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Not peer-reviewed version

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Posted Date: 2 October 2024

doi: 10.20944/preprints202410.0157.v1

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Article

School Mathematics in Kazakhstan: A Blueprint for Digital Transformation

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Abstract: The article discusses the problem of digital transformation of school mathematics education. Two traditions of mathematical education in Kazakhstan are considered in historical perspective: "factory" and creative, research. The key features of the current state of the school education system in Kazakhstan in the framework of the mass school system and alternative systems are considered. The system of state final and current student assessment, elements of the digital economy of education are characterized. The socio-economic and political prerequisites for the possibility of significant changes in the education system are formulated. The necessity is substantiated for the effective development of the country in the 21st century of personality qualities brought up in creative mathematical education in the context of tasks that are "not known how to solve". It is shown that due to the use of digital technologies, in particular AI technologies, the process of transformation of the education system can be started in modern Kazakhstan. This transformation will be aimed at bringing the education system in line with the needs of the modern economy and modern society. The main components and dimensions of this process are considered. In particular, the necessary changes in the system of training and professional development of mathematics teachers and the necessary elements of continuity of this system with a comprehensive school are indicated.

Keywords: Kazakhstan; general education system; math education; problems "not known how to solve", digital technologies; AI technologies in education; teacher professional development; continuity of math education

1. Introduction

The main goal of these paper is to outline how the world-outstanding model of mathematical education that was working for a tiny minority can be extended to a mass school of a whole country.

The possibility of this extension is based on:

- Understanding of how the model works and exploiting of its core educational philosophy.
- The unique historical, geopolitical, political, social and mass-attitude situation in the country.
- The level of digital technologies achieved today and the adequate use of them in learning and teaching.

We believe that today Republic of Kazakhstan has exceptional capabilities to reproduce, extend, and upgrade this model. Factors determining the choice of mathematics as a school subject as an axis of change are:

- Mathematics is central to today's digital world.
- Mathematics education in the model discussed in this paper is the most important in terms of personality traits beyond mathematics necessary for successful life in the 21st century.

 doi:10.20944/preprints202410.0157.v1

2. Historical Foundation for the Proposed Model

In the 1930s an impressive model of mass school was built in Kazakhstan, as well as in the entire Soviet Union, to which Kazakhstan then was a part of. It was the 'factory model' targeted on industrialization of the country. The ideal image of the graduate assumed readiness for further education for an engineer devoted to the goal of building communism. The step down was a future technician, then – qualified worker, etc.

These happened during the dramatic period in the country life. In 1926, among Russians the percentage of literate people aged 9 to 49 years was 64.3%, among Kazakhs aged 9 to 49 years, literate was 9.9%[1]. Historically, the 1930s were tragic for Kazakhstan due to the policy of collectivization which had very negative consequences, with a wave of famine that reduced by half the native population [1].

Already in the 1930s, observing the emergence and formation of this 'factory school' model in USSR, working mathematicians of Russia became concerned with the search and educating of future professional mathematicians. One way or another, in 1934–1935, a movement of **math olympiads** and **math circles**[2] arose in the main mathematical centers of the country – in Moscow and Leningrad [2–5].

The essential feature of this way to study mathematics was **solving challenging problems – problems not known** (to the student) **how to solve**. So, it was very similar with 'doing' mathematics in Paul Halmos sense [6] we shall discuss later.

In the 1960s, the model of olympiads and circles was transferred to the core-curriculum of specialized high school, where it was happily combined with computer programming – interpreted for the authorities as industrialization of the emerging Digital Era, as a technical specialty, 'real labor', and not as kind of creative even too intellectual one. Importantly, all this was implemented within the framework of the main, mandatory program of special mathematical schools, that is, teaching hours were not extracurricular, but simply included in the main timetable. Children were selected for math classes through circles and olympiads: those who were interested in going to the circle, say, for a year, came study further in math class.

Among special schools were boarding schools at Moscow, Leningrad, Novosibirsk and Kiev universities (the main university for each city). On October 16, 1972, by Decree of the Council of Ministers of the Kazakh SSR No. 55, on the initiative of the famous mathematician O. Zhautykov, the Republican Physics and Mathematics Boarding School was opened, with the enrollment on a competitive basis students from city of Alma-Ata and from the regions of the Republic[3].

