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Technology as a Tool in STEM Teaching and Learning

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Abstract: STEM (science, technology, engineering, and mathematics) education nowadays becomes more and more topical; however, there are still few students who choose to study these sciences therefore it is important to develop students' interest in these subjects already at school. Meaningful use of technology in the teaching and learning process of STEM could be one of the ways how to attract students' interest. The aim of the research was to identify the role of technologies in the teaching and learning process of STEM. One hundred and twenty-eight (128) STEM teachers and 257 students in general comprehensive schools of Latvia have been surveyed with the help of the *QuestionPro* e-platform. The obtained data showed that teachers and students had similar and different views on the use of technologies. Both teachers and students mainly use technologies reproductively as consumers of information not as productive developers of knowledge. There are problems with the specific STEM technology: the sensor – data registering and processing system, the use of the computer-adjusted microscope and computer laboratory simulations for carrying out virtual experiments. This means that the impact of specific technologies in STEM education is still largely provisional. Exploring the obstacles that prevent teachers from applying technologies it has been found that both institutional and personal factors are important.

Keywords: school education, STEM, technology, teachers, students.

Introduction

Education in science, technology, engineering, and mathematics (STEM) nowadays becomes more and more topical and it attracts ever-increasing attention; many countries set it as the priority of education. The acronym STEM has caused broad discussions in the last decade (Honey, Pearson, Schweingruber, 2014; Brown et al., 2011; Stohlmann, Moore, Roehrig, 2012; Tsupros, Kohler, Hallinen, 2009). Historically, STEM was first "coined" as an educational term by National Science Foundation (NSF) of the USA in early 2000s. (Dugger, 2010). In the 1990s, NSF started using "SMET" as a shorthand for "science, mathematics, engineering, and technology", when describing the respective disciplines of science. The abbreviation "SMET" for a better sounding (pronounced as "smut") was changed to the acronym "STEM" (Sanders, 2009). Today this term is widely used and it is considered that STEM - a curriculum based on the idea of educating students in four specific disciplines — Science, Technology, Engineering and Mathematics — in an interdisciplinary and applied approach (Breiner et al., 2012; Gonzalez, Kuenzi, 2012; Hom, 2014; Gibilisco, 2013). The English acronym STEM is mainly used in Latvia for a common designation of science disciplines together with the denomination "exact or hard sciences", which are described as sciences that "use mathematical methods, calculations, mathematical logics in the descriptions of their phenomena, research and previsions; definitions and rules can be formulated mathematically precisely. The exact sciences are biology, physics, chemistry, mathematics and informatics (Beļickis et al., 2001, 45). The Latvian version of the STEM, namely "DZIMT" – *Dabaszinātnes, Inženierzinātnes, Matemātika un Tehnoloģijas* has also been suggested by Aivars Gribusts.

Why has STEM education become so important? R.V. Bybee considers that STEM-literate citizenry is prepared for the grand challenges of the 21st century (Bybee, 2010b) and, implementing the STEM education programmes, teachers have greater possibilities of helping their students to develop 21st century skills (Bybee, 2010a).

Despite the importance of science, the learning of STEM subjects at school is still problematic, so one possible way to make the subject more interesting is to use technology, therefore, the aim of the present study was to identify the role of technology in the STEM teaching and learning process.

How to teach science better: integration versus isolation?

How are STEM subjects learnt at school? There are several ways. One of the ways is to teach each discipline as a separate school subject S–T–E–M with some or no integration at all. The second way is to teach each of the four subjects separately but to choose one or two subjects to learn in-depth (the denomination SteM). The third way is to integrate one of the STEM disciplines in the other three subjects for instance, the content of engineering science can be integrated in the courses of science, technology and mathematics (E–S, T, M). The fourth way is a more embracing integration of all four subjects into one school subject. For instance, technology, engineering science and mathematics are integrated in the science content (T, E and M in S) (Dugger, 2010).

Nowadays an integrated science course is taught in schools of humanitarian direction in Latvia and each STEM subject is usually taught separately in general comprehensive schools. There can be a situation in the specialized science/mathematics schools when one or *two STEM subjects are taught in-depth*. According to the new *School 2030 (Skola 2030)* reform (National Reforms…, 2019), schools will choose the directions of teaching/learning domains and the chosen subjects will be taught in-depth.

