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SUMMARY OF PH.D. DISSERTATION

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DIAGNOSIS OF DYSCALCULIA FROM DIFFERENT FACULTY ASPECTS

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Introduction

The diagnosis of dyscalculia, dating back several decades in Hungarian, is based on practical experiences. In recent years, a need has emerged for evidence-based procedures that have previously been present throughout other branches of special pedagogy. In addition to the considerable professional experience gained from the practical exercises, to develop of the diagnostic area of dyscalculia, a review and analysis of the achieved results and methodology of frontier sciences is necessary. Furthermore, the development of the disability science approach, which provides the basis for domestic special pedagogy, has an impact on the dyscalculia diagnostic system.

Currently, in Hungary, only a small number of scientific literary works analysing the diagnosis of dyscalculia and its interdisciplinary background have been published, which were written based on the strict interpretation of the diagnostic process. The phenomenon of dyscalculia can be interpreted beyond the special pedagogical system from an individual perspective.

A complex overview of the field can provide a basis for implementing the current model of the system, clarifying related terminologies and definitions, defining the gaps and the developing alternatives offering a solution for them.

The approach providing the focus of the research

Diagnosis of dyscalculia is a test system focusing on special pedagogy following the terminology and concepts defined based on the results of frontier sciences. Including multiple diagnostic elements, it aims to explore the method and means of individual assistance for the individual being examined, for the purpose of re-education of dyscalculia.

The primary task of complex dyscalculia diagnostics is to develop and successfully implement the therapeutic activity taking into account the autonomy of the individual being examined, furthermore, for the development of tailor made coping strategies adapted to everyday life it is necessary to identify the complex personal and environmental profile with respect to providing a permanent control of the counting, numerical ability and mathematical attitude etc.

The definition basis of research

As the first phase of my doctoral research I redefined the subject of the diagnostic analysis based on the analysis of the literature (Farkané Gönczi, 2008, 2011). My elaborated complex dyscalculia definition: *Dyscalculia is a difficulty with a wide spectrum of symptoms occurring in mathematical performance, which is not related to the general intelligence level, associated with mental dysfunctions, which is caused by a difference in the structures and functions of multiple processing circuits that can be specifically related to numbers, which, in the case of comorbidity, affects further neurological networks or functions as a result of an inherited and/or acquired injury. The form, size, and extent of the appearance of dyscalculia is greatly influenced by the environment but does not constitute a causal factor (e.g. personality, attitude, behaviour, frustration, family habits, educational methods). The presence of dyscalculia can change the social participation of a person and their environment, hence their quality of life depends on their own copying strategy and the opportunities provided by their environment.*

For the complex definition, from the currently applied classifications the DSM V formed the basis of the special pedagogical focused system I developed, which clearly separated the different areas and their applicable diagnostic unit.

Definition	Background	Diagnostic focus	
Mathematical learning/performance difficulty	Personality or environmental impact, which in some cases provides a neurocognitive background (e.g. amygdala function)	Motivation, attitude, frustration, environmental barriers and support	Complex pedagogical diagnosis (discovering deficiency and base areas, defining the development direction)
Mathematical learning/performance disability (MLD) - counting difficulty DYSCALCULIA (DysC)	Neurocognitive background: numbers core system and related neurocognitive injuries (arithmetic concept, RTM, WM, attention, visual-spatial ability). (table 3 of dissertation)	Basic numeric and arithmetic abilities, non numeric cognitive functions	Complex dyscalculia diagnosis (mapping of neurocognitive deficiency and base areas, defining the development direction)
Mathematical learning/performance disability (MLD-CD) DYSCALCULIA (DysC-CD) - with comorbid difficulties	Neurocognitive background: Dyslexia comorbidity (grapheme and phoneme classification), ADHD comorbidity (executing functions)	Arithmetic, language, attention, executive cognitive functions	Complex differential diagnosis (injury-specific separation according to complex symptom characteristics, then determination of a development direction)

Table 1: The special pedagogical focus of the mathematical learning disability (MLD) clusters according to the definitions (Farkasné Gönczi, 2018/a)

Both diagnostic procedures and therapeutic special pedagogy procedures require individual application. The realisation of which depends on individual abilities and the identification of gaps, the definition the results, time frame and devices of the development process during the diagnostic and therapeutic procedures (Mesterházi, 2004).