An important feature of the circles and leading mathematical schools was the individual one-to-one dialogue between the teacher and the student. As a rule, the dialog was related to the solution presented by the student. In many cases, this solution had flaws, gaps in the presentation and simply errors. The teacher's task was to help the student take the next step towards a right solution, being the least 'invasive'. There is an obvious drawback to this model. Practice shows that the model works if the number of students per teacher is 5–8. It is impossible for mass public school to find a staff of teachers, nor the means to pay them. In the case of the circles, the solution was formed spontaneously. Initially, the main leader of the circle was a university professor, sometimes an outstanding mathematician. The payment was insignificant for them. Other teachers of the circle were students, often pupils of this professor working for a non-material motivation. Over time, a culture was formed in which all the teachers of the circle were the students themselves once went through a circle.

This model was transferred to school. The role of the professor gradually passed to a teacher, who felt that working at school was their vocation. The additional teachers in the class were still university students, often graduated from this school. Students often worked here for free, or for a meager salary, "paying for the bus".

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1. Population of Kazakhstan in 1917–1939. Qazaqstan Tarihy, 6.10.2019. Available online: https://e-history.kz/ru/seo-materials/show/29324 (accessed on 29 September 2024).
2. Math circle. Wiki page. Available online: https://en.m.wikipedia.org/wiki/Math_circle (accessed on 29 September 2024).
3. Ministers – graduates of school named after O. Zhautykov. Qazaqstan Trihy, 20 Oct 2016. Available online: https://e-history.kz/en/interactive/show/23383 (accessed on 29 September 2024).

 doi:10.20944/preprints202410.0157.v1

In the USSR the Correspondence (distant) Math School was also launched, operating with regular mail. Children were receiving assignments and educational content by mail, packed in paper envelopes. They were solving problems in their (paper) notebooks and sending these notebooks to the School. There the students at Moscow University were checking the works. The children, who had high motivation and dream to enter good university, could really enter there. The students who were checking the schoolchildren works did not receive payment. The incentive for the students, was that they were graduates of the same Correspondence school, so they were paying their duty to 'alma mater'. Also, the university system assumed that students had volunteer work; so, checking the notebooks, as well as working in a special mathematical school, was considered as volunteer work.

The next great story was started in 1981 when Novosibirsk professor Andrei Ershov announced the slogan "Programming is the second literacy". In the mid-1980s, by decree of the top authorities of the country [7] a computer science course was introduced to all high schools in the country, including Kazakhstan. The course was designed by a team of mathematicians of the same 'Moscow mathematical school' of Nikolay Lusin as were involved into circles and schools discussed above. The leader of the team was Ershov and organizer and member – Alexei Semenov (an author of the present paper) [8].

It was a course in "computational thinking" reflecting the research style of learning and teaching that was present in circles and special schools, but not in mathematics of mass school.

The model of mathematical circles was successfully reproduced by Russian emigrants in the USA, Great Britain and other countries[4] [9].

3. Republic of Kazakhstan Today

The second component of the background of our Blueprint is understanding the situation of the country today. Here are the major important factors in the development of this large, 9-th in size of the World, country situated in the heart of Eurasian continent.

3.1. Demography

The population, that two centuries ego was mostly nomad, today (as of August 2024) is cca. 20 mln., of which 63% is urban and 37 % is rural. Age group 0 – 14 constitutes 30%.

Ethnic Kazakhs make up 70%, Russians 15%. The 20 century geopolitical processes made contribution to the situation as of exiles of German and Korean origin as well as of other groups were concentrated in labor camps and settlements in Kazakhstan; some of them stayed there.

Kazakhstan in the 21st century is characterized, firstly, by very rapid population growth. The "fertility rate" is about 3 provided by ethnic Kazakhs. In European countries today it does not reach 2.

3.2. Digital Economy

Second, after the population growth, factor in our Blueprint, is the government's focus on the priority of the digital economy reflected in executable political decisions, real actions, real investments [5][6][7]. The large territory of Kazakhstan makes digitalization difficult in a way, but even more important. There is a considerable increase in connectivity and access to the Internet in the

