the questions accordingly.'

questions: (1) the number of houses of a specific colour in a particular row, (2) the number of houses of a specific colour across the entire stage and (3) the total number of houses in a row. In the in-class version of the task (**C6**), pupils were also given a printed, uncoloured picture of the houses. Their first step was to colour the houses according to the data in the table, after which they answered the same set of questions. When responding, they could refer either to the coloured picture or extract the information directly from the table. During the interviews, we asked pupils about their approach to solving the problem in order to understand the strategies they employed. Since they were not provided with the picture during the interview, they had to rely solely on the data in the table to answer the questions.

With task **C7i** (and **C7),** we explored a different aspect of pupils' understanding – specifically, their ability to create their own version of a similar task for their classmates (see Fig. 9). The analysis of this part of the interviews, along with the classroom solutions to task **C7**, yielded results that were both insightful and extensive. However, as these findings do not directly address our primary RQ, we have chosen to present them separately in another publication.

Fig. 10 illustrates the intended translations between multiple representations in the design of tasks **C5**, **C5i**, **C6** and **C6i**. When designing task **C6**, we were initially uncertain whether pupils would answer the questions by referring to the picture (i.e. translating first from the table to the picture, then from the picture to the text) or directly from the table (i.e. translating from the table both to the picture and to the text). This ambiguity was clarified through the analysis of the interview data, the findings of which are presented in Section 6.

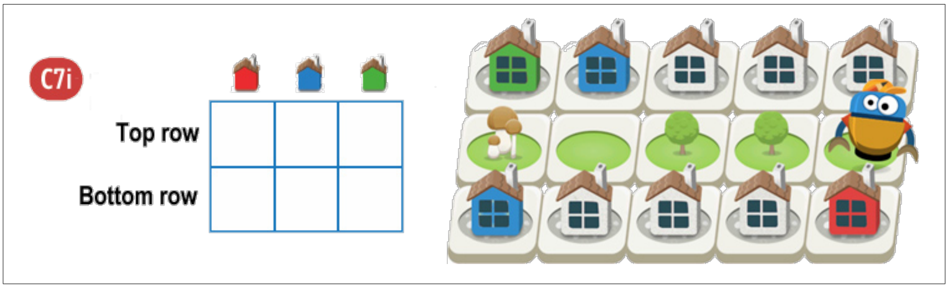


Fig. 9. Task **C7i** without a computer: 'Create your own task for your classmates.'

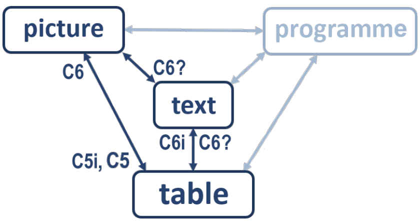


Fig. 10. Multiple representations and corresponding translations in tasks **C5i, C5, C6i** and **C6.**

The data collected from the interviews with the six participants (excluding task **C7i**) were analysed using standard qualitative research procedures, following the guidelines of Saldaña (2025) and Creswell and Creswell (2022). We began by transcribing the audio recordings of the interviews into written form. The analysis was conducted within the MaxQDA software environment using an inductive approach. In the initial stage, all transcripts were coded based on ideas that emerged through multiple readings. Related codes were then unified and consolidated. In the subsequent stage, we iteratively developed broader categories that encompassed groups of interrelated codes, which were eventually organised into three overarching themes. Throughout the analytical process, both authors engaged in collaborative discussions to reflect on and refine the findings, making necessary adjustments based on shared interpretations. The results of this analysis are presented in the following section.

6. Results

Following an iterative consolidation process, we distilled the codes identified during data analysis into three main themes:

- Perceptions of tables and their usefulness.
- Perception of the lesson.
- Working with tables in the context of *Emil the Keeper*.

We considered the third theme to consist of two distinct components: entering data into a table and interpreting data from a table. In Sections 6.3.1 and 6.3.2, we examine how pupils approached the task of entering data into a table and how they interacted with the data represented in tables within specific tasks.

6.1. *Overall Perception of the Tables*

We explored pupils' perceptions of using tables in subjects beyond informatics, as well as the significance they attributed to them. Responses varied, with some pupils expressing differing views despite having studied the same subjects together in previous years. While one pupil stated that tables were rarely used in other subjects, others identified multiple subjects and specific ways in which tables were utilised. One interviewee even claimed that tables were used in all subjects.

