The Blended Methodology of Learning Computer Networks: Cloud-based Approach

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Abstract. The article considers the use of blended learning as an effective methodology of encouraging students' cooperation in the process of solving practical problems and as a means of developing their essential professional skills. The following pedagogical approaches and techniques of blended learning are discussed: combination of face-to-face and distance learning, group members' partnership, development of group work skills, heterogeneous grouping, combined use of individual and peer assessment, teacher's monitoring of the students' work, task-oriented approach, chance for every member to be a leader, essential feedback. The authors suggest using private and public cloud technologies in an integrated academic cloud to support the implementation of group methodology in the teaching process. The analyzed academic cloud includes Apache CloudStack and EVE-NG Community platforms. This cloud environment was deployed at Physics and Mathematics Department of Volodymyr Hnatiuk National Pedagogical University of Ternopil (Ukraine). The developed methodology is used in course "Computer Networks". It has been verified experimentally by using appropriate statistical methods.

Keywords: blended learning, ICT-competence, cloud-based environment, Apache CloudStack, EVE-NG Community, computer science trainee teachers.

1   Introduction

Development of cloud technologies visibly affects both the aims and the content of ICT education. In view of this, researchers are currently looking for new and improving the existing forms and methods to combine the benefits of face-to-face and online learning.

Today it is impotant to develop methodological principles of blended learning in training students. Various aspects of developing blended learning in an information society have been studied by C.J. Bonk, C.R. Graham. A.G. Picciano, C.D. Dziuban [1], [14].

Works of D.R. Garrison, N.D. Vaughan, H. Kanuka [6], [7] offer the ways to improve the effectiveness of the educational process at higher educational institutions. Some aspects of using blended learning as an effective model of building ICT competence have been researched by U. Köse [10]. N.P. Napier, S. Dekhane, S. Smith, R. Collopy, J.-M. Arnold describe the experience of blended learning organization from the perspective of teaching a specific discipline [12], [2].

In view of the appropriateness of using cloud technologies for systemic implementation of the principles of blended learning and activity approach, as well as for hands-on in-context learning based on cooperation, these technologies are seen as an effective teaching tool in training computer science teachers.

For higher educational institutions, deployment and use of cloud-based environment remains a priority, a prerequisite for effective addressing of current educational challenges.

O. Glazunova and M. Shyshkina in the paper [8] develop the concept of cloud-oriented educational scientific environment of a higher educational institution. Various aspects of introducing such environment in educational practice have been researched by O. Pinchuk, S. Lytvynova, O. Burov. The authors conclude that the effective learning environment should be immersive, creating the effect of "immersion" on the part of a student [15]. H. Kravtsov and V. Kobets in their study develop the model of the curriculum revision system in computer science. The authors single out generic competences for Master program in Information Systems [11]. O. Spirin and O. Holovnia suggest a variant approach to the application of virtualization technologies in the training of computer science bachelors. This approach involves integration of several virtualization tools and appropriate adaptation of training materials [17]. Yu. Nosenko's paper [13] studies cloud technology in Open Education Space.

Cloud-oriented environment of an educational institution, which combines hardware, software and information resources and services, functions on the basis of cloud computing technologies and provides the academic process with the resources of the university's local network and Internet access. University clouds are aimed, above all, at facilitating personal development of the faculty and students, encouraging their professional self-realization.

The goal of this article is to design the cloud-based environment for learning computer networks and to research effectiveness of blended learning in such environment.

2   Presentation of the main results

Currently, a major challenge in training computer science teachers is adjustment of education content and tools to the continuous advance of information technologies. This problem can be solved by means of combining students' theoretical education

and practical training, on the one hand, and increasing the effectiveness of their self-study through creative tasks and project methodology, on the other. Such approach lies at the basis of the blended learning concept. Literature on the subject makes use of several terms, among them hybrid, mixed, integrative, blended learning, technology-mediated instruction, web-enhanced instruction, mixed-mode instruction. The main interpretations of the concept are as follows:

1. A learning process which combines traditional and innovative technologies - electronic, distance, mobile learning.
2. Mixed learning combines various pedagogical approaches (e.g. constructivism, behaviourism, cognitivism) to achieve the optimal effect.
3. Mixed learning combines technological teaching facilities and face-to-face learning under the teacher's supervision.
4. Mixed learning combines traditional teaching with solving hands-on professional tasks.