Structure and methodology of the research

The exploratory research of dyscalculia diagnostics was carried out in three phases. The first phase is the literature analysis of the science field and frontier sciences, the clarification of the concept and terminology, as well as the elaboration of the criteria for the analysis of the diagnostic tools and the completion of the analysis.

The second phase is the surveying the specific field, the related professional group and the affected participative segments by conducting a diagnostic focused questionnaire. The questionnaire survey was repeated in 2012 and 2016. During the survey, we addressed 3 target groups with specifically designed questionnaires. The target group 1 consisted of experts performing professional committee activities (2012: N = 13; 2016: N = 21). The questionnaire containing 37 questions for the target group was designed to explore the practical experiences and expectations of the field. The target group 2 consisted of teachers teaching mathematics to younger children of elementary schools (2012:N=207, 2016:N=178). The aim of the questionnaire containing 20 questions, in addition to data collection, was the collection of practical recommendations on the lack of a filtering tools in literature analysis. The target group 3 consisted of younger students of elementary schools diagnosed with dyscalculia (N=218 /108 girls- 110 boys/). We were only able to survey the students in 2012. The purpose of the 13 question questionnaire was to collect the participative suggestions of the students and to explore the participation in the shaping of the test. The questionnaire was made with easy-to-understand communication to support reading comprehension.

The third stage is to test a series of 57 elements that can be applied for filtering during empirical research that responds to the uncovered gaps, in an abstract and story embedded format The two types of tests were analysed on the basis of the results of 143 responses (typical N = 116, students demonstrating learning difficulties categorised in a mixed group N = 20, student diagnosed with dyscalculia N = 7).

The results of the research considering the hypotheses

The main purpose of the research was to explore the diagnostic system of dyscalculia based on the results of different disciplines and to develop a response to the gap identified within the system. Hypotheses formulated at the beginning of the research reflected the expected results in the phases of the research process. In response to the purpose of the research, results were generated based on the hypotheses. Among others, the definition of dyscalculia, its special pedagogical classification system, its terminology and its complex diagnostic model.

<table>
<tr><td>Neurological background (Neurology)</td><td>Numbers core system and related neurocognitive injuries (arithmetic concept, RTM, WM, attention, visual-spatial ability). (table 3 of dissertation)</td><td rowspan="4">Other independent influencing factors
(Pedagogy)

emotional factor (attitude, frustration)

social factor (effects of the environment)
(Sociology)</td></tr>
<tr><td>Etymology</td><td>Primary: epigenetic and neurocognitive risk factors

Secondary (accompanying): language development, dyslexia, ADHD, syndromes</td></tr>
<tr><td>Cognitive representation (Psychology)</td><td>Quantity and number representation
Triple code model (mental number line, etc.)</td></tr>
<tr><td>Accompanying factors</td><td>executive functions
visual-spatial perception skills
attention
language skills
working memory
cause and effect</td></tr>
<tr><td colspan="3">Age specific characteristics ⇨</td></tr>
</table>

Table 2: The complex presentation of dyscalculia based on the findings of frontier sciences (The table was created by taking into consideration the dilemmas published by Szűcs et al. in 2016, according to Figure 1 of Kaufmann and von Aster's 2012 publication)

Table 2 gives an overview of the complex definition of dyscalculia in line with the findings of frontier sciences, the modern theory of disability science and the applied classification system. The change in the definition is also influenced by the legal environment, and by its place and role within the care system. The above definition outlines diagnosis of dyscalculia based on the data shown in Table 1.

