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Factors in the productive use of information and communication technologies by mathematics teachers

Ilyas Yessengabylov, Shynggys Nurgozhayev, Aigul Aldabergenova, Yessengali Smagulov & Liliya Krivankova

Ilyas Zhansugurov Zhetysu University
Taldykorgan, Republic of Kazakhstan

ABSTRACT: The aim of this study was to identify the factors that impact on the productive use of information and communication technologies (ICT) by mathematics teachers. Therefore, the researchers conducted an analysis of mathematics teachers' activities involving ICT to examine the main factors hindering or contributing to the productive use of ICT in teaching mathematics. The qualitative and quantitative comparative analysis included representatives of different groups of teachers with contrasting levels of ICT proficiency, and it was focused on the actual work of those teachers. The findings indicate that a low assessment of the importance of using ICT in teaching mathematics is a hindering factor, while a high level of knowledge and skills in working with ICT increases the use of ICT for that activity. However, even a high level of individual skills does not lead to a substantially more productive use of ICT, and the development of a wide range of teachers' skills at a sufficient level is a prerequisite for being more productive in the use of ICT to teach mathematics. A high level of purely technical skills in working with ICT is desirable, but not sufficient to increase the productive use of ICT.

INTRODUCTION

At present, Kazakhstan is undergoing serious transformations in the field of society informatisation and the transition to ICT, automated, science-intensive industries. The informatisation of society involves the widespread introduction of ICT in almost all spheres of human life and activities. It transforms all structures of society and influences the education system. The informatisation of the education sector should outpace the informatisation of other areas of social activity since it is here that social, psychological, general cultural and professional prerequisites for informatisation of the entire society begin to develop. However, many issues remain unaddressed [1]. The main burden of informatisation has been carried *on the shoulders* of teachers. Some educational institutions have become substantially advanced, others are critically lagging behind. This indicates a contradiction between the real and the necessary level of teachers' activities involving ICT in the educational process [2-5].

Determination of efficiency factors concerning the teachers' use of ICT to teach mathematics in academic institutions should be based on a detailed analysis of this type of pedagogical activity, carried out from the standpoint of a systematic approach [6-9].

The purpose of this study was to conduct a qualitative and quantitative comparative analysis of the activities involving ICT by representatives of different groups of teachers in terms of productivity of such activities, through the lens of selected factors indicative of pedagogical, psychological and ICT capabilities. The results of this analysis were expected to confirm or reject the assumption that these factors serve as conditions and prerequisites for the emergence, establishment and development of highly productive activities for using new information technologies in teaching mathematics, thus facilitating the core aspect of this study.

MATERIALS AND METHODS

The subjects of this study comprised 92 college teachers in Kazakhstan. The entire sample of the surveyed teachers was then divided into groups based on the selected factors: group 1 - a high productivity group in terms of ICT use (15 people); group 2 - an average productivity group (60 people); group 3 - a low productivity group (17 people). The main focus of the study were general and specific similarities and differences between representatives of group 1 and group 3. The intermediate group (group 2 - representing the average productivity level) was not included in the general analysis. Indicators with loads above the homogeneity threshold of each of the identified productivity factor regarding the use of ICT made up three blocks for analysis. Each of these blocks was analysed separately.

The first block, which corresponds to the factor of general pedagogical skill or pedagogical mastery in activities involving ICT, with high loads included the following parameters: knowledge of the psychological and pedagogical possibilities facilitating ICT use; analytical, planning, constructive and organisational skills in working with ICT. The difference in the extent of knowledge and skills of using ICT among teachers of groups 1 and 2 was analysed.

There are different ways of presenting the results of comparing two subjects with regard to a certain indicator. One of them; for example, involves calculating the average estimates in groups, the variances of these estimates, and verifying the significance of the differences between them using statistical criteria. Another way is to build a histogram of estimates. The authors of this article set up a goal to demonstrate the differences in the microcomponents of the structure of activity involving ICT in regard to teachers with high and low productivity levels. A regulatory map was chosen as the most visual way of presenting the comparison results.

The essence of the technique is as follows. The indicators that were evaluated are plotted on the abscissa axis (x) of the regulatory map, their scale estimates - on the axis of ordinates (y). The lower border of the regulatory map is formed by the minimum estimates of the indicators that the subjects received. The upper border is derived from the maximum values for each indicator. The distance between the upper and lower border (along each ordinate) is halved, the dividing line forms mid-0.