Currently, researchers tend to look at the blended learning as a synergetic concept (a system of ideas, theories, models, levels, methods and tools of organizing educational activities) characterized by a new vision of the process and results of learning.

We see the following benefits of blended learning of computer science trainee teachers:

— blended learning improves students' performance, especially when ICT-technologies support cognition (for instance, in modeling) or facilitate students' interaction with other students and the teacher;
— blended learning changes the role of the teacher, who becomes a facilitator in students' research, a manager of educational projects;
— the traditional classroom is converted into an open virtual space, where students can study at their own speed;
— students' motivation for self-study and self-improvement increases;
— study based on reproduction and repetition is transformed into the process of discovering knowledge and presenting the results of such discovery;
— students get an opportunity to go through all stages of creating an IT-product, from an idea to creating a model, and then to final realization and testing.

In the previous study we developed a group methodology of using university cloud, which involves the project method as an effective tool of encouraging students' cooperation while solving practical problems and as a means of developing their essential professional skills [16]. At the second stage of our research we further developed the proposed methodology of blended learning in the course "Computer Networks", drawing on the approaches suggested in [9].

The essential characteristics of the used methodology are:

— transformation of a classroom into a virtual cloud laboratory;
— unlimited access of students and teachers to the objects of study;
— combination of formal and informal modes of study;

— focus on visuality, necessitated by the fact that virtual objects are often not easy for students to perceive and comprehend;
— combination of face-to-face and online communication, of self- and teacher directed instruction;
— achievement of personal and group goals.

The components of the educational model of blended learning include [5]:

— specification of mixed learning environments, modes of interaction and corresponding resources and facilities;
— study of knowledge attainment options;
— knowledge organization decisions.

It is important that the content be structured, in particular, by means of singling out the key concepts. Here the course developers can use a three-dimensional educational project, which includes key concepts, basic facts and basic skills required to perform the tasks [4].

For the course "Computer Networks", we enhanced the academic cloud, modifying its infrastructure so as to be able to create a lot of virtual subnetworks. Each of these subnetworks can be associated with a certain physical hypervisor network. Traffic marking in these networks is done using virtual local area network (VLAN) technology. Correspondingly, on the basis of OS FreeBSD, we configured a router to transmit data between VLAN.

Addition of these networks should not require changes in the topology of physical networks in the cloud-based environment. We divided the traffic transmitted between students' virtual computers among 120 VLANs. With such number of VLANs available, each student has an opportunity to store their virtual computers and other devices in their personal or several guest networks. That is, each of the virtual machines can be supplied with network adapters working in different subnetworks. The general layout of the expanded cloud infrastructure looks like this:
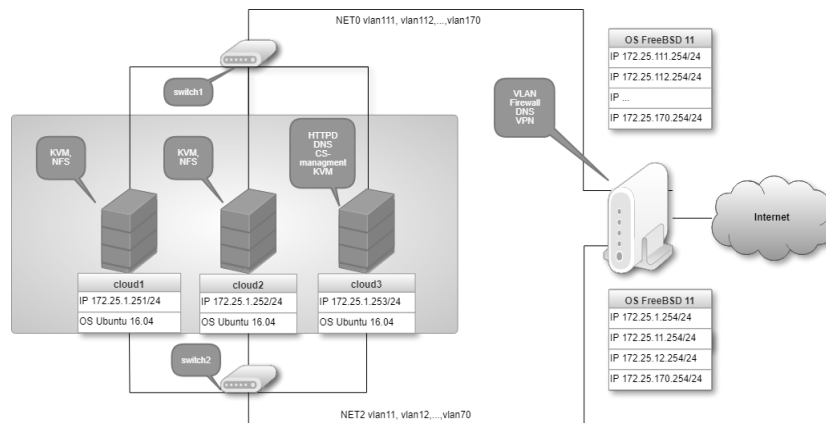

Fig. 1. Diagram of the cloud infrastructure

To determine the correspondence between physical adapters and traffic in CloudStack system, they are marked by VLAN tags. As a result, physical network adapters installed on hosts cloud1, cloud2, cloud3 are aggregated by the system in two. The traffic of these adapters is transmitted via switch1 and switch2 to the router. As our main task was to deploy separate guest subnetworks, the corresponding traffic is also marked by separate tags. For each of the tags, we created network offering templates, which give the possibility to indicate services to be functioning in the corresponding network. In our cloud infrastructure, such services include a DHCP-server, a NAT-translator, a firewall, a traffic load balancer and others. For these services to function, in each guest network Apache CloudStack platform creates a system virtual machine, virtual router. These services work in virtual networks vlan11, vlan12, …, vlan70.