Based on the detailed findings, dyscalculia is categories as a specific learning difficulty, defining its position as part of the mathematical learning difficulties system.

Hypothesis 1: The continuously evolving results of the different aspects of disciplines (neurology, psychology, pedagogy, sociology) expand and clarify the terminology of dyscalculia.

The definition of dyscalculia has become more refined, based on the findings of frontier sciences. Based on the results of the literature analysis and the Hungarian questionnaire survey, the use of the dyscalculia terminology is uniform and consistent, the underlying definition changes by frontier sciences, which are contained within the detailed definition.
The elaborate definition of dyscalculia is based on a complex diagnostic model that uses uniform terminology.

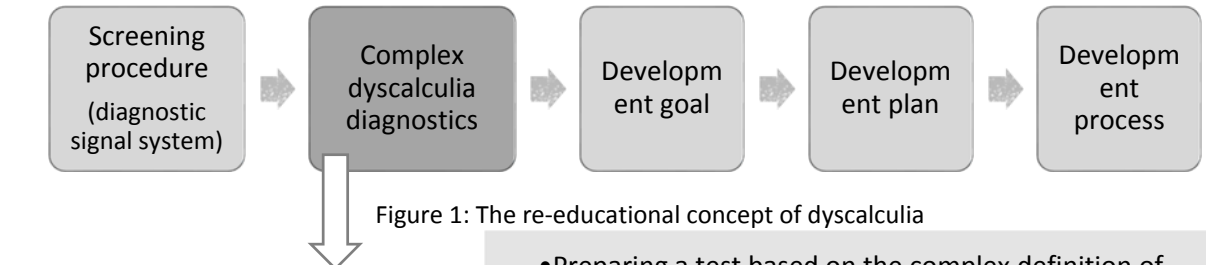

Figure 1: The re-educational concept of dyscalculia

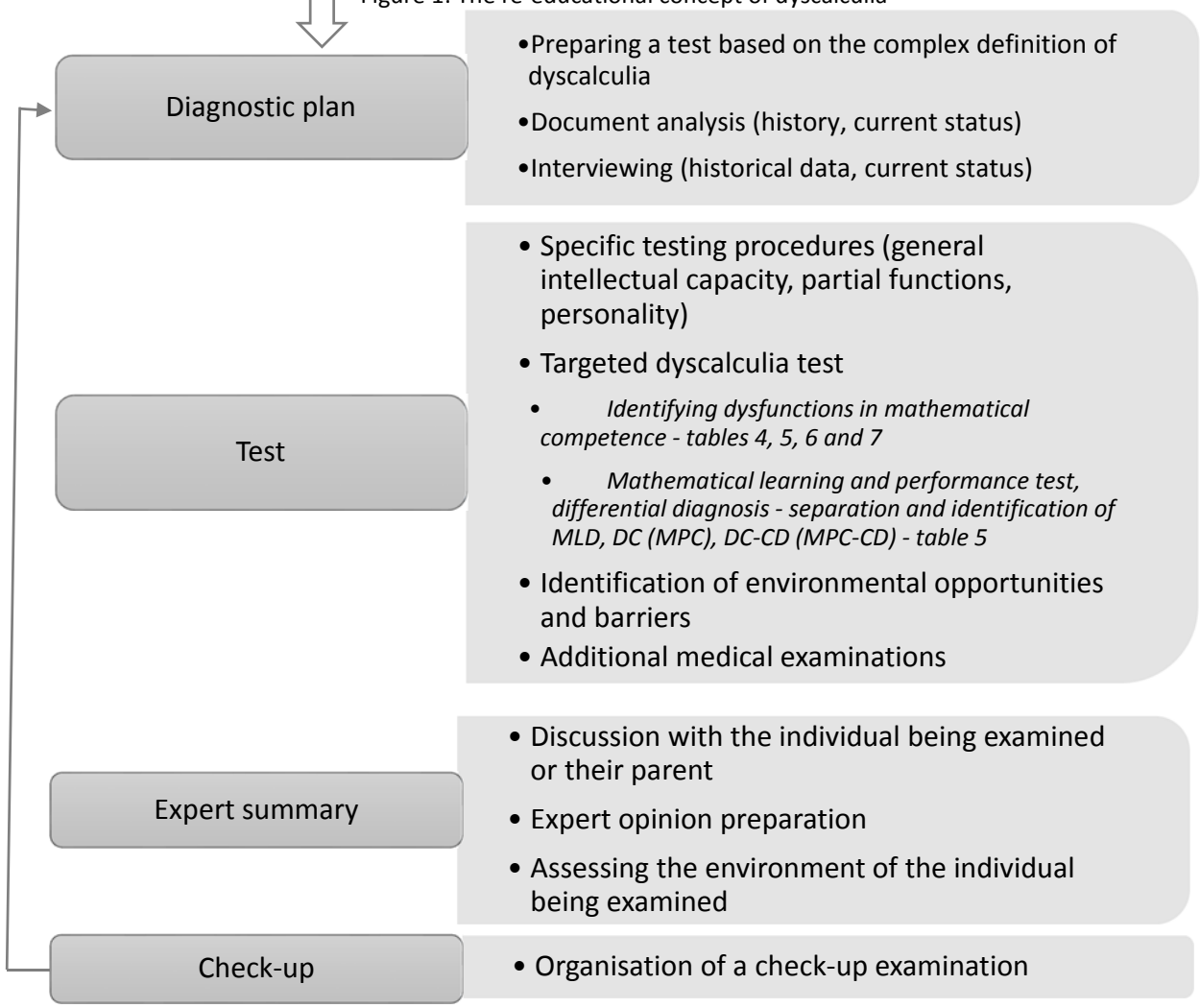

Figure1 2: Structure of the complex dyscalculia diagnostic model (based on Mohai, 2009; Nagyné Réz et al. 2015)

In order to analyse the domestic and international testing tools used in the complex diagnosis of dyscalculia, the basis of the system developed in this research is formed by the results of the disciplines collected during the development of the definition and the answers of the questionnaire survey. The set of criteria consisting of 15 points includes scientific (10) and practical (5) indicators: 1. Use of terminology, 2. Appearance of the neuropsychological models, 3. Human perception model, Scientific model of disability, 4. Pedagogical diagnostics approach, 5. Motivation type, 6. Communication tool and linguistic structure, 7. Context of the task, 8. Relationship between the individual being examined and their environment, 9. Appearance of IKT devices, 10. Level of scientific description, 11. Standard, 12. Type of difficulty, 13. Age, 14. Test time, 15. Device requirements

The question is which dyscalculia filtering and diagnostic tools analysed on the basis of the system of criteria have been applied in practice and to what extent. Hypothesis 2 assumed the dominance of the most commonly used diagnostic tool in Hungary based on the results of a questionnaire survey research conducted at university level (Farkasné Gönczi, 2008, 2011 / b).

Hypothesis 2: In order to develop the dyscalculia diagnostic tool system, the criteria examined from different aspects of the disciplines are the same as those provided by the professional committees.

Needs appearing among the responses in the questionnaires of professional committee members show the same development direction as those set by frontier sciences. In addition to the cross-section of common criteria of the different areas, the specific impacts of both sets of criteria are visible. Based on the questionnaire responses, there are several needs that are generated from practices, such as the need for minimal data entry. The basic pillar of dyscalculia diagnostics is the use of a standard-based testing tool that has full impact analysis (Illyés, 2004; Mohai, 2009). An element appearing in the set of criteria of the frontier sciences is, for example, the definitive nature of human perception of the testing tool or the definition of the level of child related context. "ICT-based testing excludes paper-based tools due to which the purpose and the possibilities of measurement and evaluation change" (Molnár, 2010, 22) providing individual assessment for special pedagogy and making progress more measurable (Virányi, 2014, 145).