Pupils mentioned both recording data in tables and extracting information from them, with a stronger emphasis on data entry. Based on this, we infer that they associate writing in tables with active engagement. Specific examples included recording calculation results in mathematics and categorising words by type in Slovak. One pupil also recalled solving a crossword puzzle in science. In terms of data interpretation, pupils reported learning new vocabulary from tables in English and referencing a table of shape properties in geometry.

Pupils recognised the importance of tables, noting that they allow data to be presented clearly. They appreciated that information displayed in a table is more structured and easier to interpret. Additionally, they viewed tables as an effective tool for categorising data: *'... so that we know what belongs to what.'* One pupil remarked that transcribing data from a word problem in mathematics into a table could facilitate problem-solving. *'It makes it easier. And we sort of have it in order so that we know exactly.'* This suggests that pupils perceive recording data in tables as a more systematic and transparent process than relying solely on text.

This perception aligns with specialists' perspectives discussed in Section 3.2. Specialists emphasised that tables enhance data organisation, encourage a systematic approach and improve clarity, thereby supporting problem-solving processes.

6.2. *Overall Perception of the Lesson*

Analysis of interview data from the six selected participants revealed that pupils perceived the lesson positively. They found the tasks engaging and relatively easy to complete. Notably, they expressed greater enthusiasm for tasks involving Emil in the software environment, describing them as more enjoyable than those completed solely on paper. Pupils also felt that Emil provided valuable assistance in solving the problems. One participant remarked, *'If I didn't know something, I could try it with Emil.'* Another pupil, reflecting on Emil's role, said, '[I used Emil] ... *to help me with those tasks.'* However, this pupil also acknowledged their own active role in directing Emil:[13] *'It was more like I was moving Emil. But he was helping me sometimes; he somehow knew where to go, and when I told him where to go, that's where he went.'*

The pupils clearly enjoyed working on tasks with Emil on the tablet. Interestingly, despite being more challenging than the paper-based tasks, they still found these activities valuable. While the paper tasks required pupils to either fill in a frequency table based on the colours of houses in a picture or to colour houses according to data from a table, the software-based tasks introduced an additional layer of complexity. In these tasks, pupils not only had to interpret and apply the data but also control Emil using commands, while adhering to a predefined limit on the number of steps.

Based on the pupils' comments, we conclude that programming Emil held special significance for them. A bond appeared to form between the pupils and Emil – a phenomenon also discussed by Ackermann (2013) in her reflections on why children enjoy programming. According to her, the appeal lies in the sense of mastery it offers: *'… through giving instructions, young children gain mastery over their world. They create and control things to execute their orders. They set them in motion, make them do things, and "boss them around". How could this not satisfy a three-year-old's*

[13] Reminder: Decision-making, management and evaluation are entirely up to the learners solving the problem. Emil executes their commands (in direct control) or the whole programme (in computational control) without evaluating, in any manner, the correctness of the pupil's solution.

craving for omnipotence!'. However, as she later points out, the excitement of programming is not only about issuing commands but also about how the programmed artefact responds. A relationship based on dialogue and role reversal develops between the child and the artefact. Initially, the child is in control, issuing instructions in a language the artefact understands. Then, the artefact autonomously executes the commands, after which control returns to the child. The child evaluates whether the artefact behaved as intended; if not, they reflect on how to modify their instructions. Ackermann refers to this dynamic as the *take-over – let go – take-over* process. The pupils in the present study also recognised this reciprocal interaction when programming Emil. They understood that they were in control, yet they also perceived Emil as helping them – following their instructions precisely and thereby assisting in solving the problems.

Pupils were not discouraged from evaluating their experiences with Emil positively, even when they did not arrive at a solution on the first attempt. Two pupils who rated their enjoyment of working with Emil highly, one of whom emphasised her proficiency, also acknowledged that they initially struggled with some tasks. The main challenge was the limited number of allowed commands: *' ... because I needed one or two more* [steps], *and it wasn't working out. So I had to start anew.'*

Another aspect of the lesson that pupils appreciated was the opportunity to work in pairs. One pupil even rated collaboration as the most interesting part of the lesson. Working together also motivated some pupils to extend the assignment on their own initiative. For example, one pupil shared that in the second task her pair completed on the tablet, she and her partner discovered up to four different solutions instead of the expected two: *'We actually thought that we had to find two solutions each – so I found two, and she found two. In the end, we had way more.'*

