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CURRENT TOPIC / АКТУЕЛНА ТЕМА

The application of simulation in medical education – our experiences “from improvisation to simulation”

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SUMMARY
While the use of simulation in medical education has a long history, it has seen its greatest strides in the past 15-odd years. It may be defined as imitation, artificial while at the same time faithful, of various clinical situations through well-crafted medical “scenarios” where, instead of actual people, we use standardized patients: plant, animal, or synthetic models, computerized interactive manikins – simulators, with audiovisuals, as well as medical equipment used in everyday clinical practice. The fundamental goal of using simulation in medical education is an optimal balance between professional education on the one hand and complete safety and protection of patients on the other. Depending on the available finances and the level of advancement of the healthcare and education systems, medical simulation can take various forms – from simple improvisation to the creation of a high-fidelity simulation in centers for medical simulation. Our example shows that, even with modest financial means, enthusiasm, creativity, and good ideas make it possible to establish a center for medical simulation. A separate section of the paper is devoted to the staging of a simulation scenario based on the authors’ experiences.
Keywords: education; medical; teaching; manikins

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INTRODUCTION

Medical simulation (MS) is artificial and faithful imitation of various clinical situations using well-devised medical “scenarios” featuring, instead of actual patients, either standardized patients (patient actors), plant, animal, or synthetic models for practice, or computerized interactive manikins which include audiovisual equipment, in addition to the medical equipment employed in everyday clinical practice [1, 2]. The purpose of MS is to ensure the optimal proportion of educating healthcare workers on the one hand, and patient safety (including respecting patients’ ethical and legal rights) on the other.

HISTORY

Archeological discoveries of sculptures, figurines, and carved models reveal that techniques of simulation had been part of education even in times of antiquity [3, 4]. In ancient China, teaching acupuncture involved life-size bronze human figures filled with liquid, which had wax-covered perforations for the insertion of acupuncture needles [3, 5]. As many as 2,500 years ago, a comprehensive text on surgery titled Sushruta Samhita emerged in India. This volume, considered the precursor to Arabian and European medicine, describes in great detail methods of medical education using plant and animal models [3]. Under the Qing dynasty in China (1644–1912), only men were permitted to enter the medical profession. Prohibited from touching female patients during examinations, they performed examinations indirectly, using miniature models of naked female figures made of ivory [6, 7]. Specialized workshops named La Specola appeared in Italy in the 18th century and made out of wax anatomically accurate models for student education, today preserved in the eponymous museum in Florence [8]. Louis XV, concerned over an increase in the mortality of newborns in rural France, ordered the construction of a childbirth simulator dubbed the Machine for the purpose of better educating midwives and obstetricians. The Machine was shaped like the lower half of a female torso and included uterus and genitalia, fetuses of various ages, and even contained a sponge that released colorless and red fluid (to simulate the amniotic fluid and blood) [9]. The first simulation-executed training programs in medical education were organized in the late 1960s, when researchers at the University of Miami made the Harvey Cardiology Simulator, which could provide realistic simulations of many cardiological conditions. The first realistic manikin, the Sim One simulator, was created in 1966, long before the introduction of computer technology in medicine [10, 11, 12].

MS is not an original method of teaching; rather, it evolved from simulation in other disciplines, where any error could have equally disastrous consequences – primarily based on experiences in aviation, where simulation began to be used after World War I [11, 12, 13].

ADVANTAGES OF SIMULATION IN MEDICAL EDUCATION

MS is becoming an increasingly important link in the so-called education chain, where students move from the acquisition of theoretical to that of practical knowledge through the use of simple simulators, going on to learn in high-fidelity simulations and simulation scenarios, and completing their education at the end of the chain with real patients in real circumstances.

The application of simulation in medical education changes the motto of the old, traditional method of learning, "See one, do one, teach one," into the new, more contemporary and successful, "See one, practice many, do one" [1]. Simulation-based learning allows a move from the traditional to the much more integrative approach of using cognitive (perception, thinking, memory, learning), psychomotor (practical, manual skills and techniques, the execution of risky and complex procedures, managing new technology), executive (independent decision-making, building professional opinion), and interpersonal (interview, communication, teamwork) functions [2, 12].