The distance between the upper mid-0 line and the lower border of the regulatory map, and between the mid-0 line and the upper border of the regulatory map is also halved and, respectively lines mid-2 and mid-1 are obtained. Thus, the regulatory map is divided into four zones called the superzone, and prospective, potential and nominal zones (Figure 1). The prospective zone and superzone include good and excellent estimates; the potential zone usually includes those surveyed with average and satisfactory estimates of the analysed indicators; the nominal zone is the zone of low estimates. The mid-2 line is considered to be the border of positive and negative values of the studied qualities. Up from this line, the qualification rates are counted, down - the opposite rates.

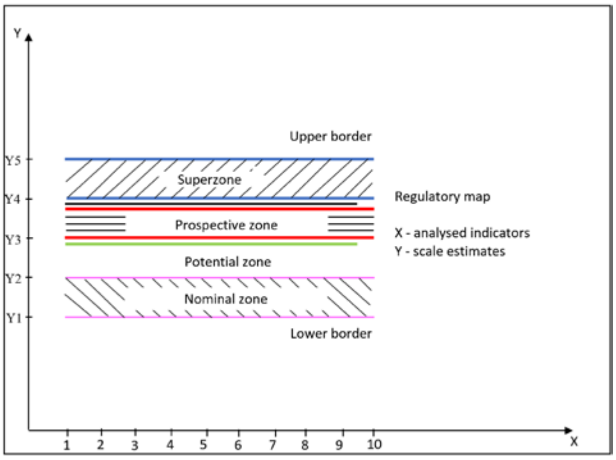


Figure 1: Four zones of indicator estimates.

Taking the described methodology as a basis, the authors of this article slightly modified it, depicting on one regulatory map the upper and lower borders separately for assessments of group 1 and 2, thereby obtaining a *zone of productiveness* and *a zone of non-productiveness* in activities involving ICT. The procedure for making the zone borders was based on the example of difference analysis in the values of teachers' ICT capabilities (Figure 2). This indicator was assessed by five components based on a five-point scale that included the knowledge of:

1. essence and classification of ICT;
2. constructive features of ICT;
3. operating rules and safety measures when working with ICT;
4. psychological and physiological characteristics of the perception of audio-visual information by students;
5. students' attitudes towards working with ICT.

The numbers of these components (analysed indicators) were plotted on the abscissa axis, and the degree of their expression in the examined teachers - on the ordinate axis. The upper border of the regulatory map of component completeness in the structure of teachers' knowledge of the psychological and pedagogical capabilities, and ICT means was formed by the maximum scale ratings that the surveyed teachers received for each of the components.

Next, the authors visualised the areas under study. As Figure 2 demonstrates, high and low productivity zones do not intersect despite a number of common points (the lower border of the high productivity zone partially coincides with the upper border of the low productivity zone). This indicates that the representatives of group 1 as a whole have a better idea of the essence and classification of new information technologies in education, they know their didactic functions and methodological capabilities, which are provided by ICT for the implementation of these functions. These teachers know the design features of ICT, operating rules and safety measures when working with them. Representatives of group 1 adequately assess the attitude of their students towards activities involving ICT.

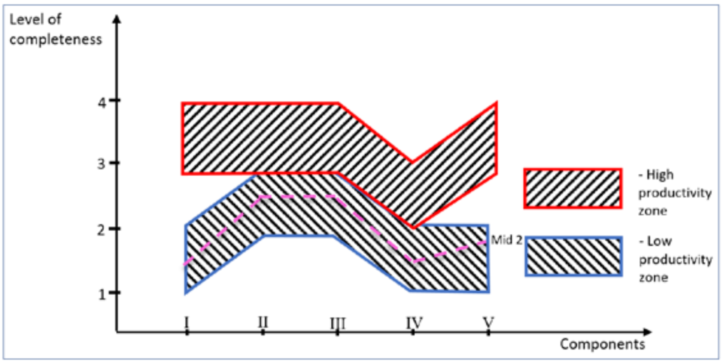


Figure 2: Regulatory map of component completeness in the structure of teachers' knowledge of pedagogical capabilities and ICT.

In Figure 2 the following components are demonstrated: I - value of the essence and classification of ICT; II - value of the design features of ICT; III - knowledge of the operating rules and safety measures when working with ICT; IV - knowledge of the psychological and physiological characteristics of the perception of audio-visual and computer information by students; and V - knowledge of the attitude of students to work with ICT. The levels of completeness included the following values: 1 - does not know; 2 - has an idea; 3 - knows well and applies this knowledge in practice; and 4 - knows comprehensively and systematically applies one's knowledge in practice.