The use of technology in science

Science that is one of the greatest achievements of culture of the Western society cannot attract the young people's interest (Osborne, Hennessy, 2003:9) despite the fact that nowadays it has the potential much bigger than ever before to motivate students for STEM subjects, and it would be important to maintain their interest in STEM subjects in the basic and secondary school (Sanders, 2009).

Technologies is one of the tools that could increase young people's interest in learning science. ICT offer a possibility to engage actively in science activities using different technological options. Today digital technologies are an integral part of a modern teaching/learning process (European Commission, 2018). Europe has to develop and introduce innovations in school education. Schools have to adjust to the changing context in which they function, including the digital age and the increasing diversity among the students (European Commission, 2016). European Commission is working on several political initiatives, e.g., the Action Plan on Digital Learning in order to modernize education and training by promoting the use of digital technologies in the teaching/learning process, thus developing the ability of individuals, education institutions and education systems to adjust better to the life and work in the age of rapid digital transformations (European Commission, 2018).

The standard developed by the International Society for Technology in Education (ISTE) for students and teachers shows how the guidelines for using technologies have changed over the time: from 1998 - Learning to use technology, 2007 - Using technology to learn, till 2016 - Transformative learning with technology. It means that school also must change the quality and effectiveness of using technologies in science education. Modern students have to be ready to function continuously in the constantly changing technological environment. ISTE standards have been developed in order to ensure that learning is a student-driven process (ISTE Standards, 2019). ISTE standards for teachers, in their turn, is a guide how to help students to become empowered learners and will urge teachers to reflect on the traditional approaches and prepare students to drive their own learning.

Undeniably, schools change along the time. However, as mentioned by M. Fullan and M. Langworthy (2014), the problem is that school, firstly, concentrates on students' learning targets, secondly, on precise pedagogy, and thirdly, on how technology could enable and accelerate learning in high level standards. Without denying the importance of technology in the learning process, in practice they are perceived as an additional tool rather than as one of the resources of the learning process (Anspoka, Kazaka, 2019). But it is not the technologies that transform methods of traditional pedagogy, it is how teachers use them that changes the methods. The important question is whether the current use of technologies at schools and classrooms is connected with using digital tools and resources for a meaningful teaching/learning process. The Innovative Teaching and Learning Research project, which identified teachers' view on using ICT in seven countries, has shown that technologies are still mainly used in basic ways that layer technology on top of traditional teaching and learning, rather than for collaboration and knowledge creation (Fullan, Langworthy, 2014).

It is self-evident that teachers use different digital resources to help students explore and learn, to support collaboration in the class and to perform formative assessment. They also use the internet and webinars to help students deepen their knowledge on concrete topics. Indisputably, technologies are the tools that the teacher uses when preparing for lessons as well as for sharing experience with other colleagues. It means that technology has changed the methods of teaching and learning (Byers, 2016).

The usage of technology in science can be divided into four broad areas (Table 1): data handling, information, communication and exploration (Gras-Velázquez, 2016).

Table 1

Classification of using technology in STEM

Data handling	Information	Communication	Exploration
Data logging	Internet	E-mail	Simulation
Spreadsheets		Collaboration	Modelling
Graphing tools			

Technologies, e.g., computers, probeware, data collection and analysis software, digital microscopes, hypermedia/multimedia, student response systems, and interactive white boards can help students to engage actively in the acquisition of scientific knowledge and development of the nature of science and inquiry (Guzey, Roehrig, 2009). Science resources: from virtual laboratories to computation tools; there are tens of possibilities of integrating technologies in the science school programme (Byers, 2016). The above-mentioned ways of teaching and learning, by all means, attract students as representatives of the digital generation for whom learning takes place by applying technologies intuitively in their everyday life (Punie, Zinnbauer, Cabrera, 2008). It is possible that the use of such technologies makes students' learning more interesting, effective and qualitative.

As science is essential for understanding the way the world works, then the use of technologies in the acquisition of STEM can be viewed as the formation of science literacy in five following stages (Figure 1).