MS erases the compromise inherent in balancing education and patient safety in a real clinical environment [1]. When a simulation is performed, the focus is on teaching and the student, while, in real conditions, the patients – their treatment and protection from medical error – are always in the forefront [1, 11, 14]. In this way, the fundamental medical ethics principle of "first, do no harm" is fully actualized [12].

MS permits the creation of scenarios that can rarely be encountered in typical student exercise classes, like emergencies, life-threatening or rare situations. Also, MS can be used in the design and testing of new clinical equipment [2, 11, 14].

Conversely, when working with actual patients, education time is limited and access to the patient for the purpose of education sporadic [14].

The greatest advantage of simulation is the possibility of repeating procedures that have not been learned to a satisfactory degree for the purpose of education, as the manikins and computer software absorb all mistakes made in the course of learning. This makes it possible to institute a very efficient educational principle – learning from mistakes [11, 14]. In a clinical setting, mistakes must be prevented or corrected immediately to protect the patient. In addition, errors made in simulation may be discussed by the doctor in training and evaluated without constraint, worry, guilt, ethical responsibility, or legal liability. The basic differences between MS and contact with real patients are shown in Table 1.

MS has applications both in undergraduate and postgraduate medical studies, in the continued education of medical professionals, as well as in the acquisition of the knowledge needed to resolve critical situations in emergency situations during natural disasters and armed conflicts [1, 11].

Table 1. Basic differences between medical simulation and learning with actual patients

Medical simulation	Actual contact with patients
Education and students are the priority	Priorities are treatment, patient safety, and respect for the patient's autonomy
Unlimited duration of education	Duration limited by the patient's condition and needs
Practicing skills while learning from mistakes	Limitless repetition and mistakes not permitted
Students actively participate in solving emergency, life-threatening situations	Medical professionals manage emergency situations without active student participation
Open discussion of omissions in debriefing, with no ethical, moral, or legal responsibility attached	Fear of liability and guilt, which are limiting factors for an objective critical review

The integration of simulation methods into educational curricula for healthcare workers at the national level has become standard practice in many developed countries and the day is not far when the formation of simulation centers will be a requirement in accrediting medical education facilities [2, 14]. One of the first obstacles is convincing healthcare institutions' financial sector of the economic justification and usefulness of applying simulation in the education of medical professionals. Examples from practice indicate indirect benefits in the long term in the form of increased patient safety, reduced likelihood of medical error and complications, and hence reduced cost of treatment [1].

However, learning in a simulated environment must on no account be allowed to become a goal unto itself. Simulation cannot replace clinical experience; but it can be a useful model for preparing the doctor for practice [2]. It is not realistic to expect students to exhibit complete mastery in the clinical world after simulation learning, but the training can be an ideal transition stage from theoretical knowledge to the practical experience of working with actual patients. Also, students must not be permitted to acquire a sense of comfort and ease through learning in simulation that may carry over into the real clinical setting, as this may have repercussions on patient safety [2].

TYPES OF SIMULATION AND THEIR BASIC CHARACTERISTICS

Based on the available literature and the authors' personal experience, we have divided all simulation into six basic groups according to fidelity [1, 2, 11, 12, 14]. Each has its advantages and drawbacks, as shown in Table 2.

Over the past 15 years, it has become almost unthinkable to educate medical students and healthcare workers without some of the abovementioned simulation techniques and methods. With regard to space, all high-fidelity simulations can be performed in three ways in virtual real-