Pedagogical diagnostics use methods known to the child, such as games (Szilágyi, 2009). The activity of the child is also an indicator of their abilities and the environmental effects

absorbed by them, that corresponds to the diagnosis based on the definition of dyscalculia in this research.

Hypothesis 3: In the case of suspicions of dyscalculia, professional committees use at least 50% of the Dékány-Juhász dyscalculia pedagogical examination tool or the Dyscalculia Pedagogical Examination (DPE) tool.

Based on a questionnaire survey of this doctoral research, in 2012, 92% and in 2016, 95% of the respondent experts performing professional committee activities selected the Dékány-Juhász Dyscalculia Pedagogical Examination as their preferred applied method. Among the responses of the 2016 year end questionnaire survey the new Dyscalculia Pedagogical Examination DPE tool developed by Dékány et al. was listed, which was selected by 14% of respondents. The emergence of the new testing tool may change the emphasis of using the domestic diagnostic tool in the long run.
Based on the theory and current practice of dyscalculia diagnosis, the development focus of the diagnostic tool system can be determined.

Hypothesis 4: In relation to the content and the format of screen or diagnostic tools, the needs of the respondent teachers and the staff of the institutions performing professional committee activities are the same as the respondent children's needs.

The hypothesis comes from the assumption that the development of disability science has an impact on the theory and practice of special pedagogy. The current post model is based on the falling apart of the disability concept that has so far been a secure referral point. One of the starting points for the new approach is “emphasizing the priority of the experience and knowledge of people living with disabilities" (Könczei, Hernádi, Kunt, Sándor, 2013). Based on the post model approach, during the doctoral research the special pedagogical diagnostics, including dyscalculia diagnostics, can be interpreted from within environment of the individual being examined by exploiting the opportunities originating from it. The approaches providing an overview of the applicability of diagnostic tools (Krajcsi, 2010), as a result of this research, have become a set of criteria from the aspect of frontier sciences, a further indispensable element of which are the expressed needs of the participants of diagnostics. The needs highlighted in the 2012 questionnaire survey of students, teachers teaching mathematics for

the younger classes, and experts performing professional committee activities relating to the diagnosis of dyscalculia were added to the complex set of criteria of the research expanded with new elements. The modern disability science approach behind the hypothesis has not yet appeared in the answers of the three segments, as the needs of experts performing professional committee activities and primary school teachers teaching mathematics to younger students, who during the response period were dealing with student demonstrating counting difficulties, and the response providing younger students demonstrating counting difficulties were not the same. Students need computer-based (2012-29%) activity requiring (2012-27%) testing tools, while the experts prefer the activity requiring (2012-31%, 2016-38%) paper-pencil format (2012-21%, 2016-24%). The needs of students, as experiential experts, has a only a minimal impact on the development of diagnostic tools. The current domestic diagnostic tool provides the target group with the activity requiring paper-pencil test format, which based on the responses, matches the needs of the performers of professional committee activities and teachers teaching mathematics to younger classes. However, the rise of computer-based tests is continuous (e.g. PISA tests, Development of Diagnostic Measurement 2009-2015: edia.hu), which strengthens the significance of the students' demands, therefore the hypothesis is likely to be verified within a few years.

Hypothesis 5: The performance points of the task elements of the dyscalculia diagnostic tools currently used in Hungary enable the criterion-referenced development activity.

The purpose of the diagnostic evaluation is to provide the criterion of learning, i.e. the ultimate goal of the development (elements to learned and the level of optimal preparation), and to know the current skill level of the children (Józsa et al., 2009). There are only a few international and domestic dyscalculia diagnostic tools that have standards or criteria based on test figures, according to which they may be appropriate for the preparation of criterion-referenced development by exact measurements of the specified criteria. Based on the questionnaire responses of experts performing professional committee activities, the dyscalculia filtering and diagnostic tools currently used in Hungary include the *Dékány-Juhász dyscalculia pedagogical examination* developed for the child population, its version published in 2017, the *Dyscalculia Pedagogical Examination* (DPE), and the *Developmental dyscalculia filtering and test forms* (DDF) developed by Ottilia Szabó. For the testing of adults the *Numeric Processing and Calculation Test* (NPCT) and the *Cognitive Development Testing of Arithmetic*

