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Models of integration of virtualization in education: Virtualization technology and possibilities of its use in education

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ABSTRACT

At present, virtualization and virtualization technology represent a powerful tool for the consolidation and simplification of vast hardware and software structures administration. Their potential is extensive, considering their employment; they are used in numerous branches and fields. It is therefore logical that the issue of virtualization technology is becoming a priority for educational institutions not only in terms of their internal information systems, but also as a means of solving particular educational issues regarding advanced administration and operation of information systems. The employment of virtualization and virtualization technology in educational institutions may therefore seem not only beneficial, but also, from the perspective of both teachers and pupils, stimulating. However, there emerges a question—is virtualization technology really employed at schools, and if so, in what way? Would it be possible to systematize this employment? In order to find at least a partially satisfactory answer to these questions, a theoretical model of integration of virtualization in education was designed, its aim being to systematize and describe possibilities of the said employment in education. In order to prove the model, a research was carried out, aimed at the explanation of the current state of employment of virtualization technology at school facilities as well. The submitted study deals with the description of both the designed model and the theoretical bases, which led to its composition (including the preparation, course, and results of the realized research).

1. Introduction

The term *virtualization* is nowadays frequently used, mainly in the business field. According to the research performed by the Association of Small and Medium-Sized Enterprises and Crafts of the Czech Republic, more than 30 per cent of these enterprises employ virtualization technology and more than 23 per cent are seriously considering its employment. They are interested in this technology mostly due to significant cost cutting in terms of administration and operation of server and network infrastructures, which it brings about. The technology itself is not only a matter of server virtualization (or client workstations), as individual applications may be virtualized as well. Subsequently, many other fields develop, which gradually supplement the virtualization technology, e.g. virtualization of the whole network layer or even complete virtual data centres (Ruest & Ruest, 2010).

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The actual meaning of the word *virtual* itself may translate as *fictitious* or *apparent*. This term may therefore mislead us to an opinion that *virtualization* is something unreal or even false. In fact, to a certain extent, this technology does stem from fiction. There are unique processes taking place in a certain "envelope", while outside of this "envelope", the whole shows itself as something completely different, something clearly defined by its structure (Lowe, 2010). Nobody or nothing in interaction with this object doubts its relevance.

The original meaning of the term *virtualization* comes from the 60's and it expresses a possibility to create a virtual machine via the combination of hardware and software—to simplify, also a term *platform virtualization* is used (Besemer & Eve, 2009). For the first time, the term *virtual machine* itself was used in connection with an experimental paging mechanism of the IBM M44/44X system, while the founding and administration of virtual machines was also described as founding and administration of *pseudo-machines,* and later as a *virtualization of servers*.

The platform virtualization itself is performed for the given hardware platform via the specialized *host* software (control application) which creates a simulated computer environment (*virtual machine*) for the *host* software. The software of the *host* (which is often the whole operating system—OS) runs as if installed on a separate hardware platform. Typically, more virtual machines are simulated on one physical machine. For the correct function of the host, it is necessary to have a sufficiently robust simulation, which would support all of the external interfaces of the hosting system, which may (considering the type of virtualization), include the drivers as well (Virtualization, 2015). The whole situation is shown in Fig. 1 below, demonstrating the difference between the traditional and virtual architecture. The machine on the left includes only one OS and several applications whereas the machine on the right includes a hypervisor (virtualization tool) and several OS with their applications. These OS are mutually independent and they act like one physical machine. (OldanyGroup, 2013).

2. Types and ways of virtualization

Based on the abovementioned facts, the hardware virtualization may be defined as the creation and operation of a virtual machine (VM) which acts as a real computer with an OS. The physical computer, on which the VM is installed, is called a *host computer* or HOST (VmWare, 2011). The OS of this computer does not influence the used OS of the VM; therefore, any OS supported by the VM may be used on the virtual machine. The OS and other software of the VM are separated from hardware sources of the host computer, which is emulated by virtual environment. From this perspective, we can classify the hardware virtualization into three sub-groups (Fitzpatrick, 2013):

- Full virtualization—an almost perfect simulation of the real hardware, which enables applications dependent on the OS of VM to run without any necessary modifications.
- Partial virtualization—only a part of the target environment is simulated. Some of the applications have to be modified before being operated on this type of VM.
- Para-virtualization—hardware not simulated at all. However, the applications are launched in separate, isolated areas as if they ran on a separate system.

Whereas the abovementioned classification takes into consideration principally the technical aspects, i.e. core, place of origin, and/or principal solution of the employment of these technologies, another system of classification of virtualization technologies follows a more *user-related* approach. It deals more with the possibilities of the employment with respect to the target. From this point of view, it is possible to organize virtualization technology into three groups as they follow (Klement, 2015, p. 59):

- Desktop virtualization (workstation virtualization or virtualization run on workstations) is characteristic of a host computer not in the form of a specialized hardware server, but merely as a common workstation, notebook, or a mobile touch device. The aim of such virtualization tools is therefore not a consolidation of vast hardware or network structures, but a