Networks vlan11, vlan12,…, vlan70 do not contain any Apache CloudStack services and are switched on L2 level of OSI model. That means that using virtual machines in these networks requires that students configure network parameters manually.

As Apache CloudStack does not provide tools for visualization of network structure, students often have difficulty in designing and configuring networks in a cloud infrastructure. That fact prompted us to integrate into a university cloud a system that makes it possible to visualize the process of network design. It was vital that such system could work with networks on Apache CloudStack virtual machines. We analyzed relevant publications and compared several platforms – Cisco packet tracer, Graphical Network Simulator (GNS), Unetlab (EVE-NG) (Table 1).

Table 1. Comparing Simulation Platforms for Computer Network Learning

Parameter	GNS3	Cisco Packet Tracer	EVE-NG Community
Installing	Medium	Simple	Simple
Web (graphic) UI	Yes	Yes	Yes
CPU load	High	Medium	Medium
Free download	Yes	Yes	Yes
Routers	Yes, Cisco (not free)	Yes	Yes, Cisco (not free)
Additional components	Need to install	All in one	All in one
Integration with Apache CloudStack	+	-	+
Support external and internal (own) networks	+	-/+	+

Our choice fell on ENE-NG Community. Every student's copy of ENE-NG platform is a separate virtual machine in Apache CloudStack cloud. As each node of EVE-NG is itself a virtual machine, hosts integrated in Apache CloudStack infrastructure have to support nested virtualization.

Here are the main advantages of its use in teaching computer networks:

— visualization of network structure via web-interface;
— possibility to manipulate objects in web-browser;
— free ENE-NG Community version;
— possibility to work on a OS Linux based virtual machine;
— availability of personal templates of virtual machines and network equipment;
— support of external (for the student) networks and availability of personal networks;
— availability of integrating tools for remote access and network connections monitoring.

We can positively affirm that our academic cloud integrated virtual networks of Apache CloudStack та EVE-NG platforms.

Our methodology provides for the use of the university cloud-based environment for building basic competences and in carrying out group projects.

We determined the content of teaching computer networks on the basis of the domain ITE-NET from Information Technology Curricula 2017 [3]. It contains the following subdomains:

— ITE-NET-01 Perspectives and impact;
— ITE-NET-02 Foundations of networking;
— ITE-NET-03 Physical layer;
— ITE-NET-04 Networking and interconnectivity;
— ITE-NET-05 Routing, switching, and internetworking;
— ITE-NET-06 Application networking services;
— ITE-NET-07 Network management.

To study the effectiveness of our blended learning methodology we divided the students into two groups:
— Group 1 – control group (CG), in which students throughout the course had classroom instruction with a teacher and studied on their own out of class; the students used real network devices and computers in class and their personal equipment for self-study at home;
— Group 2 – experimental group (EG), in which students studied the topics ITE-NET-01 – ITE-NET-03 in class with a teacher and the topics ITE-NET-04 – ITE-NET-07 using our methodology of blended learning involving university cloud services.

Thus, our methodology involved the use of the academic cloud to model data transmission between virtual computers during classroom and distance learning as well as to organize group work.

We began the use of EVE-NG platform with the study of network topologies. The students designed network topologies on the basis of "building blocks", such as switches, routers, and cabling.

Principles of data transmission on channel and network levels were studied on the basis of VLAN technology. Doing such tasks, EG students used various virtual nodes of EVE-NG platform:

─ management L2-switch Cisco IOL (for example, i86bi-linux-l2-adventerprisek9);
─ routers Mikrotik;
─ OS Ubuntu Linux Server;
─ built-in node "Virtual PC".