4. Math Circle Network. Available online: https://mathcircles.org/ (accessed on 29 September 2024).
5. Order of the Minister of Education of the Republic of Kazakhstan dated December 30, 2022 No. 533 "On amending the order of the Minister of Education and Science of the Republic of Kazakhstan dated January 27, 2016 No. 83 "On approval of the Rules and conditions for the certification of teaching staff…" Available online: https://aitei.aqqulyroo.edu.kz/images/533-12-2022.rus.pdf (accessed on 29 September 2024).
6. Law of the Republic of Kazakhstan dated December 27, 2019 No. 293-VI ZRK "On the status of a teacher". Available online: https://adilet.zan.kz/rus/docs/Z1900000293 (accessed on 29 September 2024).
7. Order of the Minister of Digital Development, Innovation and Aerospace Industry of the Republic of Kazakhstan No. 227/HK dated 07/01/2022 "On approval of the methodology for building smart cities (Reference standard for smart cities of the Republic of Kazakhstan)". Available online: https://www.gov.kz/memleket/entities/mdai/documents/details/328704?lang=ru (accessed on 29 September 2024).

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regions of the country even if economically it will look unprofitable for telecommunications providers.

The digital economy of education is surprisingly strong for a country of that not big population. We shell consider this in more details below.

3.3. Language

The third factor is a peculiar language situation in Kazakhstan. The country is officially bi-lingual: official language – Kazakh, Russian is used for interethnic communication, both spoken of about 80% of the population. There are also indigenous or migrant languages like Uzbek, Uighur and Tajik, used by minorities and assumed in primary education of them.

Kazakh is used as everyday language of most ethnic Kazakhs. A part of the situation, including its ICT aspect, is the alphabets. In 1929, the alphabet was changed from Arabic to Latin-based and in 1940 to Cyrillic-based.

The government plans the transition to Latin. One example of the peculiarity of the situation – the president of the country Kassym-Jomart Tokayev expressed a preference of the new Latin name for the country Qazaqstan instead of former English transcription of the Russian name Kazakhstan.

There is the Russian language, which continues to be the main language of science and culture for the middle and older generations, as well as interethnic language. But today there is a natural and enforced process of reducing the role of the Russian language.

English is the language of integration to the world community, the language of science and technology for the younger generation. Education in Britain and other Western countries plays the role for the elite that was the education in the metropole capitals of USSR before.

Another feature of the language situation is the high role of oral communication (in all three languages), including in the digital environment, compared to written communication, more than, say, in Russia.

3.4. Pre-University Education

There is a shortage of schools (as well as of kindergartens, of course) and teachers caused by the rapid growth of the young population. There are still schools operating in three shifts, not even two.

The construction of modern schools, in a climate that is traditionally called 'continental' is expensive and labor-intensive task. This is further aggravated by the presence of seismically unsafe areas.

Currently, a massive construction of new schools is underway in Kazakhstan, in particular, but not only, within the framework of the "Comfortable School" National education project [8]. Construction is carried out at the expense of national and local budgets, funds from corporations conducting housing construction as a fulfillment of the obligation for the use of land, public-private partnerships, investors planning a school as a commercial enterprise, etc.

By the decrees of the President of the country and by laws, teachers' salaries were considerably upgraded.

On the other hand, there is a willingness of the "upper middle class" to invest in education of their children. The cost of tuition in a private school in Kazakhstan supports a balanced educational model, so that teachers there, on the one hand, receive a higher salary than in public schools, and, on the other hand, provide a greater degree of personalization for children.

In addition, there is a relatively high level of educational philanthropy inspired by the urgent need.

All this creates such fertile ground for investment, charity, educational business, and so on. On the other hand, the problem of the quality of education arises, because training new teachers in pedagogical programs is a serious problem.

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8. Implementation of the pilot National Education Project "Comfortable School". Available online: https://skcn.kz/en/page/komfortnaya-shkola (accessed on 29 September 2024).

 doi:10.20944/preprints202410.0157.v1

3.5. Digital Transformation of Education

Digital transformation of education is one of the proclaimed slogans, as in a number of other countries. Thanks to a combination of government slogans, attitudes, and funding, and private mechanisms, in Kazakhstan considerable results have been achieved and mechanisms for change have been built. In particular [10,11]:

- A high level of connectivity and equipping schools with digital tools exists.
- The main procedure for final high school exam – Unified National Test (UNT) is carried out on a computer, using proctoring, provided by the corporation UStudy.
- An electronic diary Kundelik (and there are alternatives) has been introduced, basically similar to a paper diary, providing parents, through a mobile phone, with information about their child's current progress and class attendance.
- Educational literature (including major Ministry approved textbooks) is posted on the Internet by the corporation Bilim Media Group.
- Starting from the first grade, a mandatory digital literacy lesson has been introduced.