Table 2. Types of simulators and simulations – basic characteristics

No.	Simulators by fidelity	Basic characteristics	Example of simulation
1.	Screen-based text simulators; clinical problems are solved using printed or electronically displayed material: presentation of the patient, laboratory test results, treatment charts, vital sign charts, photographs, X-ray and CT scans	• Low-fidelity simulators • Passive approach • Development of cognitive function • Non-realistic approach, no interactivity or teamwork • Low education cost • A large number of students may be educated simultaneously	ECG learning, interpretation of blood gas or laboratory test results
2.	Part task trainers: parts of plants, animal organs, static life-size manikins, models or human body parts	• Low-fidelity simulators • Used for hands-on practice • Unrealistic approach, no interactivity or teamwork • Low education cost • A large number of students may be educated simultaneously	Air management heads, central line placement torsos, cardiopulmonary resuscitation, store-bought items such as pigs' feet or banana peel (suturing)
3.	Screen-based computer simulators; simulation using computerized audiovisual and graphic animations: anatomic animations, monitoring physiological functions, pharmacokinetic and dynamic processes associated with drug administration, effects of applied treatment, watching surgical techniques, images, and animations	• Medium-fidelity simulators • Basic computer equipment and software necessary • Develop cognitive functions • Insufficiently realistic degree of interactivity • Good grasp of computer program use necessary • Independent learning and reception of feedback possible • Low education cost • A large number of students may be educated simultaneously	May be used in all pre-clinical and clinical branches of medicine; e.g.: simulation of general anesthesia, auscultation (heart sounds and murmurs and lung sounds)
4.	Standardized patients (patient actors) are educated and rehearsed actors (medical professionals) who simulate various clinical conditions and diseases and provide guidance toward a diagnosis in direct communication with students through information about patient history and partial physical examination	• Realistic approach • Partly interactive approach • Permits acquisition of cognitive, psychomotor and interpersonal knowledge, development of communication skills • Invasive procedures cannot be performed • Clinical signs cannot be acted out, only symptoms can • Low education cost • Education in small groups of students assembled around one "patient"	Simulated clinical situations
5.	Complex task trainers for performing certain diagnostic or treatment procedures; various physiological parameters may be automatically controlled by a physiological and pharmacological model incorporated within the software or may respond to instructor inventions in response to actions of the trainee	• Medium-fidelity simulators • Realistic approach, simulating various emergency medical conditions and diseases • Develops cognitive, psychomotor, and interpersonal knowledge • Interactive approach • High cost (includes manikins and software that can simulate the interaction between the student and the teacher) • Work in small groups	Ultrasound simulator, videolaryngoscopy simulator, advanced life support cardiopulmonary resuscitation protocol
6.	Integrated simulators with realistic patient simulators and environments; virtual reality trainers offer a transition from the two-dimensional world of the textbook to the three-dimensional world of simulated patients	• High-fidelity simulations • May only be performed in simulation centers or as simulation in situ with appropriate computer equipment, software, audio and visual equipment connected to manikins and medical equipment • Develops cognitive, psychomotor and interpersonal knowledge and teamwork • Multi-professional training possible • Evaluation after completed scenario • Sensitive and expensive equipment that presents difficulties in transportation	Creation of clinical scenarios of various medical conditions and diseases – diagnostics and treatment; example scenarios: anaphylactic shock treatment, tension pneumothorax treatment, treatment of venous air embolism, etc.

ity in medicine: in centers for MS, using in situ simulation, and in remote-facilitated simulations.

A center for MS is a spatial, technical, organizational, and personnel unit operating within medical schools or healthcare institutions. In addition to manikins of varying degrees of fidelity, computer and audiovisual equipment and accompanying software, adequate space is needed too. We shall discuss the establishment and operation of a simulation center further in the text based on our experience.

In situ simulation is a model of mobile training within the working environment of medical professionals, with the equipment they use daily, but employing standardized patients or manikins. Its advantages, other than the economic factor, are a more humane and relaxed approach for the medical personnel, who are being educated in their own familiar and current clinical surroundings, in the same place where they treat their patients, together with colleagues by whose side they work every day, at the same time testing their own equipment. Simulation sessions can be performed in a similar way in pre-hospital conditions, like ambulances or helicopters [15].

Remote-facilitated simulations entail the existence of a centralized command center for simulation which runs simulations that can be held in distant areas hundreds of kilometers away. This, of course, requires sophisticated equipment, computers, software, audio and video equipment, but also a high-speed internet connection. Computer equipment in the command center is connected to high-fidelity simulators in the simulation unit, while instructors in the command center monitor students' work and communicate with them using cameras and microphones. Remote simulation is a combination of in situ simulation and a simulation center. This centralized approach provides a consistent system of education for a large number of healthcare workers [16].

