EVALUATION OF "MAKE PRACTICE" SIMULATIONS

1. Introduction

Constructivism is a contemporary model of instruction in which a student acts as a researcher. On the basis of competences already acquired, inspired by a teacher using various sources of information, the student independently gains new knowledge and skills. The "Constructivism in teaching math - open educational resources" Erasmus+ project has aimed at supporting secondary school teachers through developing solutions that can promote student interest in the subject, assist in discovery-based learning, and foster collaboration among learners.

During the project, 10 "Make Interest", and 20 "Make Practice" simulations have been developed and pilot tested. The "Make Interest" simulations were designed to inspire student interest in math, and to support self-directed acquisition of new knowledge and skills. The "Make Practice" simulations' aim, on the other hand, is to reinforce already acquired knowledge and skills. The project involved the organization of short-term training for mathematics teachers on interactive simulations, and the evaluation of the suitability of these simulations in the teaching process. The current document reports on the findings from the evaluation of the "Make Practice" Simulations.

2. Which math topics are covered by "Make Practice" Simulations?

The "Make Practice" simulation cover a wide variety of mathematical topics, including the following:

- Stereometry (The Two Towers of Polyhedron City)
- Planimetry (Plan a Town)
- Linear functions (Air Traffic Controller 1, Air Traffic Controller 2, Air Traffic Controller 3, Lizworlds 2: Point of Origin)
- Exponential Functions (Virus)
- Logic puzzles (Critical Thinking 1, Critical Thinking 2)
- Prime Numbers (Prime Run)
- Algebra (Algebra I, Algebra II)
- Stochastics (Probability)
- Statistics (Data Collection and Analysis)

The simulations allow learners to further practice some important, already acquired, mathematical-algebraic skills, while at the same time helping them to build their critical thinking and problem-solving skills.