3.6. The Quality Issue

The state is trying to ensure quality of education by strengthening and changing government regulations: introducing a system of continuous certification of students, certification of teachers, and so on. We know that in some economies with promising educational system, such as the Finnish one, the way to improve quality was to weaken state control.

Here is an information about UNT [12]: "… a secondary school leaving examination and entrance exam for the higher education in Kazakhstan. The UNT is:

1. Examinations in schools (for obtaining a certificate of secondary education and obtaining "Altyn belgi").
2. Exam for admission to universities and the system for the allocation of state grants.

Final certification in schools is conducted in the following subjects:

- Mother tongue and literature (written in the form of essay).
- Kazakh language in schools with Russian, Uzbek, Uighur and Tajik languages of instruction. Russian language in schools with Kazakh language of instruction (testing).
- History of Kazakhstan (oral).
- Algebra and basic calculus (in writing).
- Subjects of choice (Physics, Chemistry, Biology, Geography, Geometry, World History, Literature, Computer Science, Foreign Language (English, French, German)) (testing).

A total of 120 questions are asked". "Testing" means multiple-choice test.

3.7. The Main Educational Systems Alternative to the Mainstream

An important feature of the country is the presence of school systems here, which are little subject to government regulation.

The most visible are the Nazarbayev Intellectual Schools[9], created under the direct patronage of the previous president Nursultan Nazarbayev. The system is highly selective, formally and informally focused on Cambridge Assessment.

The second system was the Kazakh-Turkish lyceums (KTL), currently united as a general education non-profit structure Bilim-Innovation[10], and in the practical management of specific schools Bilim Orda [11]. They were created with the broad support of one of Turkey's former major political and business leaders.

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9. Nazarbayev Intellectual Schools. Available online: https://en.wikipedia.org/wiki/Nazarbayev_Intellectual_Schools (accessed on 29 September 2024).
10. Bilim-Innovation (in Kazakh and Russian). Available online: https://bil.edu.kz/?lang=kk-kz (accessed on 29 September 2024).
11. Bilim Orda. Available online: https://bilim-orda.kz/en/admissions/ (accessed on 29 September 2024).

 doi:10.20944/preprints202410.0157.v1

The third system, we have already mentioned, are the republican physics and mathematics schools, which arose in the 1960s and later as a part of broader movement in the Soviet Union and exist now in regions of the country.

Graduates of the mentioned 'alternative' systems, as well as of individual private schools play a significant role in the life of the country. For example, the Republican School of Physics and Mathematics is proud that the founders of Yandex Arkady Volozh and Ilya Segalovich are its graduates.

A certificate of general education is given upon successful completion of a school course, without the mandatory passing of the UNT. Graduates, for example, of the International Baccalaureate system, often do not pass the UNT and enter foreign universities.

Another alternative for UNT systems is Advanced Placement in accordance with the requirements of American education[12].

4. The Opportunity Now

In most of countries, changes, even obviously progressive for education, encounters resistance from society and, to an even greater extent, from professional teachers. This is due to natural inertia and the attitude: "it wouldn't be worse".

The situation with school places and with schoolteachers in Kazakhstan creates **window of opportunity** for growth and progress towards promising side of modernization. There is an opportunity for many people trained in and for new educational models to enter education.

We believe that proper school mathematics can best prepare a person for the digital world. Not only because it will give them specific mathematical or programming digital skills, but because it will prepare them for solving unforeseen, unpredictable challenging problems, what is necessary in the digital world of today.

So, our Blueprint is based on:

- Strong existing tradition of special math school extended to mass school with the help of digital technologies and AI.
- Innovation potential of young generation raised in strong schools and powerful alternative school systems.
- Attitude to digital economy and education by the state and society.

4.1. The Educational Philosophy

4.1.1. Mathetics

In our historical introduction, we have described our school mathematics education model that is the realization of the principle of 'learning-by-doing'. 400 years ago, it was expressed by Jan Amos Comenius – 'the teacher of nations': fabricando fabricamur – creating we create ourselves [13]. In the 20th century, the famous Hungarian-born American mathematician Paul Halmos said and implemented in his books and courses the principle: "the only way to learn mathematics is to do mathematics" [6]. The experience described above is the successful implementation of these principles.

The focus on the student, personalization is the important concept for educational trends of 20th century. In the book of Comenius, published posthumously, the science, art, and technology of learning is called "mathetics" [14].