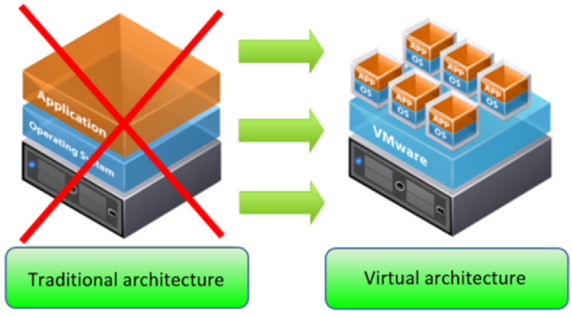

Fig. 1. The difference between the traditional and virtual architecture sec. OldanyGroup, 2013.

virtualization of common types of user operating systems in order to perform the testing, the development, or to provide a backward compatibility of applications.
- Infrastructural virtualization (server virtualization or virtualization run on servers) focuses on a total consolidation and simplification of the administration of vast hardware and network infrastructures. Specialized virtualization servers, disk arrays and, mainly, complex virtualization tools (hypervisors) are used. Hypervisor is capable of administering and managing the whole infrastructure even in areas geographically distant from each other.
- Cloud virtualization (server and service virtualization or services for virtualization) means the provision of virtualization solutions by external providers. It facilitates the access and the use of shared infrastructures via web services. By means of these, often paid services, it is possible to create dedicated virtualized servers or services run in areas geographically distant from each other in the form of outsourcing.

At present, a wide range of virtualization technology are on the market, satisfying various users' needs—e.g. virtualization of the desktop OS, server virtualization, or consolidation of individual services. In the following part of the treatise, the most common virtualization tools are introduced; the ones to be used for the types and ways of virtualization mentioned above.

3. Tools for virtualization solutions

In the following overview, the most frequently used virtualization tools are stated. According to their availability, they are classified into three groups: commercial software (i.e. tools that are used for the desktop or infrastructural virtualization and are provided after the purchase of the license); non-commercial software (tools for the desktop and infrastructural virtualization provided free of charge), and cloud solutions (tools for the desktop, server and service virtualization). For the sake of completeness, it should be pointed out that the costs associated with the procurement and the operation of the virtualization tools stated spread over a wide price range. In fact, costs connected with the tools used in the non-commercial area are close to zero, whereas the costs of the tools designed for the commercial area, where the construction of an overall infrastructure might be necessary, can be in hundreds of thousands of euros. The purpose of the particular virtualization tool and its infrastructure is always the decisive factor.

Commercial software:

- Hyper-V—a server system based on a hypervisor architecture for x86-64 (32 and 64 bit) systems by Microsoft.
- Citrix Delivery Center—a complex set of products for the transformation of static data centers into dynamic "service-providing centers".
- Citrix XenServer—a commercial platform for the administration of virtualization applications among an unlimited number of servers of a data center via an aggregated sum of computational resources.
- VMware Workstation—a virtual machine for more than one OS. It is possible to support both platforms of x86 and x64 on computers with a processor of x64 architecture via this virtual machine. It also supports the largest number of operating systems.
- Vmware GSX Server—a virtual machine mainly for servers. Recently, it has been replaced by Vmware Server, which is free of charge.
- Vmware ESX Server—a virtual machine for big servers and their consolidations.

Non-commercial software:

- Citrix XenServer Express Edition—a free starter pack for starting virtualization.
- Bochs—a universal emulator of x86 platform.
- KVM—a virtualization of x86 hardware for Linux.
- Microsoft Virtual PC 2004 and 2007—a virtual machine for more OS at once. It officially supports only Microsoft Windows.
- Windows Virtual PC—a tool integrated in Windows 7, its free part XP Mode enables not only OS virtualization but also virtualization of individual services and applications.
- Klient Hyper-V—a tool included in Windows 8, 8.1 and 10 for more than one OS at once.
- Microsoft Virtual Server 2005 R2—a virtual machine mainly for servers. It officially supports Microsoft Windows and some Linux distributions.
- VirtualBox—a virtual machine by InnoTek published under GNU GPL.
- Vmware Player—a virtual machine only for demonstrative purposes and for the virtual machines already created in Vmware Workstation.
- Vmware Server—a virtual machine replacing Vmware GSX Server, mainly for servers.
- XEN—a virtual machine enabling the operation of more than one OS on a computer of x86 architecture (however, a specific modification of the OS has to be performed, or a processor supporting the virtualization has to be present in the PC).

Cloud solutions:

- Amazon Web Services—currently probably the most developed cloud, as for the number and variety of services provided, to which customers can subscribe more or less independently.
- VmWare vCloud Air—a hybrid cloud platform based on Vmware vSphere which supports current services and third-party applications, and also the development of new applications.
- Microsoft Azure—a cloud platform by Microsoft which may be used to create, host, and scale web applications via Microsoft data centers. It mediates so-called Microsoft Online Services—a pack of online applications (with no installation needed) providing data transfer, data sharing, and online communication (online conferences), etc.

Despite the fact that the overview of virtualization tools is certainly not complete, and a brand new virtualization technology might have been created during the very preparation of this treatise, it provides a clear idea of the variety of available tools applicable in different situations. Mainly the quick development of cloud solutions, which provide a possibility of virtualization to those who do not intend or cannot invest in a complicated and expensive virtualization infrastructure, is worth noting. Although the application of those solutions is charged, the expenditures do not represent a huge financial burden. It is possible to spread the payment over a longer period, in the form of resource rental. It is therefore only a matter of time until school institutions begin to employ more virtualization technology not only during instruction, but also in order to solve their infrastructural needs and services. Next part of the paper deals with the employment of virtualization technology and virtualization tools in the operating and educational conditions of schools.