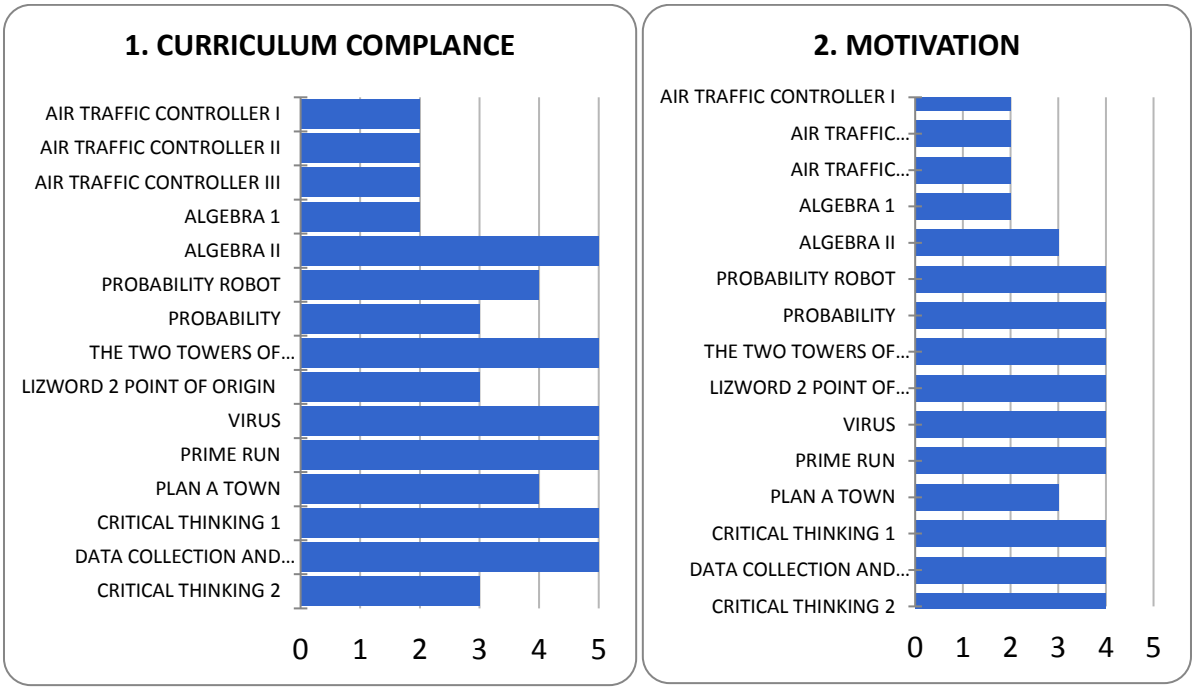
3. Methodology

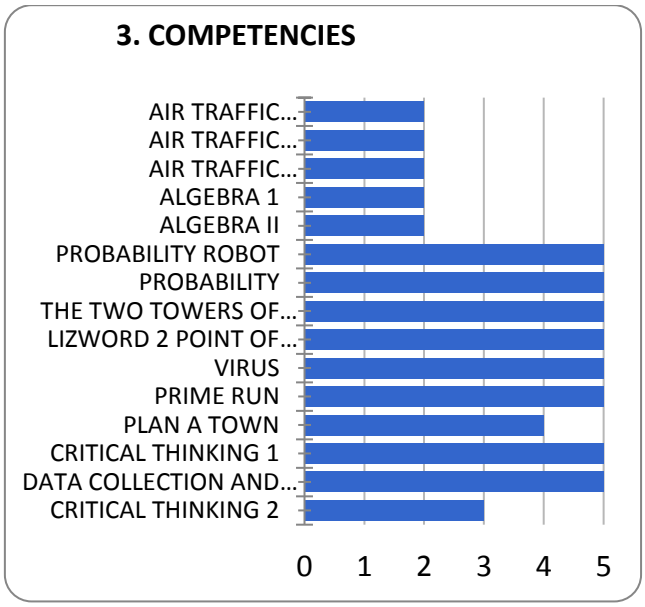
For each "Make Practice" simulation, teachers and teacher trainers have been asked, during C2, to fill out a questionnaire containing both a quantitative and a qualitative evaluation of the corresponding simulation. The qualitative part was mostly used to explain the ratings given in the quantitative part, and to highlight the reasons for particularly good or particularly bad ratings of the simulations.

4. Results

4.1 Curriculum Compliance, Motivation, Building of Competencies

The factors "Curriculum Compliance", "Motivation", and "Competencies" of each simulation were each rated by an integer number from 0 ("not at all") to 5 ("large extent") indicating the degree to which the teachers believed the simulation met the criterion. The following graphs present the ratings given by teachers to each of the 15 "Make Practice" Simulations in relation to each of these criteria.





To aid in the analysis of the data, teacher ratings were summarized as follows:

$0 \leq n < 1.25$ … not at all
$1.25 \leq n < 2.5$ … some extent
$2.5 \leq n < 3.75$ … fair extent
$3.75 \leq n \leq 5$ … large extent

The following table indicates the number of simulations rated by teachers as falling under each category.

	Curriculum Compliance	**Motivation**	**Competencies**
Large Extent	8	9	9
Fair Extent	3	2	1
Some Extent	4	4	5
Not at all	0	0	0

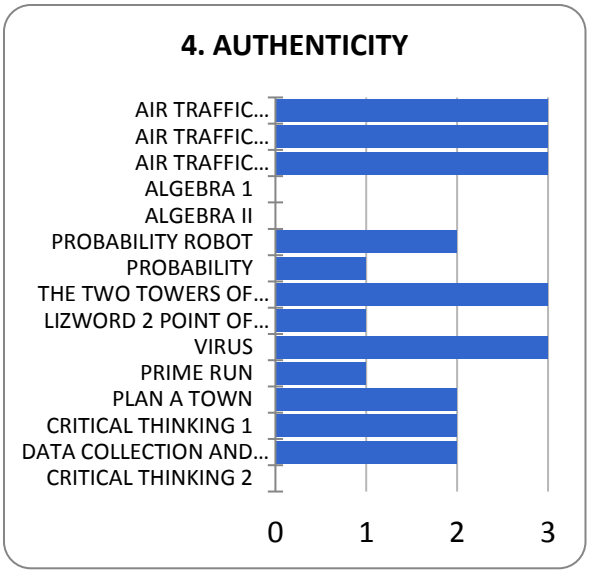
As shown in the table, out of the 15 "Make Practice" simulations, 11 simulations were considered by the teachers to be curriculum compliant to a large or, at least, to a fair extent. Similarly, 11 simulations were rated as being motivating to a large or fair extent, and 10 simulations as building students' competencies to a large or fair extent.