4.1.2. Expanded Personality

When discussing the issue of the results and course of the educational process, we consider a person, a student as an "expanded personality", constituted by integration of their biological component and digital component. This is a continuation of the line of Lev Vygotsky [15,16], Andy

12. Advance Placement (AP) Program – Kazakhstan. Portal kazakhstaneducation.info. Available online: https://www.kazakhstaneducation.info/international-tests/ap (accessed on 29 September 2024).

 doi:10.20944/preprints202410.0157.v1

Clark [17], Michel Serres [18], Iosif Feigenberg [19]. On the other hand, this same person, turns out to be connected to a community of people also expanded, see Luciano Floridi's book [20] and his other works. So, we have digitally expanded community, society, the Humanity. That means that talking today about an individual person or a group of people, not talking about their digital component, is meaningless and harmful. We consider the results of learning not just for a person deprived of everything, who must rely on their memory, arms and legs, eyes. We should consider results of a person whom we allow to use, say, paper and pen, abacus, ruler and compass, as well as calculator and Internet search. Of course, this position weakly combines with the existing education system. We consider it as a direction of transition, at least as educational philosophy [21].

4.1.3. Constructionism

The third concept of our philosophy is Seymour Papert's constructionism [22]. The core paradigm of constructionism is the construction by learner of internal models of reality, learner's orientation and acting in this reality. It happens in the relevant to the learner material and social environment, relations, and with support (scaffolding) of the teacher. From the very beginning digital environments, tools for scaffolding, acting and communication are assumed.

4.1.4. Motivation

The key question for modern education is whether children will learn at all is the problem of motivation. Different types of motivation can be classified accordingly to "Types of Personality Adaptations" [23]. This, in particular, suggests that different types of learners have different ways of motivating them. We are not talking about children only, of course.

Of course, the element of competition in different communities is interpreted and perceived differently. For modern Kazakhstan competition between students, as well as discussion of future prospects, namely local ones, turn out to be important.

The issue of motivation lays next to the problem of cheating. If the assessment mark is the major motivation, cheating is almost inevitable. If we are successful in motivating the student by their activities in solving problems 'not known how to solve' and discussing ideas with an interested person exiting with the discussion, then cheating is just missing the point – "I am spending my tuition fee and time for nothing".

4.2. Productive Mathematics Education

4.2.1. The Process of Learning. Personalization

In modern learning for the modern world it is necessary for a student to discover, invent, experiment, and conduct research. Computer-assisted experimentation in the mathematics reality is becoming an important part of mathematics education. Next is the use of a computer to solve problems, in particular to model phenomena, processes, and objects. Both types of problem-solving can require programming the computer by the student, and then using it.

One more element of the process is dialogue with the teacher. We will use university students as teachers first of all 'teachers-to-be', as well students from other university programs.

We have already said that we want to move away traditional industrial technological model of the school. In this traditional model student reaches the top five, being able to fast solve problems of known types without error. We want to move on to another model where a student is given a task he / she initially does not know how to solve. At the same time, their mistakes are a material for feedback from the teacher, or the digital part of the teacher, which helps the student to move on [24].

4.2.2. Digital Learning Environment

Digital learning environment should contain:

- a system of goals of various levels, from which each student chooses their own,

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- tasks whose sequential execution allows the student to achieve goals, tools for constructing individual trajectories, fixing tasks (with the ability to choose) and the planned completion time,
- task execution environments – tools for 'doing mathematics' that also monitor and record task completion: keyboard work, class discussions and presentations, project group meetings,
- means for communication between students and teachers, presenting assignment results to the teacher, and receiving feedback.

Digital learning environment should allow:

- identify the degree of achievement of the goal, compare with the plan,
- identify situations of deviations from the trajectory, excessive expenditure of time and effort (measuring motivation and fatigue),
- make predictions for different periods of future (from seconds to decades),
- visualize the process for each student, subject, assignment, etc. with varying degrees of detail to the class and the school as a whole, with a visual representation of deviations of predictions.

Environments and tools for completing mathematics assignments are discussed further in the educational content section.

4.2.3. The Education Goals

Now we will talk about rapidly evolving goals of education that are priority in the digital transformation of schools.