4. Ways to use virtualization tools in education

The use of virtualization technology in education (or in school conditions) is still a relatively unexplored area. Despite the few literary sources partially dealing with this issue, we are not aware of the existence of an overview study striving to systematize possibilities and ways to employ this progressive technology within the framework of the process of education. Upon an analysis of the existing available information sources, it is possible to identify two main thought streams in respect of the employment of virtualization technology.

The first thought stream focuses on the support of the operation of school's infrastructure. It is based on the description of hardware and software optimization of schools by the employment of virtualization technology (server virtualization or virtualization run on servers), including the services of virtualization (cloud solutions). We refer the readers to the works by Tharam Dillon, Chen Wu & Elizabeth Chang (2010); Chun-Hee, Jin-Kyung, Yoo & Lee Nam (2016); Woodard and Orr (2015); Hemanth and Mahammad (2016), Klement (2007, 2009), or the oldest study in this summary—the study by IBM—Virtualization in education (2007).

The second thought stream mainly deals with the employment of more specific tools aimed at creating and operating of virtual laboratories or virtual educational environments. It is possible to mention here works by Zhang (2015); Pizzonia and Rimondini (2016); Garcia and Entrialgo (2015); Redel-Macías, Pinzi, Martínez-Jiménez, Dorado & Dorado (2016); Ionescu and Iana (2015), and others.

In terms of information sources devoted to the issue of virtualization instruction or instruction with the use of virtualization at schools, there are not that many information sources. However, the work by P. Drahoš (2013) should be mentioned here, as it delimits some of the basic possibilities to employ virtualization tools for solving selected educational contents focused on advanced administration and installation of OS by pupils or students. The work by Klement and Kubricky (2009) has a similar focus as it reflects the employment of virtualized software infrastructure as an educational content integrated in the training of basic and secondary school teachers of IT.

The overview of available literature, dealing with the issue of employment of virtualization technologies or virtualization tools in education, is far from being complete. A complete bibliography would exceed the extent of this treatise whose aim is not just a mere mapping of publications devoted to this field. However, it does provide a useful overview of the currently solved issues in this field and based on it, it was possible to proceed to the construction of a theoretical model focused on a complex perspective of possibilities of employment of virtualizing technology and tools in the process of education. The proposed model (with a working title *Model of integration of virtualization into the education—IVE*) operates with three basic dimensions and one integrating dimension. The first basic dimension covers the issue of operation and optimization of operation of schools, where the role of virtualization technology is that of running information systems (operational infrastructure of a school). The second basic dimension focuses on the possibilities of the employment of virtualization technology as a subject content (teaching about virtualization). The third basic dimension delimits the employment of virtualization technology for teaching (teaching with virtualization). The last, fourth dimension, integrates the areas of influence of the three basic ones. Therefore, it defines the scope of activity of virtualization technology when used as a means for teaching about virtualization and simultaneously as a means for teaching with virtualization. In this case, virtualization means of schools infrastructure are used. For the sake of clarity, the concept described above is virtualized below (see Fig. 2).

In the next section, we shall try to clearly delimit and describe the particular dimensions of the proposed model and, in some cases, outline the educational content or concrete examples of employment of virtualization technology in teaching, which fall into the above stated dimensions.

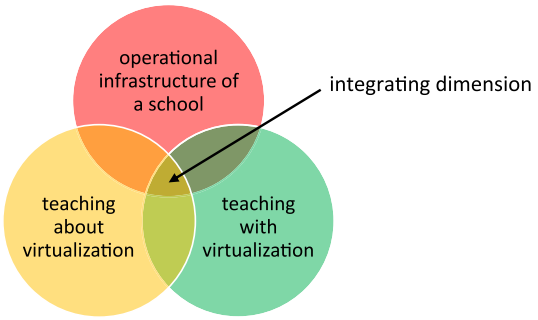

Fig. 2. The model of integration of virtualization in education.

5. Dimensions of the model of integration of virtualization in education (IVE)

The first basic dimension of the proposed IVE model describes the possibilities of employment of virtualization technology for the purpose of infrastructural virtualization (virtualization run on servers or server virtualization). This application of virtualization technology aims at a total consolidation and simplification of the administration of hardware-and network-based infrastructures of school information systems (Dostál, 2011, p. 68). Specialized virtualization servers are used as well as disk arrays and, mainly, a complex virtualization tool (hypervisor) which is capable of administering and managing the whole infrastructure. This dimension covers these parts or activities:

- virtualization of servers for the operation of economic or accounting administrative work at schools,
- virtualization of servers for the operation of directory services (Active Directory) and network attached storages,
- virtualization of servers for the web-related, database and email services,
- virtualization of servers for terminal services (RDP, etc.),
- virtualization of hardware and software infrastructure of the network services (DNS, DHCP, WINS, etc.),
- etc.