Skills (CDTAS) are available. Informal testing procedures include diagnostic tools developed and used by the fault analysis and response experts. Currently from the filtering and diagnostic tools listed in responses the Dyscalculia Pedagogical Examination (DPE), the *Numeric Processing and Calculation Test* (NPCT) and the *Cognitive Development Testing of Arithmetic Skills* (CDTAS) have a standard or large scale element scoring system. The Developmental dyscalculia filtering and test forms (DDF) can become a diagnostic evaluation tool of criterion-referenced development following the development of a large scale element scoring system.
The task elements of the story and abstract tasks detailed in this research are not suitable for establishing the basis for criterion-referenced development, as the vast majority of tasks discriminate well in the Θ <-1 range. However, more than half of children with learning difficulties and a quarter of children with dyscalculia have higher capabilities than this. As a diagnostic evaluation tool for criterion-referenced development, firstly, existing exercises should be complicated and simplified at the same time.

Hypothesis 6: More than 50% of children prefer a story-embedded filtering tool that is familiar to their usual stories, compared to the regular tests.

In the questionnaire survey of the present study, based on the responses detailed in tables 17 and 18 provided by younger students demonstrating learning difficulties, the playful story tasks (48 responses; $r_t = 0.51$) and the mixed format story tasks (41 responses) are preferred. The final questionnaire replies of the students participating in the empirical test unit further reinforce the hypothesis. 91% of the respondents found it playful, 79% of them thought it was exciting to have computer-based story embedded tasks, while only 7% of the respondents considered the abstract tasks exciting and 25% of them found it playful. 79% of respondents rated the computer-based, abstract tasks as the norm and 68% considered it familiar.
Both during the course of the questionnaire survey defining the basis of the research and during the testing of its filtering tool the respondents who experienced solving the story-based and abstract tests, prefer to filtering tool embedded in a story that resembles the stories they are used to instead of the usual list of tasks. In addition, the response rate of above 50% as defined in the hypothesis can be observed in both the questionnaire survey (see diagram 10) and the questions following the testing of story-based and abstract filtering tools. Based on the justification of the hypothesis, it is recommended to reconsider the methodology and

tools of dyscalculia diagnostics by merging the needs of individuals being examined and the diagnostic protocol and procedures.

Hypothesis 7: The filtering tool developed in the research shows an almost identical result in the mathematical performance factor of the story embedded and the listed task format.

According to significance level of McNemar's test, there was no significant difference in the ratio of the correct responses in 49 of the 57 items of the story embedded and abstract tasks. According to the Wilcoxon test, analysis of the reaction time (RI) of correct solutions of tests embedded in a story and abstract tests based on the minimum, maximum, median and average solution times, there is no significant difference between the dyscalculia (RI story: average: 24.3; median: 19.2 – RI abstract: average: 20.3; median: 16.0) and the typical (RI story: average: 7.8; median: 6.6 – RI abstract: average: 8.2; median: 7.0) group's performance. In the case of dyscalculia testing, both the scores and the reaction times of the dyscalculia and the typical groups involved, resulted in almost the same level of performance.

Further research prospects, and the applicability of the results of this research

In a special pedagogical sense, the diagnosis of dyscalculia is intended to reveal the specific ability profile of the individual concerned and the environmental factors effecting them, in order to tailor the accurate re-educative support and to map out the development strategies that fit into the individual's personal life management system. This is why, the identification of dyscalculia and the definition of areas needing development cannot be the only **purpose** of **dyscalculia diagnostics**, but rather **the laying down of foundations for a personalised complex development system that supports later life.**