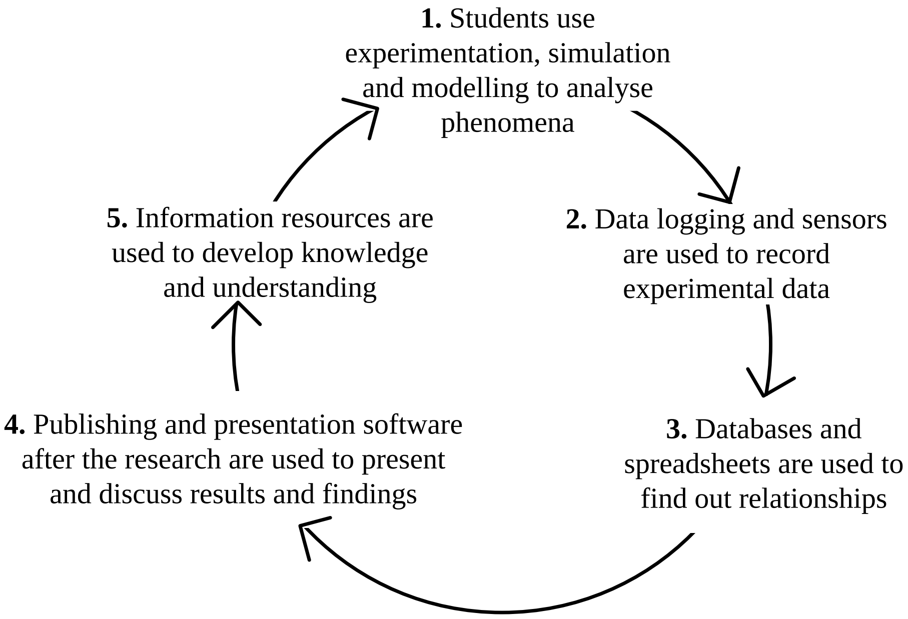


Figure 1. Five stages of technology use for STEM learning.

Factors influencing the teacher's use of technology

Teachers usually use technologies according to their own professional and their students' needs (Ottenbreit-Leftwich et al., 2010). However, different factors affect the possibilities of using technologies. British Educational Communications and Technology Agency indicates that factors influencing teacher's work can be divided in several groups and sub-groups. For instance, teacher's incompetence in using technologies can be connected both with the lack of time for training, and the lack of pedagogical training. Other important factors are the lack of access to resources, as well as technical problems and teacher's resistance to change and his/her negative attitude (Jones, 2004). Other authors (Ertmer et al., 2012) distinguish external and internal barriers, emphasising the teacher's attitudes, beliefs, knowledge (internal barrier) as the most important. In any case, the integration of technologies in the teaching/learning process is a complex process that is connected with personal, organizational, institutional and even cultural barriers (Mumtaz, 2000). It means that the use of technology is related to teacher's age, computer skills, beliefs and factors on the school level: accessibility of computers and technical support (Inan, Lowther, 2010).

The aim of the research was to identify the role of technologies in the teaching and learning process of STEM.

Methodology

The present study is connected with finding out the role of technologies in teaching and acquisition of science. The selection of teachers and students' target group was defined by the fact that science teachers are smart and "savvy" users of instructional technology (Byers, 2016). Two research questions were put forward to clarify the issues of using technology:

1. What differences and similarities there exist in using technology by teachers and students as a means in science teaching/learning?
2. Which conditions determine the teachers' use of technology in the STEM teaching/ learning process?

Research design. The study adapted two questionnaires developed in the ERASMUS+ project "International Diploma for School Teachers in STEM Education (eSTEM)" (one for teachers, the other for students). Data have been collected using open-closed questions on the 5-point Lickertt scale (1- strongly disagree, 2- disagree, 3 – neither agree, nor disagree, 4 – agree, 5 – strongly agree) in the on-line platform *QuestionPro*. Quantitative data are processed with the SPSS 23.0 programme. The data analysis uses the Mann–Whitney U test and Spearman's rank correlation coefficient. Two different samples: teachers and students were compared, using the non-parametrical Mann–Whitney U test. The connection between teachers' problems in using technologies was defined with the help of Spearman's rank correlation coefficient. The survey was structured in two parts: general and conceptual. The general part of the survey characterized respondents: teachers and students (Figure 2, 3).

Teachers were 110 female and 18 male aged 20 to >70 years.