As shown above, this part of IVE model is in accordance with commonly used and described approaches. It focuses exclusively on school facilities operating their own internal information systems. Although the building and operation of these independent virtualization infrastructures are expensive, it is possible to lower the costs considerably due to the introduction of cloud services (Microsoft Azure, VmWare vCloud Air etc.) and, in the administration sphere, to focus only on the operation of particular services without having to administer the hardware and software of virtualization.

The second basic dimension of the introduced IVE model covers the area of teaching about virtualization. Its aim is to create such conditions and situations, which would enable pupils and students to find about the operation and administration of these technologies. It is of high importance, as the demand for qualified operators (operating and configuring these technologies) will logically increase together with the increasing market share of the virtualization technologies (see Introduction). In this dimension, it is possible to use both tools for the infrastructural virtualization (see the overlap of the dimension of operational infrastructure of a school and the dimension of teaching about virtualization), and the desktop virtualization, which is, nowadays, often free of charge, and therefore accessible to schools. This dimension covers these parts and activities:

- administration of virtualization tools (desktop, infrastructural, and cloud virtualization),
- operation of virtualization tools (in terms of mastering of user interfaces and basic operations related to them),
- configuration of virtualization tools (in case of desktop virtualization, it includes the installation and the default configuration of a virtualization tool; in case of infrastructural virtualization, it includes mainly the configuration of a hypervisor and related hardware components; in case of cloud virtualization, it includes the accessibility and customization of provided sources),
- configuration of virtual machines and environment and their start up,
- etc.

The second dimension of IVE model therefore comprises not only the technological perspective but also particular activities and procedures, which may be acquired and consequently used by pupils or students not only during the educational process, but also outside the school (test environment, emulation of a number of OS, etc.).

The third basic dimension covers the area of possible applications of virtualization technology for educational activities themselves. This sort of support might be obvious (teaching of installation or advanced configuration of OS, testing of applications on various OS), or hidden (emulation of educational applications, terminal services, etc.) in which the pupils or

students do not even know that they are working on virtual machines. Therefore, there is again a clear overlap between the dimension of teaching about virtualization and the dimension of teaching with virtualization. Once again, the teaching in this dimension does not have to be supported only by the infrastructure, but desktop virtualization tools may be used as well. This dimension covers these parts and activities:

- teaching of hardware and software installation of OS (in school conditions, it is often difficult to teach the issue of OS installation since the specialized classroom in which it would be possible to re-install the OS repeatedly is not available),
- teaching of hardware and software configuration of OS (in school conditions, it is often difficult to let pupils or students change the configuration of OS since PCs in classrooms are not usually dedicated only to this activity and a possible wrong configuration of OS may cause its failure and a subsequent impossibility to use the PC for following lessons),
- teaching of installation and configuration of user software (a similar situation to the two mentioned above),
- simulation of resolution of virus-related incidents (working with antivirus software, working with registers and services while there is no risk of spreading the virus on a host PC or within the network),
- testing purposes (development of applications for more OS platforms, porting of applications into other OS, etc.),
- emulation of educational applications or educational software (in school conditions, there is a wide range of high-quality educational applications and software used, which, however, cannot be used in newer types of OS due to the impossibility of their porting),
- etc.

This dimensions is, from the perspective of educational activities, maybe the broadest one since it enables the employment of virtualization technologies' potential in a number of educational situations. The fact that virtual machines are easy to be transferred or backed-up (in case of desktop virtualization, the virtual machine often consists of only two files) spares teachers worries about preparing suitable educational conditions.

The last, fourth dimension, delimits and states the conditions for a complex employment of virtualization technology in all three basic areas, characteristic by a full integration of these technologies into all spheres of school's activity. It is a sort of intersection of the dimension of operational infrastructure of a school, the dimension of the teaching about virtualization, and the dimension of teaching with virtualization, thus representing the highest possible level of IVE model. It is important to say here that this dimension cannot be achieved unless spending a considerable amount of money. It is not possible to run it with only desktop virtualization tools, but it is necessary to use either infrastructural or cloud virtualization. This integrating dimension covers these parts or activities:

- operation of virtual classrooms (employment of the technology of thin clients and virtual terminal farm),
- operation of virtual data centers for the support of both educational and organization activities (central access to applications and services),
- within the framework of the teaching about virtualization dimension, the infrastructural virtualization is used as educational content (teaching about administration of VmWare vSphere, Microsoft Hyper-V etc.),
- within the framework of the teaching with virtualization dimension, shared applications and systems in central storage are used,
- etc.

However, the question arises whether the proposed IVE model responds to existing presumptions and whether its concept corresponds with real conditions at schools. It was possible to prove the validity of the introduced IVE model by means of a research aimed at an explanation of the current state of the employment of virtualization technology in school conditions. A research investigation was carried out in order to map the situation in the field of virtualization technology and tools employment in conditions of schools and, consequently, to validate the proposed IVE model. The following parts of the text are dealing with the preparation, course, and results of the research.

6. The research focused on the level of integration of virtualization in education–focus, aims, methods

Since we were not aware of any study that would deal with the issue of virtualization technology and tools at basic schools, secondary schools, and universities, we decided to realize a research, which would explain the current state. The aim of the research was to find out whether and how the virtualization technology is employed in conditions of school facilities–hence validate the theoretical IVE model.