There are over 20 associations of simulation medicine in Europe and worldwide: the Society in Europe for Simulation Applied to Medicine (SESAM), the Society for Simulation in Healthcare (SSH), the Association of Standardized Patient Educators (ASPE), the International Pediatric Simulation Society (IPSS), and there are also similar organizations in Canada, Australia, Latin America, Russia, Spain, Poland, India, and Japan. In addition, several medical publications in Europe and America publish papers solely on simulation medicine (The Journal of the Society for Simulation in Healthcare, BMJ Simulation & Technology Enhanced Learning, Advances in Simulation, The Internet Journal of Medical Simulation, etc.).

ESTABLISHMENT OF THE FIRST CENTER FOR MEDICAL SIMULATION IN SERBIA: "FROM IMPROVISATION TO SIMULATION"

"A journey of a thousand miles begins with a single step" – Laozi, ancient Chinese philosopher (6th–5th century BC).

The establishment of the Center for Medical Simulation at the Faculty of Medical Sciences in Kosovska Mitrovica had several stages. We named the first the "improvisation stage," due to the lack of adequate equipment and manikins for student education, especially in cardiopulmonary resuscitation, which cannot be learned from reference textbooks alone [17, 18]. Without any MS knowledge, our students assumed the roles of standardized patients and improvised various clinical conditions. After this came the manikin acquisition stage. With modest financial means, we purchased basic manikins for the basic life support measures of cardiopulmonary resuscitation (CPR), airway manikins (endotracheal intubation, placement of laryngeal mask and combitube, oropharyngeal, and nasopharyngeal tube), manikins for the parenteral administering of medication, oxygen therapy, advanced life support CPR measures, including the use of automated external defibrillator (AED) and manual defibrillators, and pediatric manikins. The introduction of mandatory continued medical education into the Serbian healthcare system ushered in the third, medical professional education stage, which included fundraising to establish an economic foundation for founding the Center for Medical Simulation [19–22].

From improvisation to the manikin room, we wanted to take a step further and enter the unknown world of simulation medicine.

The Center for Medical Simulation was established at our school in 2012. It occupies around 100 m^2 in the immediate vicinity of the Dean's Office of the Faculty of Medical Sciences in a space that was previously a disused warehouse. It consists of a room for introductory lectures, which seats 30 and has computer and audio and video equipment, an office for administrative work and preparation by instructors, two manikin rooms, a simulation room, a command room, two water lines, and a storage area for equipment. In addition to preparing participants in simulation scenarios, the introductory lecture room can be turned into a training center for first aid training, where students practice basic life support CPR measures on mats. The earlier mentioned manikins and equipment are set up in the manikin rooms, with an anesthesia machine in a separate area, where students gain basic anesthesiology skills with appropriate preparation of the manikins and equipment. Before entering the simulation room, all students go through training on static manikins, acquiring the manual skills and techniques necessary while discharging simulation scenarios [20, 21, 22]. The central portion of the Center is occupied by the simulation room, separated from the command room by a transparent (glass) partition. The schematic and real representation of the simulation and command rooms is provided in Figures 1 and 2.

The simulation room was turned into an intensive care unit with a manikin in the bed, connected to a vital sign monitor, controlled from the command room using the appropriate software to display a simulation of continuous ECG monitoring, systolic and diastolic blood pressure measurements, heart pulse, pulse oximetry and capnometry. A central venous catheter (attached to equipment measuring central venous pressure) is placed in the manikin, which can be submitted to intravenous cannulation, the administration of infusion solutions and blood transfusions (using imitation blood, a red-dyed fluid). A urinary catheter is also inserted in the manikin and there is a urine collection bag (with imitation urine – a yellow-dyed fluid).

One of our "inventions" is the installation of audio equipment into the torsos of static manikins, which is then connected to software in the command room, allowing students a more realistic approach to studying the auscultation of heart sounds and murmurs and lung sounds (Figure 3) [21, 22].