6.3. *Working with Frequency Tables in the Context of* Emil the Keeper

Through our analysis of the interviews, we aimed to explore how pupils approached working with tables within our learning content and how they reflected on their practice. To investigate this, they solved tasks **C5i** and **C6i** in front of us, and we also examined their approaches to solving tasks **C5** and **C6** in the classroom. Task **C5i** differed from **C5** in the colouring of the houses, and pupils perceived the two tasks as *identical*. In contrast, task **C6i**, unlike **C6**, omitted the final-state picture representation and relied solely on data representations. Although pupils were able to solve **C6i** without difficulty, they emphasised the advantage of having a visual representation in **C6** to support their reasoning. As illustrated in Fig. 10, pupils navigated translations between different representations in tasks **C5i**, **C5**, **C6i**, and **C6**. These translations will be discussed in more detail in Sections 6.3.1 and 6.3.2. Notably, in tasks **C5i** and **C6i**, pupils no longer had access to the programming environment representation, which they had previously found helpful when working within the software environment (Section 6.1).

6.3.1. *Entering Data into the Table*

To better understand how learners approached entering data into the table and how they perceived their own procedures, we focused on the interviewees' solutions to task **C5i**. This task required translating a picture into a table (Fig. 10). Additionally, we explored whether the interviewees recognised that such a translation is unambiguous. At the same time, we examined their awareness that the reverse translation, i.e. from table to picture, can be ambiguous, potentially allowing for multiple valid solutions. This ambiguity was precisely the challenge they encountered in class with task **C6**.

When solving task **C5i**, two of the interviewees began by reading the short instruction aloud, while the other four proceeded directly to filling in the table. Most approached the task systematically, working through each cell row by row – completing the first row before moving on to the second. For each cell, they counted the number of houses of a particular colour in the corresponding row of the picture and recorded this information in the table. This linear strategy reflects an effective, though basic, form of decomposition – breaking the problem into smaller parts based on both spatial orientation (rows) and categorical variables (colours).

One pupil, however, took a different approach. Instead of progressing row by row through the table, she first focused on the top row of houses in the picture, then on the bottom row. As she encountered houses of a given colour, she counted all the houses of that colour in the row before entering the total into the table. She described her process as follows: *'So actually, in the top row, I'm going to do the math – one blue, so I write a one. Then there are two red ones, so I write a two. And there are also two greens, so I write a two. The bottom row is the same principle – one green, two blues and two reds.'* This alternative strategy also demonstrated decomposition, but it reflected a categorical rather than a spatial orientation in how the problem was segmented.

Across both strategies, pupils engaged in abstraction by translating the coloured visual elements into numerical representations. They omitted irrelevant visual details, such as the shape or arrangement of the houses, and focused solely on the colour and the position between the rows, which were the relevant data dimensions for the task.

All pupils described their approach to the task as either *'look and see'* or *'look and count'*, referring to how they determined the number of houses of a given colour in each row. Most explained their solutions in relation to the picture, as illustrated by the quotations above. When asked whether the problem had a single solution, they unanimously answered yes. However, when the question was extended – asking them to consider a scenario where they were given a completed table along with an uncoloured picture – they recognised that multiple solutions would be possible. This insight indicates a developing ability to apply generalisation when reasoning about the relationship between different representations.

6.3.2. *Interpreting the Table Content*

To explore how pupils approached and reasoned when interpreting data from the table, we analysed their solutions to task **C6i.** Additionally, we investigated how they perceived this task compared to task **C6**, which they had previously solved in class with the aid of an additional data representation.

All pupils began by reading the task, and two of them also read aloud the values in the table. One pupil read the values row by row without referring to the associated colours: *'In the top row: three, one, one; in the bottom row: two, two, one.'* The other pupil read the values while also naming the corresponding colours. Both demonstrated familiarity with the structure of the table before attempting to answer the questions. Two other pupils simply stated that they could see the numbers for each colour in the table and would proceed based on that. One remarked: *'We have a table here, and somehow, we have to read from it how many houses there are.'* Another noted the absence of the picture representation in this task, in contrast to the classroom version: *'Well, now we don't have the pattern here* [the resulting picture]*, but we know how* [Emil] *has coloured* [the houses]*.'* The remaining two pupils began answering the questions immediately after reading the task.

Question 1. *'How many red houses are there?'* required pupils to infer data. According to the four levels of cognitive difficulty in working with tables defined by Gabucio *et al.* (2010), this was a Level 3 question. Pupils had no difficulty identifying the relevant table cells or understanding how to process them. Several pointed directly to these cells and explained that they needed to sum the corresponding values. Most explicitly stated that, to determine the total number of red houses across the entire stage, they needed to consider both rows: *'Here, the question is how many red houses are on the stage, so we know that for the whole stage, we need to count the ones from the top row and the ones from the bottom row.'* In doing so, pupils demonstrated algorithmic thinking – identifying and executing a sequence of steps to arrive at the correct result.