The questionnaire was used as a basic means to obtain data needed for the realization of the research. In terms of the research methods' classification, the questionnaire falls into the category of indirect research methods. The questionnaire may be characterized as a *measuring instrument* via *which people's opinions of particular phenomena may be researched* (Chráska & Kočvarová, 2015). From the point of view of an individual (respondent), the researched phenomena may be related either to external or internal occurrences. For the purposes of our research, a structuralized questionnaire (Gavora, 2010, p. 261) based on the IVE model described above was constructed in order to discover the current state of integration of virtualization in education.

The questionnaire included both closed questions (with provided options to response—yes, no, I do not know) and open questions via which the respondents were able to record a variable state of observed phenomena. In order to ensure the comprehensibility of individual questionnaire items, the questionnaire was equipped with an explaining text, which delimited particular terms used. In order to discover the size of the individual groups of respondents, who responded in the same way, the basic description statistics and its virtualization via graphs were used. For the means of calculation, the statistical system Statistica 11 was applied (Klímek, Stříž & Kasal, 2009).

The created research questionnaire was distributed to 65 teachers of IT subjects who, besides the teaching, also deal with the administration and operation of the information system at their basic school, secondary school, or university. In total, 42 teachers filled out the questionnaire. The return of the questionnaire was 64.6 per cent, which clearly shows the topicality and contributiveness of the solved issue. The research sample consisted of 42 schools—27 of which (i.e. 64.3 per cent) were basic schools, 12 of which (i.e. 28.6 per cent) were secondary schools, and 3 of which (i.e. 7.1 per cent) were universities. The schools are situated in three out of 15 Czech Republic regions, i.e. Olomouc, Moravian-Silesian, and Zlin regions.

In the following section, some of the partial outputs of the realized research, whose aim was to find about the current state of integration of virtualization technologies and tools, and their real impact on the process of education at observed schools, are stated.

7. The research focused on the level of integration of virtualization in education—selected results

The purpose of the first researched task was to find out whether virtualization technology is used at individual school or not. Besides other things, this item was included in the questionnaire to enable further and more detailed exploration of the employment of virtualization technology without any interference by the results generated by schools where virtualization technologies are not used. At the same time, the purpose of the following questionnaire item was to find out whether the schools use virtualization technologies to operate the whole or at least a part of their school information system. For the results of this part of research, see Fig. 3 and Fig. 4 below.

As we can see in Fig. 3, only 19 (i.e. 45.2 per cent) out of 42 of observed schools employ virtualization technology. For this reason, the schools which declared in the opening question not employing virtualization technology (in total 21 schools, i.e. 50 per cent), or not being aware of employing it (in total 2 schools, i.e. 4.8 per cent), were eliminated from further processing. Fig. 4 also shows that out of 19 schools which declared the employment of virtualization technology, 5 (i.e. 26.3 per cent) use them for operating school information system as well. Just to be more accurate, it is necessary to specify that out the 5 aforementioned schools, 2 were secondary schools and 3 universities. There was no basic school among them. This could be explained by the complexity and intricacy of information systems of higher education, which requires virtualization of some parts to simplify administration and operation of the latter. Another reason for this state of things is obviously also the system of financing of regional schools which in fact does not allow basic schools to accumulate the money needed for building the necessary data centers.

For the sake of completeness, an investigation of the different types of virtualization tools employed at the 5 schools which declared the use of the virtualization technology for the operation of their school information systems was carried out. For the results, see Fig. 5below.

The results stated in Figs. 3–5 prove that at a part of observed schools, suitable conditions for the existence of the first basic dimension of proposed IVE model have been set up. These schools use virtualization technology for the sake of

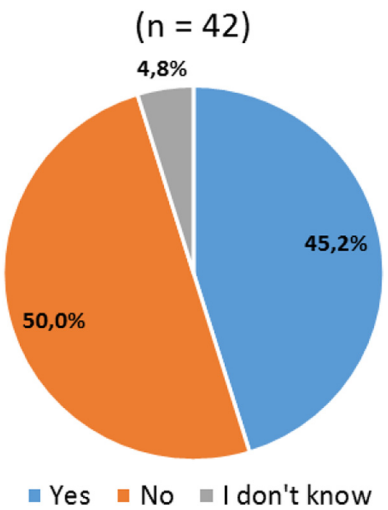

Fig. 3. Do you use virtualization technology at your school?

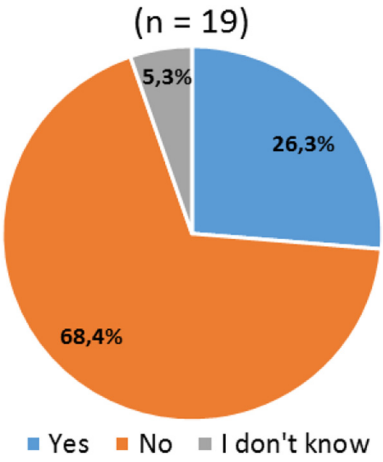

Fig. 4. Do you use virtualization technology to operate your school information system.