An "info" monitor in the simulation room briefs students on the parts of the scenario they cannot take in via audio equipment [voice recordings of instructor and/or manikin patient, files of heart sounds and murmurs, or

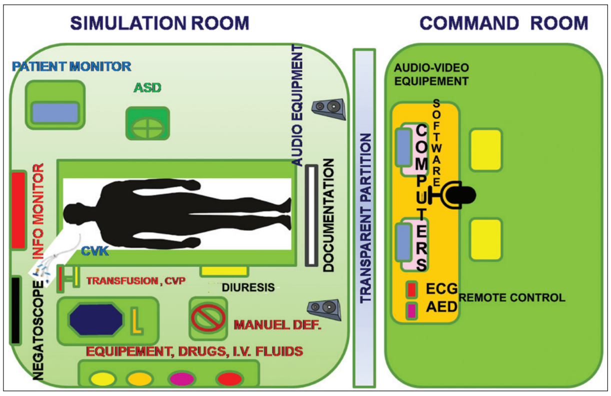

Figure 1. Schematic of the simulation room and the command room in our Simulation Center

Figure 2. Actual view of our Simulation Center and work done in it

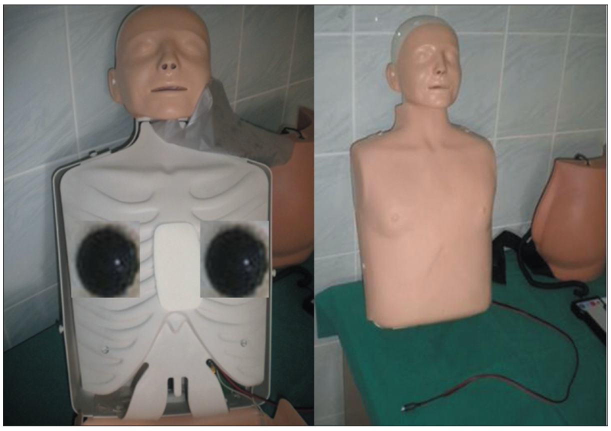

Figure 3. Speakers installed in the manikin's torso connected to the computers in the command room to emit heart sounds and murmurs, as well as lung sounds

printed materials (anamnesis, disease history, laboratory test results, therapy chart, and list of vital signs]. There are also a lightbox, manual defibrillator, and AED (remote controlled from the command room) in the simulation room. A separate part of the room is used to keep medication and equipment for airway management, orotracheal aspiration, and thoracic drainage. Depending on the type of scenario, the simulation room can be turned into an emergency room, a pediatric intensive care unit, a or patient room.

The command room has computers (connected through the appropriate software with the vital sign monitor and info monitor), an AED remote control, an ECG simulator, and microphone and speakers for interactive contact with students. The Center for Medical Simulation has a high-speed internet connection and each simulation scenario includes, in addition to the equipment, electronic and printed material deployed as needed. We have downloaded the vital sign monitor software from free download sites online. In cooperation with the Faculty of Technical Sciences, we are in negotiations about creating computer programs tailor-made for our simulation equipment [19, 22].

PLANS FOR THE FUTURE

- Positive experiences to date in the application of this model of education have opened new vistas to us and paved the way toward plans for the future, including the following Acquiring modern manikins, equipment and software;
  - Organizing seminars and conferences on MS;
  - Connecting with other medical schools and healthcare institutions in relation to MS in Serbia and the region;
  - Publishing papers on MS in publications of reference;
  - Connecting with developed MS centers in Europe, instructor education, cooperation with other schools – an interdisciplinary approach;
  - Becoming involved in international projects and foundations;
  - Forming a national Center for Medical Simulation in the Republic of Serbia.

HOW TO MAKE A SIMULATION SCENARIO

A well-thought-out simulation scenario can be compared to a play that can only be devised by someone with vast clinical knowledge and experience in the area of medicine that the scenario treats. The creativity and innovation of the instructor are brought fully to light here.

In simulation scenarios, we used the experiences of other authors who permit free access to a Template for Simulation Patient Design, based on which we designed a template appropriate to our conditions [23].

The selection of each scenario requires defining the pedagogic goals and target trainees, the issues considered in the simulation, designing the simulation model, providing didactic materials, devices, instruments, manikins, equipment, consumable materials, and the video and audio files needed for executing the simulation. Before launching the scenario, the instructor prepares and double-checks the computer and audio equipment and rehearses the prepared simulation scenario. Each scenario entails a detailed preparation of the necessary data, which will show up on info screens and the patient monitor, controlled from the command room, audio and visual information, and heart sound and breathing sound files.

If the simulation involves an actor, the scenario must be well rehearsed to present situations where diagnostic or treatment decisions by trainees are expected as realistically as possible. The instructor's task is to simulate phases of the scenario on the computer through the info and patient screens and audio equipment.