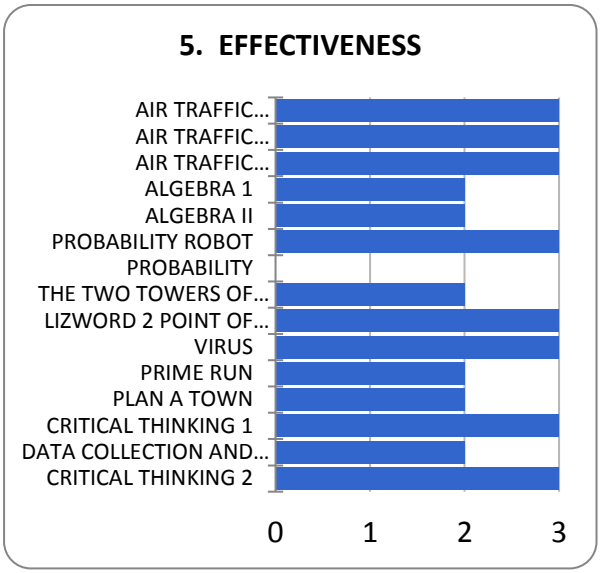
A closer look at the graphs above indicates that 9 of the simulations (Probability Robot, Probability, The Two Towers of Polyhedron City, LizWorld 2 Point of Origin, Virus, Prime Run, Critical Thinking 1, Critical Thinking 2, Data Collection and Analysis) were rated as fulfilling all three criteria ("Curriculum Compliance", "Motivation", and "Competencies") to a large or fair extent. Only four simulations received low ratings with regards to all three criteria (Air Traffic Controller 1, Air Traffic Controller 2, Air Traffic Controller 3, Algebra I).

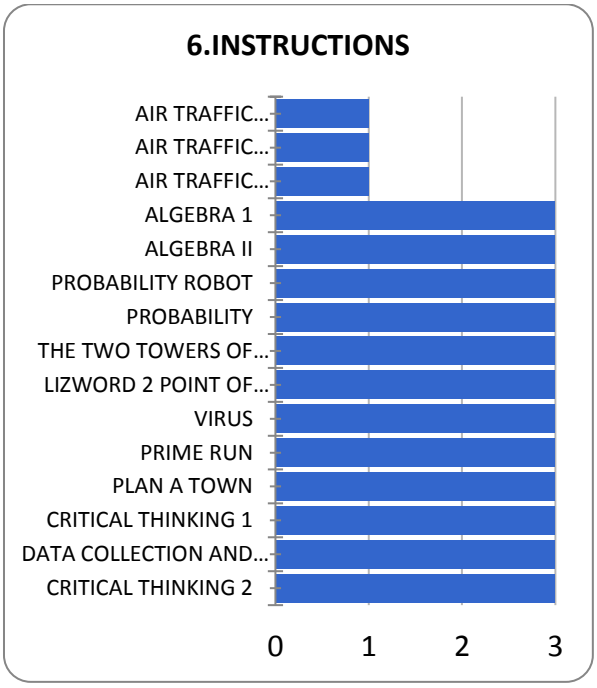
Thus, the project aim to produce "make practice" simulations that are curriculum compliant, motivating, and supportive of building of student competencies has certainly been fulfilled. According to the teachers' ratings, the majority of the simulations cover topics/competencies that are referred to in the national/regional curriculum, are attractive for students, and help increase the students' competencies in one or more areas of mathematics.