The value of the present research is an interdisciplinary review of dyscalculia diagnostics and the analysis of applied testing tools according to the set of criteria, for which it has created the conceptual and terminological framework. The developed complex diagnostic model of dyscalculia can ensure the systemic functioning of the field and the achievement of the above-defined diagnostic goal. For further detailing of the model, it is worthwhile developing a classification focusing on special pedagogy (therapy) based on the definition of dyscalculia. Certain sub-criterion of the objective definitions of some elements within the set of criteria

that assist in the comparison of testing tools appearing in the complex diagnostic model of the dyscalculia are missing, thus significantly increasing the subjectivity of the comparisons of diagnostic tools. In further research, it is recommended to specify the set of criteria based on the practices of special pedagogy and other fields.

I consider the regular questionnaire survey of the doctoral research one of its elements of sustainability, which is conducted every 4 years, not burdening professionals, and produces comparable results regarding the development of the field. To this end, it is necessary to review the sampling method and finalise the content and format of the questionnaire based on the current experiences.

In order to find a solution to the gap identified during the analysis of the dyscalculia re-educational model, a list of tasks consisting of 57 items was created, which can be used in a test format corresponding to the age-specific characteristics of the individual being examined without modifying the content of the testing tool. The test results of the abstract story version of the tasks consisting of 57 items show that the story context of a tasks does not or does not significantly affect performance in relation to scoring and reaction times, while at the same time it reduces the frustration of the individual being examined. Controlling and further development of small scale element testing on a larger sample size can result in diagnostic results beyond the field of dyscalculia.

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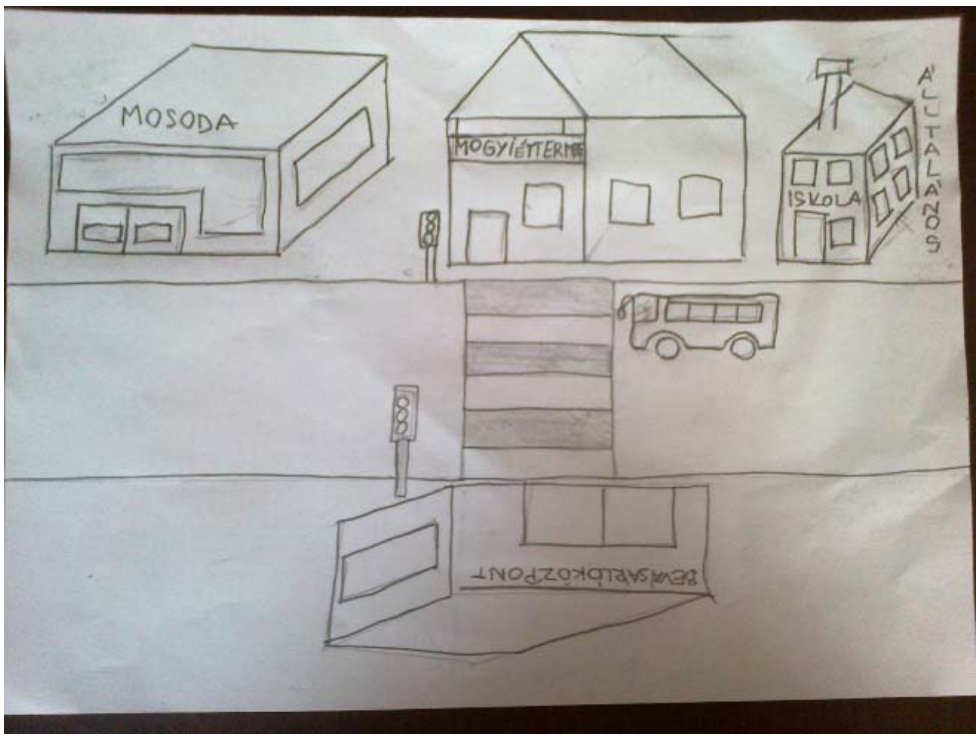
Products of online project work at the time of the development of the sreen device

Orientation



Poster design

Farewell to Mogyi