EVE-NG platform networks served as models of unmanaged switches. Fig. 2 shows an example of the described network topology:
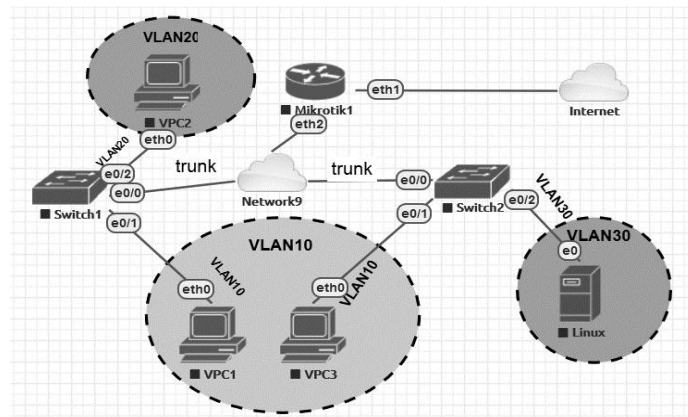

Fig. 2. Network topology with VLAN

The example shows that the designed university cloud provides all the necessary conditions for realization of the blended learning methodology. In particular, students can work on their tasks both in face-to-face and in online (via VPN-connection) modes, being able to cooperate both in class and remotely. In case of group work we suggest that students perform similar tasks, for instance, one student configuring switch 1, another – switch 2, etc. The task can be extended by one student configuring access-ports for switch 1 and another configuring trunk-ports. The teacher also has access to all virtual machines and nods, being able to help students, supervise and control their.

EVE-NG platform gives access to nods via the standard protocols telnet and vnc. If several students connect via these protocols to the same nod, they will work with that VM simultaneously. Access via telnet and vnc protocols does not depend on the parameters of TCP/IP protocols. That means that students have the possibility to make mistakes and learn without running the risk of losing control of their nods.

An important task in designing a network is monitoring the connections. To handle this task, we used Wireshark utility from EVE-NG integration pack.

We went on to study the topics of ITE-NET-07 subdomain (Network management) on the basis of an extended topology with many routers (Fig. 3).
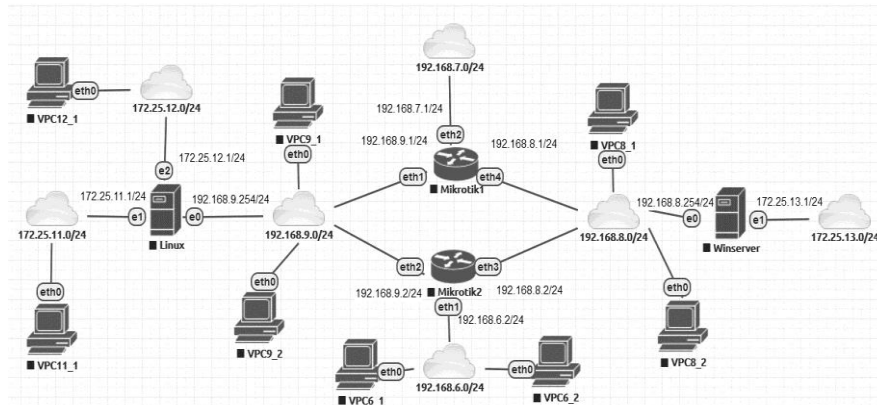
Fig. 3. Example of network with many routers

We used this configuration to look at the following issues:

— static routing;
— basic and NAT routing;
— dynamic routing protocols;
— load-balancing some Internet channel;
— policy Base Routing;
— data filter with firewall;
— network protocols and services (DHCP, ARP, DNS);
— virtual private network protocols (PPTP, L2TP, OpenVPN).

It is worth noting that in the example shown in Fig. 6, networks with 192.168.0.0/16 prefix are internal. They can be viewed as models of local networks working by TCP/IPv4 protocol. Students' routing between such networks does not happen. Networks with prefix 172.25.0.0/16 are connected to Apache CloudStack cloud infrastructure. They can be viewed as models of external networks connected to various Internet Service Providers. The proposed topology can be upgraded by transferring to IPv6 protocol. By doing this, every device in students' networks can be given a real IPv6-address.