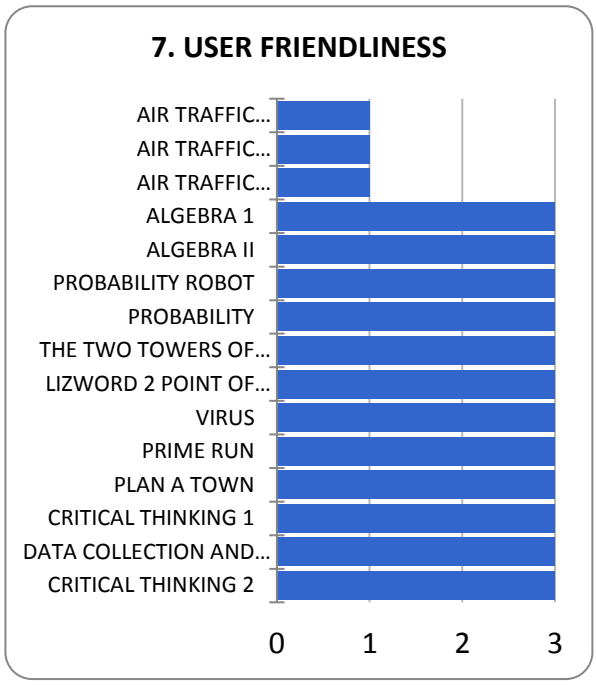
4.2 Authenticity, Effectiveness, Instructions, User Friendliness

The factors "Authenticity", "Effectiveness", "Instructions" and "User Friendliness" of each simulation were each rated by an integer number from 0 ("not at all") to 3 ("large extent") indicating the degree to which the teachers believed the simulation met the criterion. The following graphs present the ratings given by teachers to each of the 15 "Make Practice" Simulations in relation to each of these criteria:









To aid in the analysis of the data, teacher ratings were summarized as follows:

$0 \leq n < 0.75$ Not at all
$0.75 \leq n < 1.5$ Some Extent
$1.5 \leq n < 2.25$… Fair Extent
$2.25 \leq n \leq 3$ … Large Extent

The following table indicates the number of simulations rated by teachers as falling under each category.

	Authenticity	**Effectiveness**	**Instructions**	**User Friendliness**
Large Extent	5	8	12	12
Fair Extent	4	6		
Some Extent	3		3	3
Not at all	3	1		

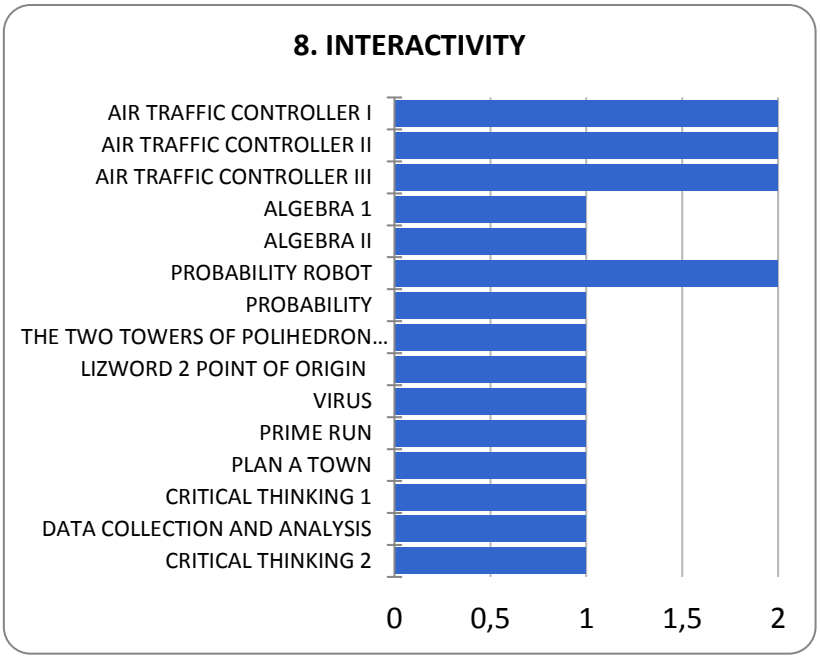
As shown in the table, out of the 15 “Make Practice” simulations, 14 simulations were considered by the teachers to be effective to a large or, at least, fair extent. Similarly, 12 simulations were rated as having instructions that are formulated in a clear and understandable way, and 12 simulations as being user-friendly. The number of simulations being rated as authentic is somewhat lower (9 rated as authentic to a large or fair extent).

A closer look at the graphs above indicates that 6 of the simulations (The Two Towers of Polyhedron City, Plan a Town, Virus, Critical Thinking 1, Probability Robot, Data Collection and Analysis) were rated as fulfilling all four criteria (“Authenticity”, “Effectiveness”, “Instructions” and “User Friendliness”) to a large or fair extent, and 5 more simulations (Lizworlds 2: Point of Origin, Critical Thinking 2, Prime Run, Algebra I, Algebra II) as fulfilling three of the four criteria to a large or fair extent.