The students get information about the patient from a text presented as disease history which they read prior to the scenario, by reading the vital signs on the patient monitor, obtaining information on vital symptoms in direct contact with the patient (voiced over by the instructor or an audio file), from the info monitor, reading data from a treatment chart, vital sign chart, laboratory test results and available diagnostic tests, and the course of the disease in the patient documentation. Each scenario is divided into "mini scenarios" or "conditions," which permit the scenario to unfold. Moving from one condition to the next is caused by triggers, which include time, the administered medication, or the manual technique performed by the trainee [13, 23].

During the simulation exercise, students are tasked with acquainting themselves with the clinical problem, making the diagnosis and responding in a timely fashion: with manual skills and techniques using the available equipment, administering medication (personally or with the help of a demonstrator, another participant in the simulation), and by responding to questions and interacting with the instructor through audio equipment.

In the course of the simulation, the instructor assesses the trainees in the following: interest and activity during the introductory interactive lectures and discussions; interpretation of vital signs and symptoms, medical history, and other documentation (therapeutic lists, laboratory findings, chest X-ray and ECG; diagnosis and differential diagnosis; emergency treatment (manual skills, administration of therapy; handling equipment, interpersonal and communications skills; teamwork) [13, 23].

Each simulation is recorded with a video camera. The final, vital part of MS is feedback, done through a reconstruction and detailed report of the simulation, with a critical review of the team members' actions, including comments and conclusions on their responses. In an interactive approach, the video and audio recording of the simulation is analyzed and unclear or poorly executed situations are explained. At the end, all participants make an evaluation by filling out a survey form rating the selection of the simulation topic, organization, duration, and pace of the training, manner and methods of working, and the spatial and technical conditions at the Center for Simulation. They also suggest new subjects, teachers, and methods for later training sessions and provide special comments and suggestions [3, 13].

We have designed and rehearsed some 10 scenarios, notably basic life support and advanced life support CPR measures in adults and children, anaphylactic shock treatment, treatment of hemorrhagic shock, venous air embolism, using an Early Warning Score, auscultation (heart sounds and murmurs, lung sounds), tension pneumothorax treatment, etc.

A video presentation of our Center for Medical Simulation is available at the following web address: https://www.youtube.com/watch?v=85K-AwR_ENQ [22].

CONCLUSION

The use of simulation in medical education has a long history. Over the past 15 years, it has become almost unthinkable to provide education to students and medical professionals without using some form of simulation. The idea of forming a simulation center is associated in the minds of many with costly, sophisticated equipment, which is hence unattainable when finances are scant. Our example proves that, even with modest financial means, when one has enthusiasm, creativity and good ideas, satisfactory results in simulation medicine are possible, allowing higher quality education for medical professionals on the one hand and the protection of patients on the other. We are aware that our results are modest and cannot compare to contemporary European and international MS centers. Yet we have taken the first steps and are trying to share them with you in this article.

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Примена симулација у медицинској едукацији – наша искуства „од импровизације до симулације“

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САЖЕТАК

Примена симулације у медицинској едукацији има дугу историју, али највећи напредак доживљава последњих петнаестак година. Она се може дефинисати као верна имитација различитих клиничких ситуација преко добро направљених медицинских „сценарија“ где се уместо реалних пацијената користе „стандардизовани пацијенти“, биљни, животињски или синтетички модели, компјутеризоване интерактивне лутке – симулатори, уз употребу аудио и видео опреме, као и медицинске опреме која се користи у свакодневној клиничкој пракси. Основни циљ коришћења симулације у едукацији је да се постигне оптималан баланс између стручне едукације, с једне стране, и заштите пацијената, с друге стране. У зависности од финансијских могућности, као и развијености здравственог и образовног система, медицинска симулација се може изводити на разне начине – од једноставне импровизације до стварања високо „верне“ симулације у центрима за медицинску симулацију. Наш пример показује да је и у условима скромних финансијских средстава, уз ентузијазам, креативност и добре идеје, могуће формирати центар за медицинску симулацију. Посебно је приказан симулациони сценарио на основу досадашњих искустава аутора.

Кључне речи: медицинска едукација; учење; лутке за едукацију