

Changes in Educational Technology and Teaching Methods Due to Technological Developments and 3D Printing

Zoltán KOVÁCS,¹  István EMBER,²  Róbert VÉG,³ 
Norbert DARUKA,⁴  Kálmán DÉNES⁵ 

Teaching methods are constantly evolving, and the amount of teaching material is increasing year by year. The more effective acquisition of the expanding range of knowledge and the easier understanding can be greatly facilitated by the illustrative materials and educational aids, produced by 3D printing. In our article, we briefly describe the main characteristics of basic teaching methods and the advantages of using novel 3D technology in education, especially in military officer training.

Keywords: 3D printing, training aid, illustrative object, military higher education, officer training

Introduction

Effective education requires rethinking who, whom, what and how to teach. The answer to the question of “who” and “whom” is easier and given, because of course the best, most up-to-date teacher should teach students who have entered the education system after a successful admission procedure and who feel a sufficient commitment to their chosen subject. Commitment to education and teaching is an essential but not a sufficient condition for teaching. Teaching is the main factor affecting the effectiveness of education, i.e. the education system is only as good as the teachers who make it up.⁶

¹ Associate Professor, Department of Combat Support, e-mail: kovacs.zoltan@uni-nke.hu

² Assistant Professor, Department of Combat Support, e-mail: ember.istvan@uni-nke.hu

³ Associate Professor, Department of Military Technology, e-mail: vegh.robert@uni-nke.hu

⁴ Explosives industrial engineer, e-mail: daruka.norbi@gmail.com

⁵ Civil engineer, e-mail: denes.kalman.1975@gmail.com

⁶ NAGY-CZIROK 2016: 45–47.

The answer to the question “what” is also determined by the need to teach marketable knowledge that can be applied to the job. Education plans determine the curriculum according to what is wanted and what is available. How to teach is essentially determined by the organisation of the teaching process, the methods and the technical means of teaching.

Education is a regulated process, not only in terms of content but also in terms of form, and can take the form of classroom-based activities (theory, practical, laboratory), professional practices (e.g. work experience, industrial placements), workshops and scientific student groups, and field trips (factory visits, museum visits).

The key to effective teaching is to choose teaching methods that are appropriate to the teaching objective and to apply them in a variety of ways that match the students’ level of knowledge and the specific nature of the subject. The types of work that can be used to teach students include frontal class work, group work and individual work.

In case of frontal class work, the teacher has the greatest role to play in explaining and delivering the subject matter through individual presentation and the use of teaching techniques. In order to achieve common educational objectives, the learning activities of the students are carried out at the same time, usually at the same pace. This is the quickest and most effective way of delivering the material, which can be used in large class sizes, but it has the disadvantage that the teacher is not informed about the different pace and depth of learning of each pupil during the face-to-face teaching, and is therefore unable to adapt the teaching to the pupils’ performance.⁷

In group work, students work in small groups (3–6 students) on a given task in which they have a relationship of dependency, responsibility and control. Groups can be formed by the teacher or by the pupils themselves. In group work, they learn to listen and listen to each other, to represent their own interests (knowledge), to learn about learning procedures, to practice time management and division of labour.⁸

In case of individual work, the student learns the assigned course material independently. Individual work develops the ability to focus, to collect data efficiently and to work independently. The teacher can differentiate and get to know the individual characteristics of the students better. A disadvantage of this form of work is that it can lead to a “pigeonholing” of learners on the basis of knowledge, which can be difficult for them to penetrate later on.⁹

It is the level and form of education that determines how much weight is given to particular forms of work. In higher education, the role of face-to-face class work in the transfer of knowledge is increasingly being reduced and more personalised forms of work, such as small group teaching or individual tutor-led learning, are being introduced.

⁷ VARGÁNÉ KISS 2009.

⁸ GAÁL–JÁSZI 2024.

⁹ RADNÓTI 2006.

Organisational forms and framework of education

The basic form of organised school education is the classroom, which is traditionally categorised according to the dominant didactic task of the class. When breaking down the curriculum, the type of successive lessons cannot be clearly defined. The intellectual and physical composition and attitudes of a given group of pupils require different formal and methodological teaching of the same subject, and therefore different types of lessons. Several views have emerged on the categorisation of lessons, e.g. that the most important task is not to set a didactic objective, but rather to choose the appropriate tools according to the circumstances. However, the most common way of describing the types of lessons is still the traditional didactic approach, which is the most concise, i.e. lessons can be a new knowledge lesson, a practice lesson, a revision lesson, a systematic lesson, a summary lesson and a control and evaluation lesson.¹⁰