We highlight **pre-adaptation**, "ability and attitude to solve problems that are not known how to solve" (relative to the learner). The very process of solving the problem, even not leading to the ultimate solution is a very effective mode of learning. We emphasize that the educational goal under consideration now is not 'internal' mathematical, it is meta-objective. But we are convinced that the school mathematics course, rebuilt as we see it, best suits the formation of this goal.

Next goal is **computational thinking**. There are different definitions for this notion. Once upon a time these words were used by Seymour Papert [22]. We believe that the Andrei Ershov's slogan "Programming is the second literacy" is about computational thinking [25]. Nicholas Negroponte issued a term 'being digital' [26].

Summing up different sources, we can highlight dimensions in computational thinking:

- Competence in use of modern digital technology means.
- Radiness and ability to master emerging and future means; willingness to abandon familiar stereotypes and to upgrade to the next level – spoken commands, blinking, or even thinking of doing something not so clear for ourselves.
- Ability to use technologies for our needs, including modeling of the real world, studying what is happening around us. Way of thinking about your own life, surrounding reality in a specific but general approach, including planning, using feedback, signals, steps, discrete time and events, reflexive and agile strategies of behavior with partners and opponents.

Next goal of mathematical and of Computer Science education is the formation ideas about **'how it works'** in the digital world. (Sometimes it is included in computational thinking.) So, we assume understanding mathematics of DT and AI obtained in the process of constructing and using them in school.

The important outcome of school education is the **formation of big ideas** by student. Big ideas give us orientation in the world – this is that which remains behind when all we have learned at school is "forgotten". Non complete list of the great people to whom the idea is attributed is: Albert Einstein, B. F. Skinner, George Savile, Lord Halifax… Big idea is not something that can be learned in the next lesson and then spoken out loud. Mostly it can be incorporated into our worldview step by step in several years.

These are the **big ideas of mathematics**. Let's say, we give names to mathematical objects, the same name can have different meanings, the laws of the world can be represented in the form of relationships between these names. And then you can substitute specific value in a specific situation,

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get conclusions. So, it is big idea of equation, and how equations can be used, and how they can be found in the internet.

4.2.4. The Curriculum. Content of Education

Recall that problems that are not known how to solve (different for each student) is **the basic, not an optional** part of our curricula. 'Entertaining', 'olympiad' problems turn out to be a considerable part of the content. Remarkably, many of these problems happen to be integrated into modern computer science (starting with 'Wolf, Goat, and Cabbage'). In fact, the basic system of objects is common to mathematics and computer science. Different programming environments provide different ways to integration Math and computer science, look, for example, to the functional language Haskell [13] etc. [27].

'Traditional' math will go with a help of computer, mostly presented as tablet: solving trigonometric equations with computer algebra system, experimenting in dynamic geometry, analyzing data of a physical experiment or a poll about school life, 'computer simulation' and games in economy etc.

Besides Wolfram's paid Mathematica there are free environments, including GeoGebra, originally made for geometry; the same Haskell and so on, to solve traditional school problems and problems arising in modeling.

Elements of mathematical modeling are traditionally present in physics courses in Kazakhstan, so, modeling becomes more systematic, based on the physical laws of reality, as well as based on biological and social processes mathematical description, big data analysis essentially using computers, from primary school calculator to statistical packages and machine learning. The routine part of solving problems, which the student should know by heart or with the instruction of a teacher, can be transferred to the computer gradually.

The skill of performing routine procedures, what arises, say, in some artistic crafts, also exists in mathematics. There is no need to forbid children who do well multiplying by minds with four-digit numbers, considering themselves as 'calculators'; this should be welcomed, like calligraphy: if some child likes not to use a keyboard or voice input, but writes beautiful poems, essays, with artistic images in the Latin or Arabic calligraphy. And, say, quickly solving Sudoku deserves praise.

The described content of education involves the use of appropriate means – environments and tools. The most obvious are:

- Dynamic geometry, such as the freely available GeoGebra,
- Computer algebra, possibly integrated with geometry, with conventional visualization capabilities,
- Statistical data processing system,
- Programming system: of algorithmic language and functional language.

The problem of entering mathematical texts is important, especially for mass schools. A reasonable approach may be a combination of keyboard input and editing, with handwriting input on the touch panel, scanning (photographing) paper text, and the use of oral input elements.