Several groups of students can be offered to change the addressing of their internal networks so as to provide static or dynamic routing between them. Also, the complex topology (Fig. 3) can be divided among students in such a way that each student will configure one of its components (Fig. 4). For such group work we used projects – specific organizational units of Apache CloudStack platform. Apache CloudStack project is a group of virtual machines which can accessed by the project participants. Our project involved 4 virtual machines with EVE-NG platform, which, in different sequence, were operated by 4 students.
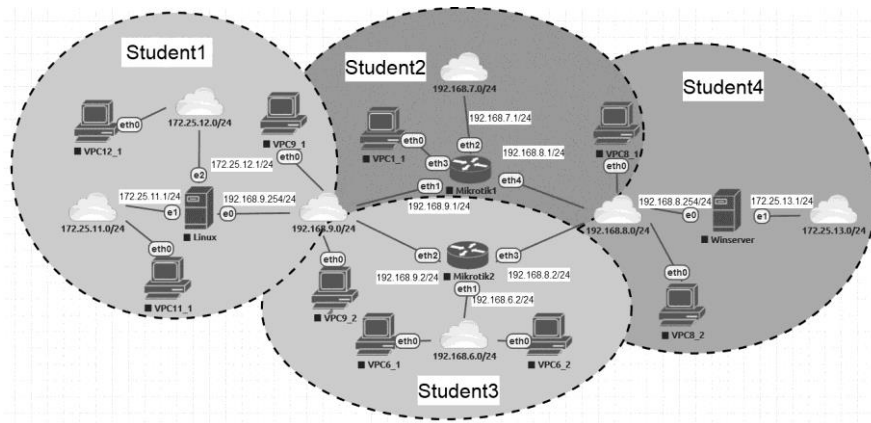
Fig. 4. Division of the topology among students

To complete the study of the topic ITE-NET-07 Network management, we asked students to carry out group project" DIY your own ISP".The major tasks of the project were:

— designing topology of the students' own network;
— making provisions for the possible expansion of the topology;
— isolating clients' computers from one another;
— blocking unwanted or harmful traffic (floods, broadcasts);
— dynamic allocation of IP-addresses from various pools (actual on the Internet and local in the provider's local networks);
— traffic shaping;
— storing user statistics;
— user database management.

While working on the project, the students had maximum independence. They themselves distributed roles in the group, analyzed billing systems, designed the network, chose the necessary equipment, configured connection switches and routers, installed the billing system, tested the network performance and analyzed its drawbacks.

At the second stage of their work, students systematically used services of the public clouds Google Suite and Microsoft Office 365. In particular, they together created protocols of network topology nods testing, graphs of their speed characteristics and summing-up reports on task performance.

To verify the effectiveness of the proposed methodology, we conducted one more research. After completion of the topics ITE-NET-01 – ITE-NET-03, we conducted a test (TEST1-NET-01-03) to assess the academic achievement of students in the control and experimental groups. The test was assessed on the 100-point scale. For each group, we got a total of grades. Fig. 5 shows a descending distribution of the students' grades in TEST1-NET-01.
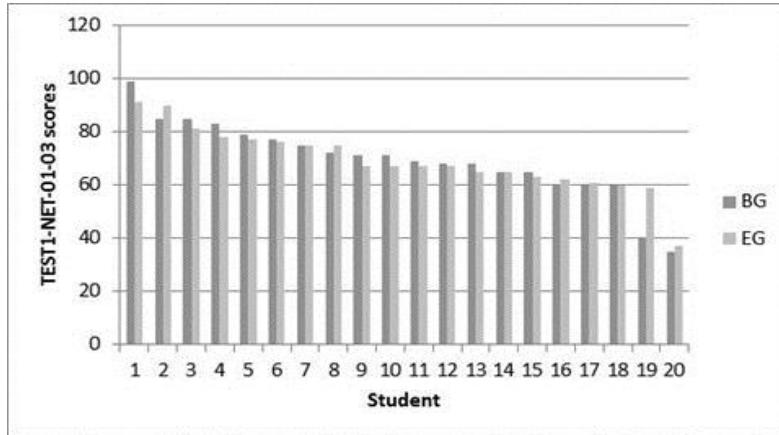
Fig. 5. Grades distribution in TEST1-NET-01-03

Using One-Sample Kolmogorov-Smirnov Test, we found out that the grades are distributed by normal law (2-tailed asymptotic significance for CG and EG: $\alpha CG=0{,}178$; $\alpha EG=0{,}127$). Thus, to check whether there are statistical differences between the groups, we can use Independent Samples Student's t-test. The statistical data of Independent Samples Student's t-test are given in Table 2.