A new knowledge class is the type of class that is used in the majority of education, the main purpose of which is to provide knowledge, to teach new concepts, laws, rules and contexts, and which can be an introductory class, a “homogeneous” class, or a “mixed” class. It should be borne in mind that new material should be based on existing knowledge. In the introductory part of the lesson, references should be made to the knowledge previously acquired, to shed light on the subject matter of the next lesson and to arouse the interest of the students in the new knowledge to be acquired. During the presentation of the new material, constant references should be made, both to reinforce the positive experience of their own knowledge and to draw attention to any gaps in their knowledge that may make it difficult to process the material. It is a good idea to have an introduction lesson at the start of a new topic, to establish a link with previously covered chapters and knowledge, and to create motivation for the next topic. The methods and teaching aids used in the introduction can be varied and can also be used to assess students’ prior knowledge. In a homogeneous lesson (the whole time), the new knowledge is covered and there is no repetition, practice or monitoring. The teacher uses an analytical, analysing method to synthesise the new knowledge, but may have difficulty in maintaining the attention of the pupils throughout the lesson. Mixed type lessons are the most common type of lesson where new knowledge is transmitted, processed and checked. It may involve practice, repetition and organisation alongside the transfer of new knowledge.¹¹

Ideally, the acquisition and application of knowledge are not sharply separated, but form a single unit. Practical lessons are important for the development of skills and competences, providing opportunities for independent tasks, group work and cooperation. It can also be a practical or experiential lesson where students can develop their sensory and manual skills. During the practical lesson, students can learn about and physically touch the structural elements, and as their theoretical knowledge increases, it becomes more of an individual or group task to be carried out.

A summary lesson should be included in the curriculum at the end of a unit of study, where the aim is to summarise, organise, unify or put the material in a new light. It

¹⁰ KRISKA–KARKUS 2022.

¹¹ CZIGLÉNÉ FARKAS 2008.

is advisable to repeat and organise a section of material from several angles, because presenting it from multiple perspectives helps students absorb the curriculum more quickly and deeply. The lesson should provide an opportunity to develop a new perspective, to highlight the essential links and to develop the relationship between theory and practice. A summary lesson can be effective if the concepts related to the summarised material are clearly and unambiguously captured. Self-checking and self-assessment play an important role in the lesson. A summary lesson is good if it is possible to point out gaps to the pupils so that they feel they have the opportunity to make up for them before the examination.¹²

The revision lesson is usually followed by the control lesson, which in many cases involves the writing of a final examination paper. In higher education, written forms of control have become almost the only form of control, because they are more suited to the requirements and quality of higher education and because oral control would take too much time.

Traditional and modern teaching methods

An important element of effective learning in education is the teaching method used, which should be adapted to the level of knowledge of the students and the specific nature of the subject. The use of a combination of teaching methods is usually advisable, as it promotes active learning, the development of critical thinking and the ability to work in teams. Teaching methods can be divided into traditional (lecture, explanation, narration, discussion, student presentation, demonstration, project method, work-based method, field trip) and modern teaching methods (M-learning, gamification, blended learning, E-learning,¹³ etc.).

The appropriate use of different teaching methods plays an important role in the training of students, not only to increase their knowledge but also to develop the key competences they will need in the labour market to meet the challenges of the 21st century. Education should include critical thinking, problem solving, creativity, communication, teamwork and independent learning.

Lectures are one of the most common and most frequently used teaching methods, where the instructor explains a topic in a logical and detailed way in an oral presentation. It is possible to use explanation and narration simultaneously. The main parts of the lecture are introduction, explanation and summary. The purpose of the explanation is to facilitate the understanding of concepts, rules and contexts and is shorter in length than the lecture. Explanations can be interpretative (to define concepts and describe characteristics), descriptive (to describe the characteristics and operation of a process), or explanatory (to explain the causes, consequences and context of a phenomenon).

Narration is a way of presenting a topic to the students in sufficient detail and in an experiential way, while the emphasis is not on exploring cause and effect, but on stimulating the students' imagination and emotions. Through narration, students can imagine events

¹² NYÉKI 2016.