Subject	Science n=27	Biology n=34	Chemistry n=18	Physics n=22	Math n=36	Geography n=19	ICT n=30	Other n=6	
Age (Years)	20-24 n=8	25-30 n=9	31-40 n=14	41-50 n=29	51-60 n=49	61-65 n=14	66-70 n=4	>70 n=1	
Education	Diploma n=51	Diploma (professional) n=25	Bachelor n=19	Master n=77	PhD n=1	Other n=5			
Experience (Years)	<1 n=3	1-3 n=8	4-6 n=7	7-10 n=7	11-20 n=22	21-30 n=33	>30 n=47	Other n=1	
Grade taught	5^{th} n=20	6^{th} n=19	7^{th} n=22	8^{th} n=21	9^{th} n=30	10^{th} n=52	11^{th} n=51	12^{th} n=49	Other n=30
Direction	No direction n=90	Humanitarian n=24	Science n=49	Other n=19					

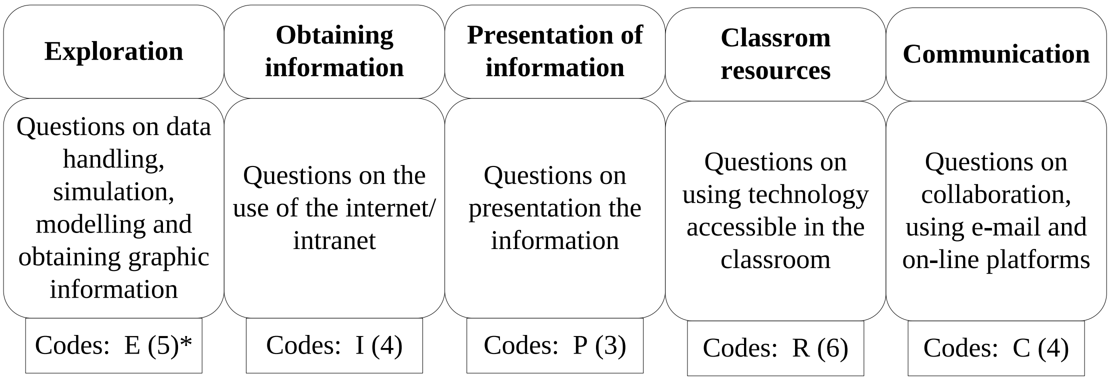
Figure 2. Teachers profile.

Students were 161 female and 96 males.

Grade learnt	10th n=97	11th n=112	12th n=48			
Entry reguirement	Average mark n=119	Test in STEM n=15	IQ test n=4	Personal interview n=5	Other n=59	
Direction School level	No direction n=2	Humanitarian n=19	Science n=96	Secondary school n=37	Gymnasium n=215	Other n=21

Figure 3. Students profile.

The conceptual part of the questionnaire on the use of technologies (Figure 4) has been developed by adapting the division suggested by *European Schoolnet* (Gras-Velázquez, 2016).



* number of questions

Figure 4. Structure of the conceptual part of the questionnaire.

The conceptual part also included questions related to teachers' problems in using technology.

The current study involved 385 respondents (128 teachers and 257 students). The results of the study are analysed by comparing teachers and students' views on the use of technologies (α = 0.87) and identifying problems that teachers have in using technologies (α = 0.88).

Results and Discussion

Teachers and students' views on using technologies

In order to find out teachers and students' views on using technologies, 22 questions were asked.

There were no statistically significant differences between teachers and students' views in five questions on such technology used in science education as social networks for learning, online discussions, tools for data capture, processing and interpretation and tablets. Low mean values mainly dominate in teachers and students' answers, which shows that these technologies are rather little used in communication, tablets as a resource, the use of data logging tools is rather problematic. The different views on the use of technologies held by teachers and students are reflected in Table 2.

There were statistically significant differences between teachers and students' views on technology used in communication, exploration and data handling, obtaining of information and presentation as well as classroom resources.