Table 2. Statistical data of Independent Samples Student's t-test after studying ITE-NET-01 – ITE-NET-03 topics

		Levene's Test for Equality of Variances		t	df	Sig. (2-tailed)
		F	Sig.			
TEST1-NET-01-03 scores	Equal variances assumed	0,232	0,633	0,047	38	0,963
	Equal variances not assumed			0,047	36,552	0,963

The table shows that Levene's Test for Equality of Variances data prove the correct choice of the statistical method. As the significance exceeds 0.05, we can state that after studying the topics ITE-NET-01 – ITE-NET-03 students in the control and experimental groups showed no statistical differences in their academic achievement.

The students of both groups then went on to study topics ITE-NET-04 – ITE-NET-07. The content of the topics was the same for both the groups, and the instruction was provided by the same teacher. The students of the control group continued working with the real equipment in class and with their own devices out of class. The students of the experimental group worked by our proposed blended learning methodology. After the students completed topics ITE-NET-04 – ITE-NET-07, we again conducted a test (TEST2-NET-04-07). Its results are shown in Fig. 6.
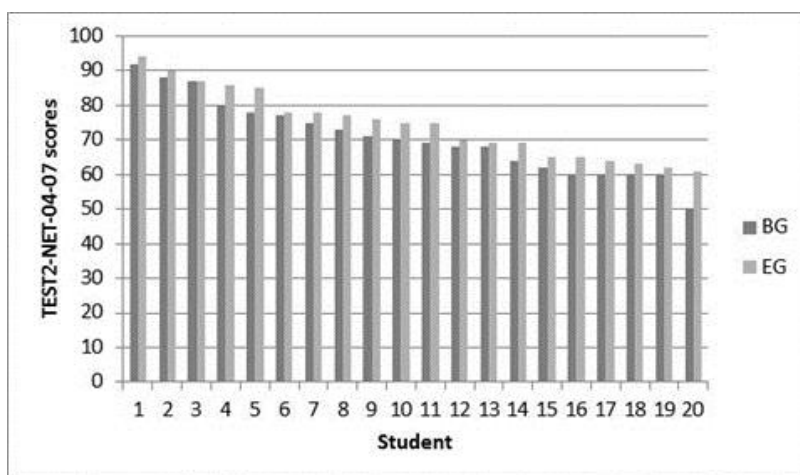
Fig. 6. Grades distribution in TEST2-NET-04-07

We used One-Sample Kolmogorov-Smirnov Test and made sure that the grade distribution in TEST2-NET-04-07 was normal. So, to check statistical differences between the grades received in TEST1-NET-01-03 and TEST2-NET-04-07 we used Dependent Student's t-test for paired samples. Differences between the grades received in TEST1-NET-01-03 and TEST2-NET-04-07 were compared separately for the control and experimental groups. Corresponding statistical data are shown in Table 3.

Table 3. Statistical data of Dependent Student's t-test for paired samples after studying ITE-NET-04 – ITE-NET-07 topics

| | Paired Differences | | | | | |
	Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Pair 1 TEST1_CG_scores - TEST2_CG_scores	-1,250	5,973	1,336	-0,936	19	0,361
Pair 2 TEST1_CG_scores - TEST2_CG_scores	-5,300	5,105	1,140	-4,647	19	0,000

Taking into consideration that SigEG<0,05, we can claim that there exist statistical differences between academic performances of EG students. Such conclusion can not be made concerning CG students. This confirms the effectiveness of the proposed methodology of blended learning at the second stage of our research.

3   Conclusions

The designed and deployed cloud-based environment provides:

— access to cloud resources through a web browser;

- simulation of network topologies in a web browser;
- service as needed – the student can immediately get the system resources;
- universal access to the network infrastructure of the student according to the IaaS model;
- elasticity and scaling of computing resources.

Our research showed that combination of face-to-face and online learning allows teachers to make use of the technological benefits offered by the academic cloud to achieve the study goals. Blended learning facilitates more rational use of resources and time, the process of study becomes more open, students have the possibility to learn how to manage their learning process and appear to be much better prepared for successful completion of the course.

This research has experimentally proved the efficiency of the blended learning methodology in training computer science trainee teachers. Suggested educational projects raise students' cognitive interest, allow them to develop essential professional skills, ability to work in a team and sense of responsibility for their joint effort.

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