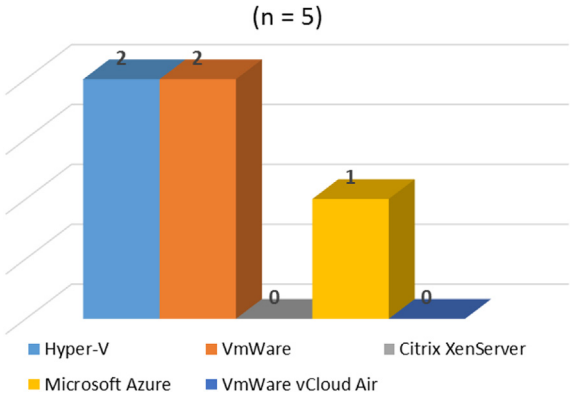

Fig. 5. If you employ virtualization technology for the operation of the school information system, which concrete tool do you use?

infrastructural virtualization (virtualization on servers or virtualization of servers). At these schools, the general consolidation and simplification of their school information system hardware and network infrastructure are the principal issue.

The next part of the research aimed at finding about the situation in the field of teaching about virtualization technology in terms of the second basic dimension of the IVE model. As stated above, this dimension focuses on the teaching about virtualization and its objective is to create such conditions and situations, which would enable pupils and students to learn about the operation and administration of this technology. Firstly, the very fact of this type of teaching being or not being applied at schools was verified, subsequently, the type of virtualization tools was inquired. For the summary of the results, see Figs. 6 and 7 below.

It is obvious from Fig. 6 that 12 schools (i.e. 63.2 per cent) actually employ virtualization technology to teach about virtualization, while 7 schools admit not using them or not being aware of using them. For the sake of completeness, we shall specify that out of these 12 schools, 3 were universities, 4 secondary schools, and the rest (5 schools) were basic schools. Furthermore, Fig. 7 presents the fact that the most used tools for the purpose of such teaching are Microsoft Virtual PC (3 schools total) and VmWare Workstation (3 schools as well). Other used tools are Microsoft Virtual PC (2 schools), a client Hyper-V (2 schools as well), VmWare Player (1 school), and VirtualBox (1 school). As it is obvious from the list of tools, mainly desktop virtualization tools are applied. These are often available free of charge, which is probably the reason why they are used for this type of teaching even at basic schools.

Further aim of this research was to find out about the type of educational purposes virtualization technology is used for, in terms of second basic dimension of IVE model. For the list of particular educational activities, see Fig. 8 below. Note: it was possible to mark more options than one because we assumed that schools might be using more educational activities in their teaching about virtualization. This is the reason why there is a higher number of responses than the number of schools.

As it is obvious from Fig. 8, the variety of educational activities focused on teaching about virtualization largely corresponds with the content of the second dimension of IVE model. Therefore, it is possible to state that this part of the theoretical model is implemented at school facilities as well. Among the most frequently employed educational activities in this part

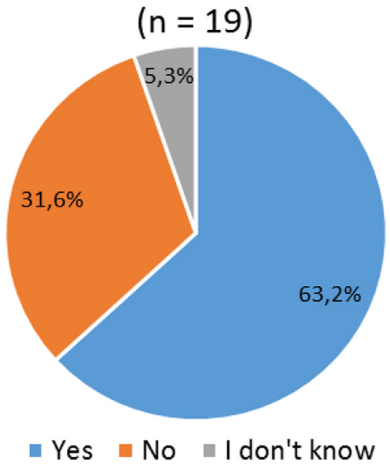

Fig. 6. Do you use virtualization technology as educational content at all (teaching about virtualization)?

belong teaching about virtual machines and environment (10 schools) and teaching about the operation of virtualization tools (11 schools). The fact that other activities are relatively frequently represented as well demonstrates that teaching about virtualization has already become an integral part of some schools' syllabus. We shall also point out that three schools declared employing virtualization even beyond the framework of the offered educational activities, two schools reported teaching about the issue of virtual switches within the framework of teaching about virtualization, and one school even declared an inclusion of the topics related to emulation applications in the teaching.

Analogically, the third part of the research focused on the current situation in the field of teaching with virtualization in terms of the third basic dimension of the submitted IVE model, facilitating the use of virtualization technologies and tools in support of educational activities themselves. This kind of support might be obvious (teaching of installation or advanced configuration of OS, testing of applications on various types of OS), or hidden (emulation of educational software, terminal services, etc.), which means that pupils or students do not even know that they are working on virtual machines. Firstly, the very fact of this type of teaching being or not being applied at schools was verified, subsequently, the type of virtualization tools was inquired. For the summary of the results see Figs. 9 and 10 below.

It is obvious from Fig. 8 that 8 schools (i.e. 42.1 per cent) actually employ virtualization tools to teach with virtualization, while 11 schools admit not using them or not being aware of using them. For the sake of completeness, we shall specify that out of these 8 schools, 2 were universities, 3 secondary schools, and the remaining 3 schools were basic ones. Furthermore, Fig. 10 presents the fact that the most used tools for such teaching (teaching with virtualization) are Microsoft Virtual PC (2 schools) and VmWare Workstation (2 schools as well). Other used tools are Microsoft Virtual PC employed at 1 school, a client Hyper-V (1 school), VmWare Player (1 school), and Virtual Box (1 school as well).

As it is obvious from the list of tools, once again mainly desktop virtualization tools are applied. As stated above, these are often available free of charge, which is probably the reason why are they used for this type of teaching even at basic schools.