Table 2

Different views on the use of technologies held by teachers and students

Code	Issue	Students (N=257)			Teachers (N=128)			ρ
		Mdn	***M***	***SD***	***Mdn***	***M***	***SD***	
C2	E-class or *Mykoob*	5	4.43	0.886	5	4.7	0.439	<0.001
C6	E-folio	2	2.50	1.21	2	4.46	1.21	0.001
C12	MOOCs	1	1.73	0.933	2	2.39	1.15	<0.001
E3	Computer laboratory simulations for carrying out virtual experiments*	2	2.62	1.00	4	3.57	1.00	<0.001
E4	Computer adapted microscope **	2	1.98	1.23	2	2.49	1.12	0.006
E13	Visual aids for presenting phenomena	3	3.11	1.11	4	3.93	1.06	<0.001
E20	Educational computer games	2	2.16	1.08	4	3.55	0.938	<0.001
I1	Internet for searching of information	4	4.12	0.920	4	4.41	0.633	0.008
I21	E-learning resources (in Latvian)	3	2.74	1.24	4	3.70	1.14	<0.001
I22	Other internet resources	4	3.67	1.05	4	4.17	.677	<0.001
P7	*MS Office* applications for home-works	4	3.93	1.05	5	4.43	0.636	<0.001
P8	Online programs for home-works	2	2.44	1.20	3	3.06	1.25	<0.001
P10	Desktop publishing	2	1.81	0.918	2	2.27	1.13	<0.001
R14	Interactive board	3	2.84	1.21	4	3.34	1.42	<0.001
R15	Voting consoles	2	2.01	1.09	2	2.48	1.28	<0.001
R18	Smartphones	3	3.09	1.17	4	3.54	0.995	<0.001
R9	*MS Office* applications during lessons	3	3.02	1.18	4	3.77	1.12	<0.001
R16	Mobile computer-class	2	2.53	1.17	3	2.88	1.44	0.026

* number of teachers (n = 79), because the question referred only to science teachers (teachers of informatics and mathematics were excluded)

** number of teachers (n = 51), because the question referred only to science and biology teachers

According to mean values there were differences in teachers and students' views on MOOCs (ρ = <0.001; students *Mdn* = 1, teachers *Mdn* = 2). It is interesting that the mean values in teachers' answers on the use of technologies had a higher value (*Mdn* = 4-5) than students (*Mdn* = 2-4):

- *exploration.* There are statistically significant differences on using Computer adapted microscope (ρ = 0.006) in biology and science (*Mdn* = 2) in both groups; (computer laboratory simulations (multimedia software for simulation of processes carrying out virtual experiments (ρ = <0.001), visual aids - models, drawings, and graphs - for presenting phenomena (ρ = <0.001), and usage of educational computer games (ρ = <0.001);
- *obtaining the information.* There are statistically significant differences on using Internet for searching of information (ρ = 0.008), usage of e-learning resources such as Latvian materials of *Lielvārds, Zvaigzne ABC, DZM project* (ρ = < 0.001), and usage of other internet resources such as data base, video, animations (ρ = <0.001);
- *presenting the information.* There are statistically significant differences (ρ = <0.001) in questions about using *MS Office* applications for home-works (students) and presentations (teachers *Mdn* = 5; students *Mdn* = 4), online programs such e.g. *Prezi* for home-works (students) and presentations (teachers *Mdn* = 3; students *Mdn* = 2).
- *technologies as a resource in the classroom.* There are statistically significant differences (ρ = < 0.001) in questions on using the Interactive board, Voting consoles, Smartphones, MS Office applications during lessons, and Mobile computer-class (ρ = 0.026).
- *technology in communication*. There are statistically significant differences in teachers' and pupils' views on the use of technology for cross-communication (*Mdn* = 5) for both e-class or *Mykoob* (ρ = <0.001), E-folio (*Mdn* = 2; ρ = 0.001) and MOOCs (ρ = < 0.001; students *Mdn* = 1, teachers *Mdn* = 2).

Conditions determined the teachers' use of technology in the STEM teaching/ learning process

There are many conditions determined the teachers' implementation of technology in STEM education.

Teachers' problems in using technologies are connected with the institutional and personal factors (Figure 5). There is a strong correlation on the institutional level between the lack of technology provision, moral depreciation ($r = 0.69$; $p < 0.001$), moderate correlation - non-compatible versions of applications ($r = 0.57$; $p < 0.001$) and the inability to ensure immediate technical assistance ($r = 0.51$; $p < 0.001$).