Question 2. *'How many blue houses are there along the top row?'* was expected to involve lower cognitive demand than the remaining two, according to Gabucio *et al.* (2010). It was classified as a Level 1 question, requiring a direct reading of data from the table. Based on our interviewees' responses, we conclude that they indeed found this question easy. For example, one pupil immediately stated, *'It is clear, it is three'*, first pointing to the row – *'Because in the top row…'* – and then to the column containing the blue houses. Another pupil remarked, *'I'll just copy how many blue houses are in the top row; I'll just copy three'*, emphasising that the task simply involved retrieving a given value. The other pupils responded in a similar manner. While solving the question, they primarily pointed to the relevant table cell and verbally confirmed they had located the correct number. Additionally, one pupil explicitly noted that the bottom row was irrelevant for this task: *'Now we have to* [count] *the number of blue ones, but we can't even* [look] *in the bottom* [row] *because it says in the top row, so only three.'* This ability to filter relevant from irrelevant data and focus on the required part of the structure demonstrates a basic form of abstraction and evaluation.

Question 3. *'How many houses are in the top row?'*, like the first, required data inference and was therefore classified as a Level 3 task, according to Gabucio *et al.* (2010). Once again, learners had no difficulty identifying the relevant cells or determining the necessary steps to find the answer. All pupils recognised that they needed to sum the values in the top row. Some explicitly articulated their process: *'I count 3 + 1 is 4, 4 + 1 is 5.'* Others simply stated the final result without verbalising the intermediate steps. One pupil also explicitly noted that the colour of the houses was irrelevant for this task: *'How many houses are in the top row? So, there is no colour, so we have to count all the houses. So, five.'* This response demonstrates a purposeful selection of relevant data and the application of algorithmic thinking, supported by abstraction from unnecessary details.

We were also interested in what additional data pupils could infer from the table, so we asked them to formulate their own questions. We were pleased to find that several pupils spontaneously proposed original questions, some of which were even more complex than those they had previously solved. Notably, some of these questions reached Level 4 in cognitive difficulty, *interpreting with broader reasoning*, according to the classification by Gabucio *et al.* (2010). An example of such a question was: *'How many more blue houses are there in the area than red ones?'* This demonstrates the pupils' ability to apply algorithmic thinking and abstraction in order to interpret data from tables.

In **C6**, the classroom variant of **C6i**, pupils were first asked to colour the houses in the picture based on the data in the table before answering a set of questions. We were particularly interested in their approach to this task. The pupils reported that they began by colouring the picture and quickly recognised that multiple valid solutions were possible. They then used both representations – the picture and the table – to answer the three questions, verifying that they arrived at the same result in each: *'I looked to see how many houses were in the picture. Then, I looked to see how many were in the table to see if that was correct. And then I wrote it down.'* Another pupil explicitly stated that counting the houses in the picture was easier than relying solely on the table: *'How many red ones are in the area, so I calculated that – one and one. But it was better for me when I looked at the picture too, because I had already coloured that in, and there were already counts, so I saw I was wrong there, too.'* Overall, pupils found it beneficial to have the data presented in both formats. While either the picture or the table alone was sufficient to answer the questions, they appreciated being able to cross-check their results using both representations, which helped ensure consistency and accuracy. This behaviour indicates an emerging ability to evaluate the correctness of their approach and outcomes – an essential dimension of CT (Csizmadia *et al.,* 2015).

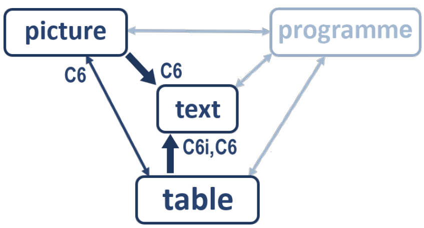


Fig. 11. Results of the analysis of tasks **C6** and **C6i**: Pupils used both pictorial and tabular representations for a 'safe' translation to text.

In terms of corresponding translations between representations, pupils initially translated information from the table to the picture. This was followed by parallel translations from the picture to text and from the table to text (Fig. 11). This finding was unexpected, as reported in Section 5, because we had assumed that pupils would use only one of these translation paths.

We consider the results of the analysis – structured around the three previously defined themes – as directly addressing our RQ, including all three specific sub-questions (*RQ1* in sections 6.1. and 6.2.*, RQ2* in section 6.3.1. and *RQ3* in section 6.3.2), within the scope of our research sample. In the following section, we will present our overall interpretation of these findings.