Thus, most of the simulations were considered by the participating teachers to be worth introducing in their classroom since students could gain something while using them that they would not have gained (or not have gained in the same time) without (“Effectiveness” criterion). They also found the simulations to be user friendly, believing that students could launch them easily and without teacher support (“User Friendliness” criterion). Similarly, teachers found the instructions within the simulations or on Help pages to be clearly formulated (“Instructions” criterion). Although to a somewhat smaller extent than the other criteria, the majority of the simulations were also rated as being set in an authentic learning environment, having connections to real-world problems or the students’ living environment (“Authenticity” criterion).

4.3 Interactivity

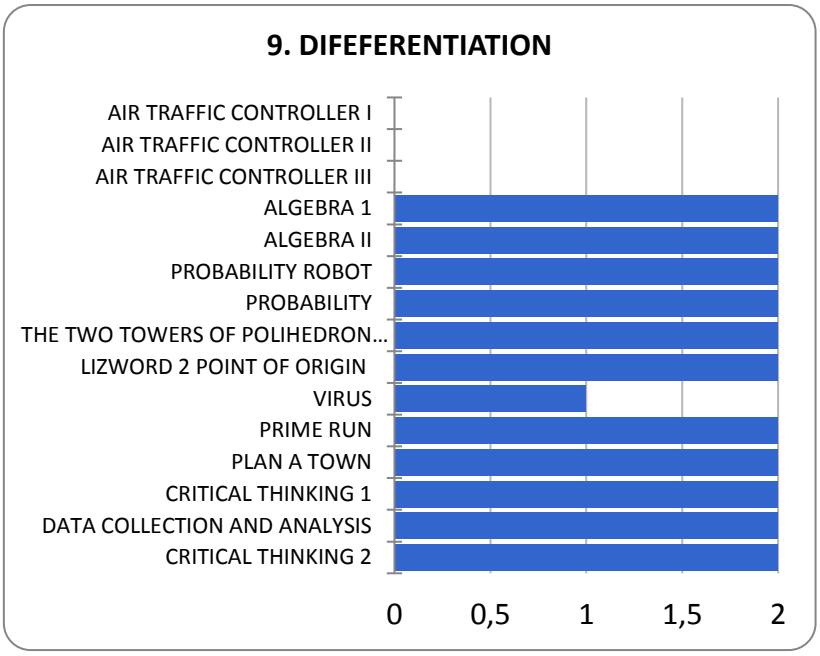
The following graph shows teachers’ ratings with regards to the criterion “Interactivity”. The level of interactivity of each simulation was rated by an integer number from 0 (“not at all”) to 2 (“Large Extent”):



Only 4 simulations (Air Traffic Controller I, Air Traffic Controller II, Air Traffic Controller III, Probability Robot) were rated as being highly interactive. Thus, the teachers would have liked most of the simulations to be more interactive. Of course, it should be pointed out that the purpose behind the development of the "Make Practice" simulations was for them to used by students for the reinforcement of already acquired knowledge and skills. Thus, it is only natural for the "Make Practice" simulations to be less interactive than the "Make Interest" simulations which were designed to inspire student interest in math, and to support inquiry-based learning.