The following should be situated in the digital environment:

- A system of goals for mathematical education, starting with the most general ones, related to mathematical preparation for moving to the next level of education, passing the UNT, IB requirements, Advanced Placement programs, etc.
- A system of tasks – cycles of tasks and projects, including those existing textbooks, literature from circles and olympiads, entertaining mathematics. Tasks must be provided with the descriptions characterizing their difficulty, guidelines for feedback and evaluation.

13. Why Haskell at School matters. Codementor, Apr 10, 2019. Available online: https://www.codementor.io/@sawadyfaso/why-haskell-at-school-matters-tuca8sdq1 (accessed on 29 September 2024).

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4.2.5. Feedback and Assessment. Exams and Embedded Assessment

Exam is considered as the instrument for choosing best students by universities. Opposingly embedded assessment can be instrument for student to choose what is more suitable between universities, or another trajectory for life. The digital learning environment incorporates embedded assessment, compiling learning history opened for universities and being a possible basis for an individual portfolio. We can imagine gradual move from high-stake exams to embedded tools for consultation.

4.2.6. Expanded Roles and Personalities of Teachers. Raising Quality and Reducing Workloads

There is a very popular claimed goal of education: to learn how to learn. The teacher shows their own learning, together with students and from them, as well as from the internet. The teacher will be eager to accept (and execute) a culinary recipe form a student (who get it from their grandmother) or from the internet.

Checking of a student's answer in a multiple-choice test can be done by a machine. Today artificial intelligence part of teacher's personality can reproduce the reaction of the teacher in the broad spectrum of cases.

This digital component of the teacher and teaching assistants can analyze the whole situation, discover critical points, observing the state of the audience, can highlight those schoolchildren who have switched off, attract attention of teacher assistants to these students. Artificial intelligence can even independently contact the student and get an answer whether they is doing the next task, find out what difficulties they has, give an advice and so on. Artificial intelligence interaction with students using natural language, written and oral, and even images can significantly relieve people, teachers, and improve the quality of what happens in the classroom.

In a situation where a conflict, misunderstanding, or irritation arises on the part of a student interacting with the digital component of the teacher, this conflict can be resolved with the help of the (biological) teacher.

4.2.7. Teacher Preparation and Professional Development

Teacher preparation in Kazakhstan consists of the so-called fundamental education in the correspondent field of science, courses in pedagogy, psychology, etc.; a relatively small amount of practice in included or supposedly included.

In accordance with our 'learning by doing' philosophy, the training of teachers is going with real immersion in the school and kindergarten environment, in school goals and objectives, in all types of work and communication with children.

This training is combined with solving mathematical 'school problems'. The level of difficulty is chosen individually as it is done for schoolchildren. The student and the system of education plans professional work of the teacher after (and even before) graduation. The high, 'olympiad' results of problem solving does not imply success at every future teaching position. The teacher can have difficulties and reflective analysis of them can help them to understand difficulties of learners.

The preparation of teachers, as well as professional development includes exploration of horizons and frontiers of mathematics and applications beyond but achievable and connected with school mathematics.

5. Directions and Tasks of Implementation

The proposed plan relies on the existing groundwork, ongoing and planned processes in the education system, a modest redistribution of financial resources. It is necessary to announce goals and objectives in advance, to indorse information and propaganda work with the educational community.

The planned processes should consider the 2-, 3- and multi-lingual situation in the country and the 2+ alphabets and use modern tools of digital technologies and AI to manage with oral and written texts.

 doi:10.20944/preprints202410.0157.v1

The proposed changes to the regulatory framework are mainly focused on expanding opportunities for participants in the educational process, and not on banning anything.

For some of the changes it is reasonable to start in several private schools, or in one of the existing or a new dedicated network. In this case specific regulations can be developed 'on experimental base' and later will be distributed wider[14].

5.1. New and Upgraded Educational Environments

5.1.1. Digital Learning Environment and Means

The digital environment includes school administration software (electronic grade books and diaries, like Kundelik etc.), bank of educational materials, etc., from Bilim Media Group; exam procedures use the UStudy environment. We assume compatibility of the next generation environment with these systems.

The extended functionality is described above in the chapters "Digital learning environment" and "The curriculum...". It will be a substantial work structured by top-down for goals; tasks can be developed by grades. As it was indicated the tasks and goal will extend considerably broader and beyond existing education.

5.1.2. Buildings and New Organizational Structures

The buildings will house a school, a kindergarten, a structure for training and professional development of teachers and possibly also vocational training in the field of IT. It will be economically reasonable because of:

- multifunctionality of premises used over the daytime,
- using classroom spaces for kids' learning and students practice,
- sharing administrative and service costs.