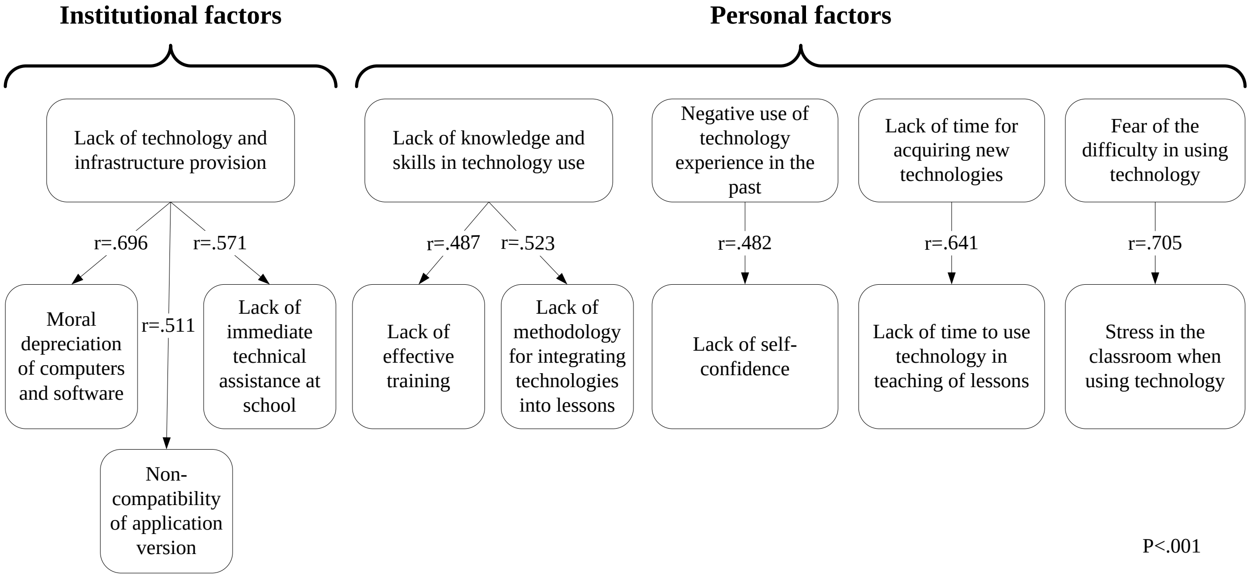


Figure 5. Factors that influence teachers' use of technologies.

The moderate correlation on the personal level develops between the teacher's insufficient knowledge on technologies that are related to the lack of training in using technologies ($r = 0.48$; $p < 0.001$) and the lack of methodology on integrating technologies in lessons ($r = 0.52$; $p < 0.001$). The previous negative experience of using technologies is personally important for the teacher because it affects his/her self-confidence ($r = 0.48$; $p < 0.001$). There is also a strong correlation between teacher's not daring to use technologies (*Fear of the difficulty in using technology in the presence of students and colleagues, since failure could lead to a reduction in the status and create a misconception of professional competence*) and the stress when using technologies in lessons ($r = 0.70$; $p < 0.001$). This relationship could be explained by the fact that the majority of teachers are aged 41-60 ($n = 78$) and thus their use of technology is problematic. The lack of time significantly interferes with the teacher's use of technology: the lack of time for acquiring technologies correlates with the lack of time to use technologies in the lessons (r =0. 64; $p < 0.001$). Table 3 summarises quotes from teachers' answers on technology use.

Table 3

Strength and weakness of technology use

Strengths	Weaknesses
Planning and materials available for primary school. *There are technologies that can be used to demonstrate a natural phenomenon / process.* *Young people have better knowledge of technology, so I am still learning.*	*Lack of resources and methodology for secondary school. Old generations' materials and educational resources in Latvian language.* *No projectors, 3D printers.* *Difficult to find tasks in electronic form, tests that are not available for students.*

Conclusions

Teachers and students have similar and different views on using technologies. The study shows that there are certain problems with the specific STEM technology: the sensor – data registering and processing system, the use of the computer-adjusted microscope and computer laboratory simulations for carrying out virtual experiments. Classroom resources not always give the possibility to use technologies to full capacity in the lessons. It means that the impact of technologies specifically needed for the acquisition of science in STEM education is still largely provisional and the teacher faces difficulties to ensure a meaningful exploration process. Both teachers and students use technologies mainly reproductively (to seek information in the internet, to summarise it and to make a presentation) as consumers of information and less productively as developers of knowledge.

Institutional and personal factors are the main that affect the use of technologies. Teaching, using technology, sets 21st century requirements to teachers and teacher's knowledge, experience and motivation can be considered as one of the key factors that has a substantial role in integrating technologies in the classroom. Actually, technology is only a tool and its meaningful use depends on the teacher.

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