Purposeful conversations with these teachers, as well as long-term observation of their work demonstrate that their knowledge about the means of ICT is systematised and constitutes a stable support for their activities involving ICT to teach mathematics.

RESULTS AND DISCUSSION

A comparative analysis of component completeness in the structure of teachers' knowledge of the psychological and pedagogical capabilities and ICT suggests the following:

1. Only systematised knowledge can be the main and stable support for the development of teachers using ICT. Unsystematic knowledge of ICT does not lead to an increase in the productivity of this activity.
2. The analysis indicates that group 1 representatives have knowledge of the psychological and pedagogical capabilities and ICT above the nominal level.
3. When training and retraining teachers to work with ICT, much attention should be paid to the study of psychological, pedagogical and physiological characteristics of students' perception of audio-visual information.
4. The presentation of the comparison results for the two groups of teachers according to the completeness of their knowledge of psychological and pedagogical capabilities and ICT according to the regulatory map is clear and accurate.

Figure 3 demonstrates areas of potentially high and potentially low productivity involving ICT, compiled according to the comparison results for the use of ICT by teachers of group 1 and group 3. The regulatory map presented in Figure 3 was built based on assessing the completeness of teachers' general ability to work with ICT (Table 1).

Table 1: Methodology for assessing the level of teachers' pedagogical skills in working with ICT.

1. Analytical skills	2. Planning skills
1.1 To analyse the curriculum to identify classes where the use of ICT is advisable.	2.1 To carry out prospective thematic planning of classes using ICT tools.
1.2 To analyse the fund of benefits for ICT, from the standpoint of their compliance with the curriculum, the level of science development, students' age and ergonomic requirements.	2.2 To carry out the planning of work with the information and communication equipment in the office.
1.3 To analyse equipment and premises to determine the possibility of using certain audio-visual aids.	2.3 To design a system of personal activities to create a comprehensive provision of the taught subject with didactic aids to ICT tools.
1.4 To control the quality of work by means of ICT.	2.4 To design goals and objectives for student engagement in activities with ICT tools.
1.5 To determine the duration of using ICT tools in accordance with sanitary and hygienic requirements.	2.5 To plan objectives to improve personal knowledge and skills in the use of ICT tools in the educational process.
1.6 To analyse classes conducted using ICT.	2.6 To design self-education methods to improve personal pedagogical skills with ICT tools.
1.7 To study methodological and technical literature, leading to advanced pedagogical experience in the use of ICT tools.	2.7 To carry out long-term planning of collective activities aimed at increasing the productivity of using ICT tools in the educational process.

3. Constructive skills	4. Organisational skills
3.1 To determine the purpose of using ICT in the classroom and implement it. 3.2 To select audio-visual and computer aids that meet educational and upbringing objectives for the lesson. 3.3 To select educational material for creating self-made aids for ICT tools. 3.4 To plan proper activities in a lesson with ICT tools. 3.5 To plan students' activities in a lesson with ICT tools. 3.6 To choose the most rational methodological techniques for using ICT tools. 3.7 To predict students' difficulties with ICT tools and identify systems of measures to address them.	4.1 To equip the class with the necessary ICT equipment and form a fund of industrial and improvised ICT teaching aids. 4.2 To prepare audio-visual and computer teaching aids, equipment and premise for the lesson. 4.3 To master ICT hardware for teaching (to use them in accordance with the rules of technical operation and safety measures). 4.4 To create improvised ICT teaching aids. 4.5 To organise activities in a lesson with ICT tools. 4.6 To organise productive activities for students with ICT tools. 4.7 To form students' skills for independent work with ICT tools and teaching aids, to organise students' activities to create improvised ICT teaching aids.
5. Communication skills	
5.1 To resolve ICT maintenance issues. 5.2 To establish rational relationships with colleagues to share ICT experiences. 5.3 To encourage colleagues to participate in the work with ICT tools. 5.4 To engage students in activities using ICT tools.	

As shown in Figure 3, the zones of high and low productivity have no common points. This demonstrates a higher level of the ability to apply ICT by teachers in group 1. For teachers of group 1 and group 3, the difference in completeness of pedagogical skills involving ICT is statistically significant at the level of 2.5%. Observing the activities, conducting interviews and conversations with the teachers, directors, deputy directors of colleges, and methodologists formed the basis for explaining the resulting pattern.