7. Discussion and Concluding Remarks

The current Slovak national curricula for informatics and mathematics education place strong emphasis on the skills required to explore, manipulate, interpret and utilise data represented in various structures – particularly sequences and tables, which are explicitly addressed in the primary curricula. In this study, we focused on tables and their potential role in developing CT within primary informatics and programming education. As noted in Section 3.1, existing research shows that tables are a challenging concept for pupils and require deliberate instructional support and thoughtful integration into learning materials. Educators and content designers cannot assume that pupils will naturally understand how to use tables effectively. In our previous, separate research (Cujdikova and Kalas, 2025), we found that specialists in mathematics and/or informatics education recognise both the complexity of working with tables and their potential importance in fostering the development of CT and MT.

The qualitative research presented in this paper confirms that a productive way to develop pupils' understanding of tables and related operations is to meaningfully integrate tables into constructive programming content from the early primary years. We explored this through a set of tasks from one of the worlds in *Informatics with Emil*. Although this was not the pupils' first encounter with tables in our learning content, the tasks in this particular world form a compact and coherent set, each involving tables and offering pupils opportunities to make their own choices, think critically and express creativity. Several tasks allowed for multiple valid solutions, which pupils identified and used effectively while collaborating in pairs – both at the computer and in their workbooks. Moreover, the design of the task set reflects all four levels of cognitive difficulty, as defined by Gabucio *et al.* (2010), making it a rich and layered learning experience.

The effectiveness of such linkage and integration, specifically, incorporating various structures, including tables, into the context of school programming, aligns with Papert's ideas in his seminal work *Mindstorms* (1980, p. 5), where he states: *'When children programme the computer, they establish an intimate contact with some of the deep ideas from science, maths and the art of intellectual model-building.'* Similarly, Ackermann's assertion that *'through giving instructions, young children gain mastery over their world'* (2013, pp. 11–12) proves equally relevant beyond early childhood, extending into primary education.[14] As one of our interviewees expressed: *'If I didn't know something, I could try it with Emil.'* This highlights how fostering pupils' intrinsic motivation not only enhances their potential but also increases their enjoyment of problem-solving – regardless of whether tasks involve other structures or present additional cognitive demands. We consider this conclusion to be the most significant practical implication of our research for designers of informatics content in primary education.

Our findings also highlight the potential of structure-based programming tasks to foster core components of CT in primary education. These include decomposition, as pupils break down visual or symbolic input into manageable parts; abstraction, as they identify and focus on relevant variables while ignoring superficial features; algorithmic thinking, as they construct step-by-step procedures to extract or calculate values; and evaluation, as they compare results across representations and validate their answers for consistency.

Given the qualitative nature of our research, we must formulate and interpret conclusions with appropriate caution. Nonetheless, we identify the following as significant findings from the present study:

- The opportunity to solve problems by controlling a character or characters is highly motivating for pupils.
- An engaging, game-like programming environment fosters perseverance – one of the key objectives of modern education.
- The thoughtful integration of varied contexts and concepts into the programming environment can support the development of complex cognitive skills beyond CT. Notably, the progression of tasks in *Emil the Keeper* helped pupils overcome identified difficulties and use tables effectively throughout their learning process.

The findings also encourage us to pursue further research aimed at systematically investigating the forms and effectiveness of integrating various structures into all components of modern informatics education. We also intend to further elaborate on the levels of cognitive demand outlined by Gabucio *et al.* (2010), not only in the context of working with tables, but across a broader range of learning tasks. Additionally, we see promising opportunities to explore the use of multiple representations of data, procedures and outputs throughout K-12 programming. This includes examining the cognitive demands involved in translating between representations and understanding how these translations contribute to the development of both CT and MT.

While our findings provide valuable insights into how primary pupils interact with tables in a programming environment, the scope of this study was intentionally limited. To gain a deep understanding of pupils' thinking and strategies, we deliberately worked with a small number of participants. This approach enabled focused observation and in-depth qualitative analysis. As such, the results should be interpreted within the specific context of the research and are not intended to be broadly generalised. Nevertheless, we believe these findings make a meaningful contribution to the ongoing discourse on fostering CT in primary education.

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[14] Based on our earlier experience in educating pre-service teachers and delivering PD trainings for practicing teachers, we have reason to believe that this enchantment and identification with the agent we control and animate through the programming language applies almost equally to pre-primary, primary, secondary and adult learners.

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Regarding the pupils' quotes (originally recorded in Slovak), we have endeavoured to preserve the natural flow of their speech in translation, including moments where they verbalised and revised their thoughts *'on the fly'*.

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