Of course, the major advantage will be teachers better prepared and coming to school in bigger proportion among university graduates.

Organizationally, new educational structures can be created as separate organizations, be part of existing universities, as their branches, or form a separate network working in the interests of the entire education system and the entire population. This network can be similar to the NIS, KTL networks.

5.1.3. Equipment and Connectivity

A framework should be developed in which all school children, teachers and teachers-to-be will be provided tablets and free access to the permitted internet resources as well as other material, digital (as sensors for science labs) and information resources.

5.2. Digital Literacy, Creative Math–Mandatory Subjects

Digital literacy lessons are present now in the primary school curriculum of the country. The lessons assumed to provide tools to be used in other subjects and in life. This should include qualified typing in the main language of instruction, gradually in three languages, voice input followed by manual editing, internet search, calculator, etc. The lessons can also include "Creative Math" problems outside standard arithmetic with the goals of pre-adaptiveness and computational thinking in a visual environment.

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14. On approval of the Rules for the development, testing and implementation of educational programs implemented in experimental mode in educational organizations. Available online: https://adilet.zan.kz/rus/docs/V1500010916 (accessed on 29 September 2024).

 doi:10.20944/preprints202410.0157.v1

5.3. Digital as Option. Assessments

The educational authorities mission should be to allow all regions to allow all schools to allow teachers to allow children to have reasonable wide use of digital technologies in mathematics and other subjects, e.g. physics, economics, language arts.

Today all schools of Kazakhstan should follow "Standard rules for conducting ongoing monitoring of academic performance, intermediate and final certification of students in educational institutions implementing general educational programs of primary, basic secondary, and general secondary education" [15]. By these rules of "intermediate certification of students in the form of formative and summative assessment": Formative assessment, including homework, is carried out to monitor the achievement of learning goals by students and further build differentiated work in the lesson and is carried out through the recommendations of the teacher in writing (in notebooks or diaries) or orally.

During the formative assessment in the lesson, the teacher provides feedback. The teacher independently determines the number of students, the form and frequency of providing feedback. According to the results of the formative assessment, summative assessment for a section / cross-cutting topic and summative assessment for a quarter, students in grades 2–11 are awarded points, which are considered when evaluating academic achievements for a quarter.

Summative assessment tasks contain the material passed by students in accordance with Standard Curricula in general education subjects.

The tasks of formative and summative assessment are compiled by teachers independently in compliance with the principles of academic integrity".

As we can see, these rules are compatible with our philosophy of:

- using digital learning system,
- personalized learning.

So, on the country level the Ministry can permit and recommend:

- using digital technologies for certain tasks
- using "off topic" tasks, randomly selected from the database of tasks.

The same should be done for UNT.

5.4. Teacher Training. Continuity

The use of students in the role of teachers, coincides with our philosophy– with the immersion of future teachers into school environment as assistant teachers in the classroom, and so on.

Based on this, changes can be made to update education standards, programs, and curricula for future teachers and students of other specialties. In particular, this can be done experimentally.

5.5. Speed of Changes

Digital transformation and introducing creative mathematics will occur gradually. We should plan it by year, to make it variable for different schools and teachers, always offering an alternative: to solve exactly standard routine tasks or to solve unexpected, olympiad ones, simpler, of course, than routine ones, but at the same time more diverse and more corresponding to the needs of real life. The same is expected with using digital technologies, etc.

15. Order of the Minister of Education and Science of the Republic of Kazakhstan dated March 18, 2008 No. 125. Available online: https://adilet.zan.kz/rus/docs/V080005191_ (accessed on 29 September 2024).

 doi:10.20944/preprints202410.0157.v1

Author Contributions: Conceptualization, D.A., A.S. and A.A.; methodology, A.A.; investigation, A.S.; resources, A.A., D.A.; writing—original draft preparation, A.S.; writing—review and editing, A.A., A.S.; project administration, A.A.; funding acquisition, A.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan (grant no. AP19680007, head — A.E. Abylkassymova).

Acknowledgments: Alexei Semenov expresses his personal gratitude to Timur Turlov for the opportunity to dive into the problem and support in its research. Authors are thankful to Elena Bulin-Sokolova for continuous help, and Tatiana Rudchenko for administrative and technical support.

Conflicts of Interest: The authors declare no conflicts of interest.

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