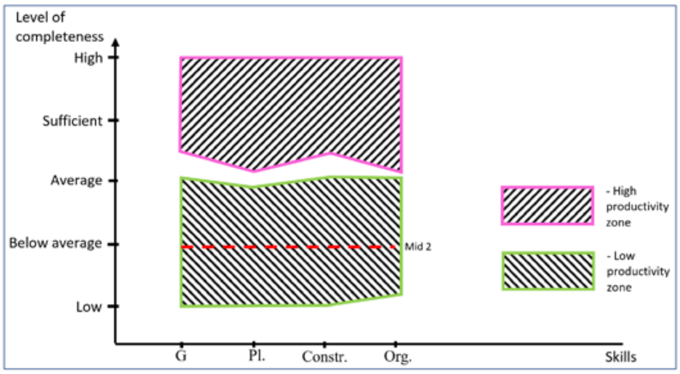


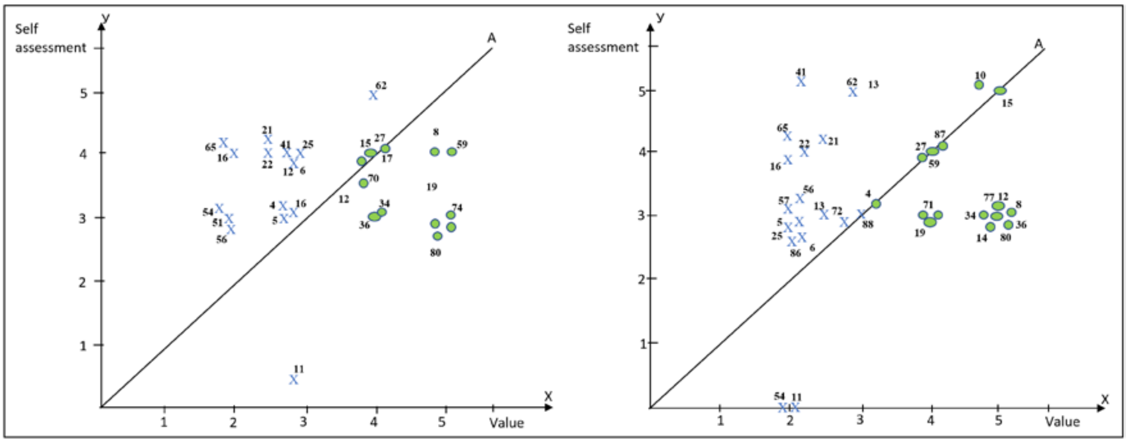
Figure 3: Regulatory map of completeness of general pedagogical skills involving ICT.

In terms of completeness of the integrated ability to determine the appropriateness of using ICT in a particular lesson, representatives of group 1 significantly exceed representatives of group 3 - in this area, the zones of high and low productivity have no common points. This fact is confirmed by the observations conducted as part this study. Representatives of group 3 often use ICT, where it is more rational to use other teaching aids, methods and methodological techniques. Observations of these teachers' activities and conversations with them show that they use ICT more frequently to illustrate their stories when explaining new material or monitoring students' knowledge.

Group 3 representatives concentrate only on using ICT in class, and do not consider it necessary to think about special methodological techniques of using ICT, to diversify the forms of cognitive activity of students in class by means of ICT. The frequent consequence of this is a decrease in students' interest in working with ICT, a low level of their cognitive activity in mathematics lessons, a low level of students' assimilation of visual and audio information. In the areas of the regulatory map corresponding to skills 1.2, 1.6-2.6, 3.6-4.1, and 4.4-4.6, the lower border of the high productivity zone coincides with the upper border of the low productivity zone. Consequently, in regard to these skills, group 1 representatives are generally superior to group 3 representatives. In the areas of the regulatory map corresponding to skills 1.4, 2.7, 3.2, 4.2, and 4.3, the zones of high and low productivity intersect. Among the overwhelming majority of representatives of both groups in the nominal zone on this section of the regulatory map, the ability to control the quality of work involving ICT is manifested in a low level of completeness of their ability to control the correct operation of a computer.

Figure 4a graphically demonstrates the correlation between teachers' performance self-assessment regarding their individual teaching activities and the assessment of this performance. OA is the line of adequate self-assessment (self-assessment coincides with the value-Y1/X1 = 1). The area of YOA is an area of high self-assessment (Y1/X1 > 1), AOX is an area of low self-assessment (Y1/X1 < 1). As Figure 4 shows, representatives of group 1 have low (66.7%) and adequate (33.3%) self-assessment, representatives of group 3 have high (76.5%) and sometimes adequate (17.6%) self-assessment. One of the representatives of group 3 (5.9%) could not provide a definite performance assessment of their individual pedagogical activity. Figure 4b demonstrates the correlation between teachers' performance self-assessment of their individual activities involving ICT in teaching mathematics and the assessment of this performance.