Further aim of this research was to find out about the type of educational purposes virtualization technology is used for, in terms of the third basic dimension of IVE model. For the list of particular educational activities, see Fig. 11 below. Note: there again, it was possible to mark more options than one because we assumed that schools might be using more educational activities in their teaching with virtualization. This is again the reason why there is a higher number of responses than the number of schools.

As it is obvious from Fig. 11, the variety of educational activities focused on teaching with virtualization largely corresponds with the content of the third dimension of IVE model. Therefore, it is possible to state that this part of the theoretical model is implemented at school facilities as well. Among the most frequently employed educational activities in this part belong the teaching of hardware and software configuration of OS (total 8 schools), the teaching of OS installation (7 schools) and teaching of installation and configuration of user software (6 schools). The fact that other activities are relatively frequently represented as well demonstrates that teaching with virtualization has already become an integral part of some schools' syllabus. We shall also point out that two schools declared employing virtualization even beyond the framework of the offered educational activities. Both of them reported dealing with the issue of remote experiments within the framework of teaching with virtualization.

The aim of the last part of the research was to determine the state of employment of virtualization technology in terms of the last, fourth integrating dimension, which delimits and states conditions for a complex employment of virtualization tools in all three basic areas, supposing a full integration of these technologies in all spheres of school's activities. It is therefore an intersection of the dimension of operational infrastructure of the school, the dimension of teaching about virtualization, and the dimension of teaching with virtualization. This intersection represents the highest level of the IVE model. The research

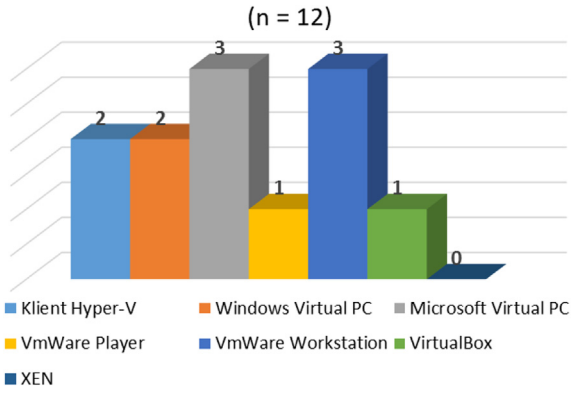

Fig. 7. If you do use virtualization technology as educational content (teaching about virtualization), which concrete tool is given preference in teaching?

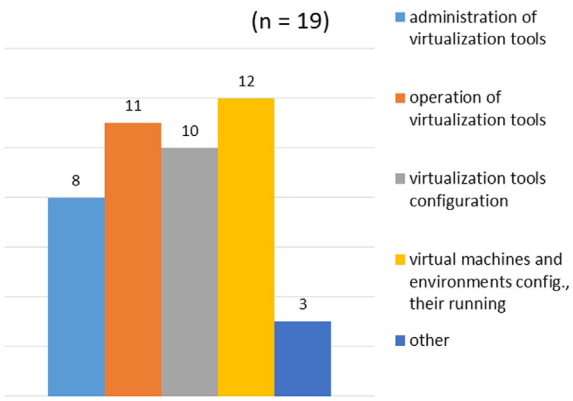

Fig. 8. If you employ virtualization technology as educational content (teaching about virtualization), which main activities does the teaching focus on?

focused on finding about the employment of this integrating dimension at schools. Furthermore, it strove to find about the type of virtualization tools used for this purpose. For the summary of the results see Figs. 12 and 13 below.

Based on the facts presented in Fig. 12, it is possible to state that also the last, integrating dimension is implemented at school facilities. There are schools, which are capable of employing infrastructural virtualization not only for the purpose of operation of their school information system, but also for the purpose of teaching (teaching about virtualization, teaching with virtualization). More specifically, the research showed that from the whole research sample of 19 schools, which employ virtualization technology, 3 schools (i.e. 15.8 per cent) are concerned, of which two are universities and one is a secondary school. For the realization of IVE model, the tool VmWare (at 2 schools) and Microsoft Hyper-V (1 school) are used most. This fact to some extent copies the share of the market occupied by these competitive technologies. However, due to the low frequency, the specific activities focused on by the schools were not researched any further. The responses would have been greatly distorted by this fact.

8. Discussion

The employment of virtualization technology at educational institutions (not only productive) provides a number of impulses for the development of pupils' and students' competences in the areas of employment and operation of information and communication technologies. The ultimate impact of the use of virtualization technology at schools may be that of decreasing the laboriousness and expenditures connected with the operation of school information systems, and a complex simplification of their administration. However, virtualization technology has a far greater potential when employed for pupils' and students' education as an object of education itself (Klement & Kubrický, 2009). The demand for experts of this field is increasing, also as a means to support education of pupils and students in more demanding fields, e.g. advanced OS configuration and administration.

Since we were not aware of any study that would deal with the issue of virtualization technology and tools at basic, secondary schools, and universities, we decided to carry out a research which would explain the current state. The aim of the research was to find out whether and how virtualization technology is employed at school facilities—hence validate the theoretical IVE model, which was delimited, based on previous experience.