4.4 Differentiation

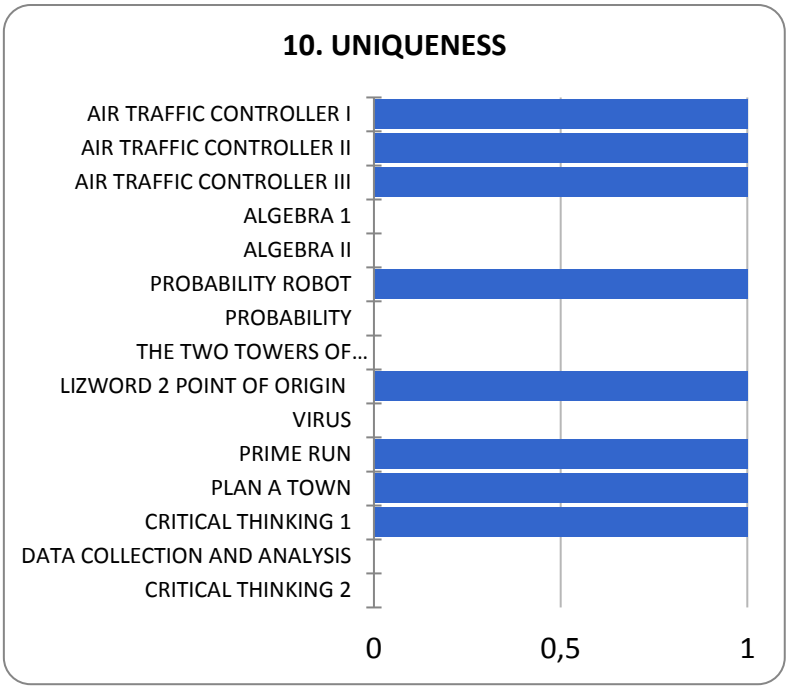
The factor "Differentiation" of each simulation was rated by an integer number from 0 ("not at all") to 2 ("Large Extent"). The ratings for each simulation are shown below:



As shown in the graph, with the exception of the three simulations relating to the Air Traffic Controller scenario, and the Virus simulation, all other simulations were highly rated. Teachers considered 11 out of the 15 simulations to allow to "a large extent" for differentiation of instruction, being characterized by flexibility with respect to students' competence levels and students' needs. The Virus simulation was considered to allow for differentiation to "some extent". With regards to the three simulations on the Air Traffic Controller scenario, teachers suggested combining them into one simulation with three different levels of difficulty so as to allow for differentiation of instruction: *"Should have prepared one game with three levels, not three games".*

4.5 Uniqueness

Finally, the factor "Uniqueness" of each simulation was rated by an integer number between 0 ("not at all") and 1("Large Extent"). Results are shown in the graph below:



As the graph illustrates, around 8 of the simulations were considered as unique, i.e. containing new aspects/ideas compared to other simulations, while the rest as standard simulations that have been implemented frequently. It is interesting to note that the simulations on the Air Traffic Controller, which were consistently rated low with regards to the rest of the criteria (with the exception of *Interactivity*), received a high rating with respect to uniquess. As the teachers pointed out, the idea behind this scenario *is "very interesting, it's about real life".*

5. Summary

Early in the MATH-FORTH project, the consortium did a study which investigated, through the conduct of questionnaires and interviews of pre-service and in-service math teachers, and math teacher educators, stakeholders' views "on the major issues or problems in teaching mathematics", as well as their views on what they consider to be "the hardest topics to teach in mathematics". The analysis of the collected data gave a good overview of potential problems in teaching mathematics, corroborating similar results that have been reported in the literature. The answers were sorted into three categories: Structural, student-related, and content-related.

The reported structural problems have been confirmed by many similar studies. The two major issues in this category were "lack of time" (this includes the oft-reported item "curriculum too full") and "too many students". These issues might be tackled by the use of ICT in general (ICT, if properly used, can save time, and several ICT media, e.g. E-Learning Platforms or electronic communication, can mitigate the effects of large number of students in learning groups). The "Make Practice" simulations, in particular, can be used to allow students to practice solving many mathematical tasks in a fairly short amount of time, particularly compared to classical paper-and-pencil tasks.

The major student-related issues were "negative emotions towards mathematics" (this includes math anxiety as well as several effects of a general society having negative attitudes about mathematics) and "lack of motivation" (as confirmed by several studies as well as by international comparison testing

like PISA). As the evaluation of the “Make Practice” simulations indicates, although having been developed with a different main goal in mind and being less interactive and authentic compared to the “Make Interest” simulations, “Make Practice” can also contribute quite a bit to the factor of motivation. Moreover, they can support individual students through the provision of activities with multiple levels of difficulty that allow for differentiation of instruction.

In the study conducted earlier in the program, although there was a variety of answers in the category of content-related issues, two mathematical topics were reported as problematic for students with higher frequency: “basic mathematical-algebraic skills” and “probability”. Although not mentioned in the questionnaires, the literature also reports “interpreting results” as a major content-related issue of concern. Despite “only” 15 simulations having been developed in the “Make Practice” area, a number of the identified topics of concern in teaching mathematics have been tackled by these simulations.