The difference between the representatives of the two groups of teachers in terms of the correlation between self-assessments and the effectiveness of their pedagogical activities and the activities involving ICT is statistically significant at the level of 2.5%. This feature makes the underproductive and non-productive workers passive, incapable of perceiving and delivering new ideas and methods. They do not feel the need for new knowledge and skills and, therefore, are incapable of restructuring their activities [10-14].



a) b)

Figure 4: a) the relationship between assessment and self-assessment of teaching effectiveness (● - representatives of group 1; x - representatives of group 3); b) the relationship between assessment and self-assessment of the effectiveness of using ICT (● - representatives of group 1; x - representatives of group 3).

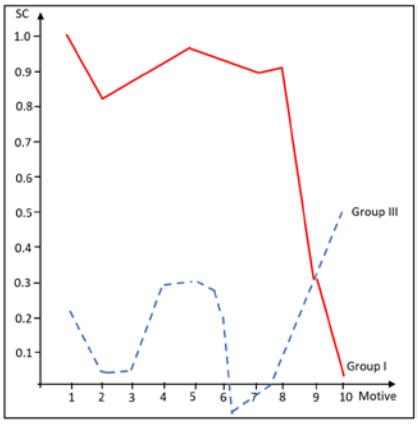


Figure 5: Main motives for using ICT and their importance for teachers.

In Figure 5 are presented the main motives for using ICT in teaching activities, and they include: 1 - the need to improve the educational process using ICT; 2 - seeking creative solutions; 3 - the need to improve pedagogical skills using ICT; 4 - the need to increase visibility; 5 - the need to intensify educational activities; 6 - to develop students' interest in mathematics using ICT; 7 - the need to eliminate the shortcomings of the existing fund and develop a complex of methodological groundwork creating improvised ICT; 8 - to organise intensive independent work of students using ICT; 9 - to facilitate teachers' work in class; and 10 - striving to fulfil the requirements of college administration.

Therefore, Figure 5 reflects the importance of the leading motives in activities involving ICT for teachers of group 1 and group 3. As presented in Figure 5, representatives of group 1 demonstrate a high level of the need to improve the educational process through the use of ICT. They strive to make the most of ICT potential to develop students' interest in the subject, to intensify their educational activities and to rationalise the organisation of students' independent work. When introducing ICT into the educational process, the desire to fulfil the requirements of college administration is of little importance for them.

For teachers of group 3, the desire to meet the requirements of administration is in the first place in the structure of motives. The most insignificant are the motives associated with the need to create comprehensive methodological support of the taught subject through self-made computer programs, video manuals, devices that dock with a computer, etc, as well as the motives associated with the desire to creatively search and improve their pedagogical mastery when using ICT (for teachers of group 1, these motives are significant). The motives associated with the need to influence the subject of pedagogical activity in order to obtain the desired product are not of paramount importance for teachers of group 3.

A comparative analysis of the structure of motives for the use of ICT by representatives of group 1 and group 3 confirms the presence of a *motivational* factor in the productivity of teachers using ICT.

CONCLUSIONS

The comparative analysis of the structure of activities involving ICT of *highly productive* and *underproductive* teachers indicated the main psychological and pedagogical factors that contribute to or prevent an increase in productivity of using ICT in teaching mathematics. The high level of knowledge and skills in working with ICT is a contributing factor, and the teacher's low self-assessment of the importance of using ICT in teaching mathematics is a hindering factor. The comparative analysis results of the completeness of pedagogical skills in working with ICT to teach mathematics suggest the following conclusions:

1. Even a high level of individual skills does not lead to a substantial increase in productivity of activities involving ICT. A case in point is group 3, the representatives of which have a high skill level in 1.4 (controlling the quality of work by means of ICT) or a sufficient skill level in 3.2 (selecting audio-visual and computer aids that meet educational and upbringing objectives , with a level of individual skills ranging from medium to low (Table 1).
2. The development of a wide range of teachers' skills at a level not lower than sufficient is a prerequisite for achieving a high productivity level in the use of ICT to teach mathematics. In this case, the low level of any particular skill (or two or three skills) is compensated by the high level of other skills.

A high level of purely technical skills in working with ICT is desirable, but not sufficient to increase the productivity of this activity. It is also necessary to have a sufficient level of pedagogical skills in working with ICT. In training or retraining teachers to work with ICT, more attention should be paid to these aspects.

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