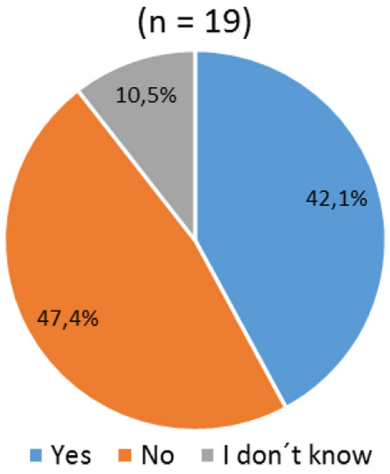

Fig. 9. Do you employ virtualization technology as a teaching aid (teaching with virtualization)?

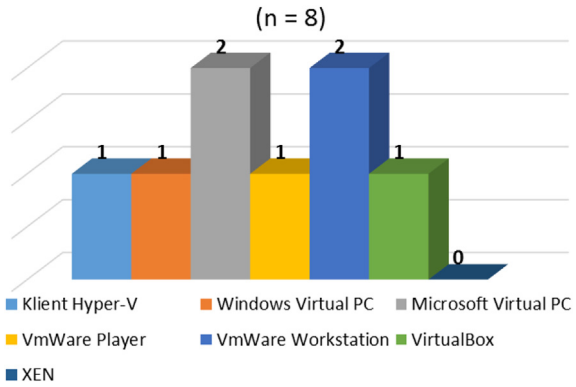

Fig. 10. If you employ virtualization technology as a teaching aid (teaching with virtualization), which concrete tool is given preference in teaching?

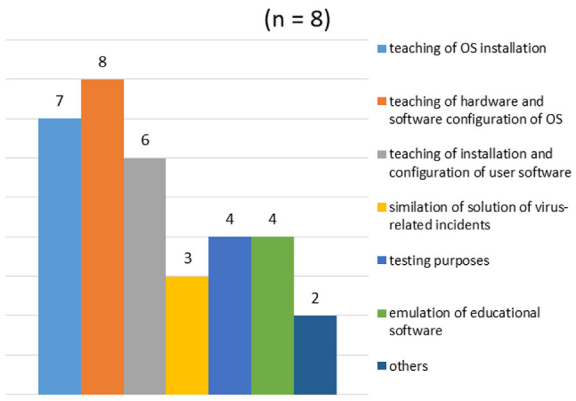

Fig. 11. If you employ virtualization technology as a teaching aid (teaching with virtualization), which activity is given preference in teaching?

9. Conclusion

Based on the above stated results (despite the fact those cannot be regarded as significant due to the low frequency of the research sample), obtained from the realized research, in which 42 schools involved, it is possible to state that virtualization technology is relatively frequently employed in teaching. It is an integral part of education at 19 schools. We managed to prove that the theoretically designed model of integration of virtualization in education (IVE) is legitimate since the delimited

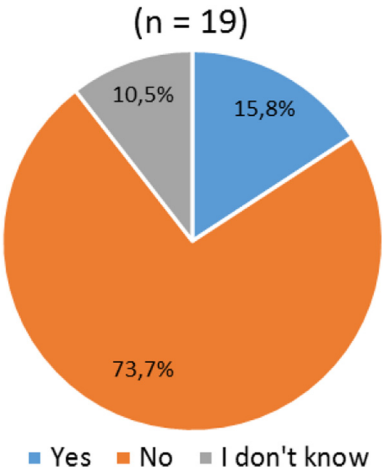

Fig. 12. Do you employ virtualization technology as a teaching aid (teaching with virtualization) and as educational content (teaching about virtualization)? Do you employ the infrastructural services of your school information system for these activities?

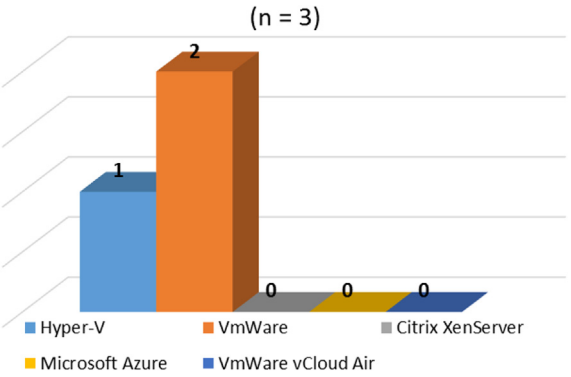

Fig. 13. If you employ virtualization technology as a teaching aid (teaching with virtualization) and as educational content (teaching about virtualization, do you employ the infrastructural services of your school information system for these activities? Which concrete tool do you use?

dimensions and activities related to it are realized at schools rather frequently. The first basic dimension of the model deals with the issue of operation and optimization of operation of schools, characterized by virtualization technology serving as a tool for facilitating the operation of information systems—i.e. operational infrastructure-of the school). This dimension is applied at 26.3 per cent of schools, which reported employment of virtualization technology. The second basic dimension, focused on the possibilities of virtualization technology use in the form of educational content (i.e. teaching about virtualization), is applied at 63.2 per cent of observed schools. The third basic dimension delimiting the employment of virtualization technology to teach (teaching with virtualization) is employed at 42.1 per cent of observed schools. The last, fourth dimension integrating the domains of the three basic dimensions, delimits the area of virtualization technology in case it is employed as a means to teach about virtualization and a means to teach with visualization at the same time, using the infrastructural virtualization means of schools. It is applied at 15.8 per cent of schools, which declared employing and implementing virtualization technology in such a complex, integrating dimension.

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