¹³ KORPICS et al. 2023: 37–39.

and processes related to the subject matter, thus becoming active participants in the learning process. Discussion is a teaching method where the processing of the material is based on discussion through questions posed by the teacher. Discussion encourages active participation and makes students think and formulate their own opinions on the material.¹⁴

Student presentations help students to participate more actively in their learning, increase their confidence and develop their research and presentation skills. It can be on any topic in which students have the opportunity to carry out independent research. Illustration can be used to study tangible things related to the topic. The student can get hands-on experience of the objects related to the subject matter and thus better understand how they work, which is beneficial for the acquisition of knowledge. Visualisation helps to develop the pictorial thinking necessary to understand concepts and to master certain activities. The project method relies on the active participation of students and the collaboration between teachers and students, which transforms the learning process into a series of projects focusing on different learning materials. The project method not only promotes the acquisition of knowledge but also develops students' problem-solving skills and creativity.¹⁵ It promotes students' active participation, autonomy and creativity, while supporting the learning process.¹⁶

In the employer approach, students acquire the necessary knowledge and skills through manipulative activities. During the activity, they observe the properties of objects and parts in relation to each other, thereby acquiring new knowledge using their previous knowledge.¹⁷ During the field trip, students leave the classroom and learn about the topics covered in the curriculum in a real-life location. The advantage of this teaching method is that students can experience what they have learned in real life, increase their motivation, gain practical experience and, last but not least, it can be an excellent way of building community.

Gamification

Gamification is a method of applying game elements outside the game, e.g. in education, to make learning more interesting and to influence students' behaviour in a positive way. Gamification is based on the human desire for recognition, so the gamification method can be a powerful motivating factor. When participants are rewarded, it encourages them to make an effort to do activities that they initially thought were boring.¹⁸ In the gamification method, participants collect various points and prizes, which play an important role in feedback and performance evaluation processes. The advantage of a points system is that the emphasis is on accumulating points and achieving small successes rather than on merit-based assessment (of course, grading based on marks is still possible). Gamification elements and small competitions can be incorporated into the curriculum,

¹⁴ BENCZÉNYÉ FEKETE – SCHLICHTER-TAKÁCS 2022: 92.

¹⁵ BENCZÉNYÉ FEKETE – SCHLICHTER-TAKÁCS 2022: 152.

¹⁶ LADA 2009.

¹⁷ KORPICS et al. 2023: 39.

¹⁸ FROMANN–DAMSA 2016: 78.

where students are awarded points for reaching a certain level. Great emphasis should be placed on careful and precise preparation in the design of playful units. The nature of the game may also involve competitive elements where the results achieved can be made public. In gamification, the points and badges achieved and earned may not be sufficiently motivating for students, it can only be successful if it is sufficiently exciting, non-monotonous and challenging.

Blended learning

Blended learning combines classroom-based learning with distance learning, allowing students to learn at their own pace, while still having the opportunity to meet the teacher face-to-face. Blended learning provides the ideal learning mode for the student without space and time constraints. “An educational technology that makes the learning material accessible through a variety of learning environment elements (methods and tools), traditional and virtual classroom learning formats, face-to-face and distance communication, print and electronic learning materials, high quality info-communication tools, cooperative, varied methods, individualised learning, ensuring the monitoring and evaluation of the learners’ progress.”¹⁹

The benefits of blended learning can be seen in the more time for teachers and students to work creatively and cooperatively in the classroom, the emphasis in lessons on deeper understanding, practical application and group work, and the ability for students to take advantage of online learning while maintaining the personal contact with peers and teachers that traditional education provides. Blended learning expands communication opportunities, allowing students to interact with instructors and peers through mixed channels (chat, video, online forum), which fosters critical thinking, problem solving and collaboration. Students will become more technologically literate and improve their digital literacy (which can be an advantage in further education and job search), increase their self-motivation, self-responsibility and develop discipline, as they are largely self-reliant in their learning.²⁰

In blended learning, it is important to keep the curriculum up-to-date, incorporating the latest information to ensure that students are up-to-date with the knowledge they need in the 21st century labour market. The disadvantage of blended learning is that not all students are ideally suited to using online modules, some find oral explanations more understandable and easier to learn. The time constraints of independent study are not always well managed by all students, and lack of motivation can also be a problem. A disadvantage is that it takes a lot of time for the teacher to prepare and develop useful learning materials.

¹⁹ FORGÓ 2004: 12.

²⁰ BÁNKESZI-SZEPESI 2018.

E-learning

The spread of infocommunication technologies provides a good opportunity for the expansion of electronic forms of distance learning. E-learning uses electronic devices (computer, smartphone) and media for learning. Modern e-learning technologies (online courses, virtual classrooms, video lessons, podcasts) allow students to acquire new knowledge in a user-friendly way, according to their individual learning path, regardless of the number of participants or their geographical location. E-learning reduces the cost of education and allows for large-scale learning, as it is not classroom-based. This mode of learning is appropriate for social sciences and data-based learning, but it is not as effective for learning complex subjects that require complex thinking.²¹

E-learning is delivered through different platforms, such as Moodle, which is widely used, easy to use, capable of storing and editing course materials, tracking student activity, assessing student work and issuing assignments. Moodle also provides the possibility of accountability, contact and messaging. The advantages of e-learning are that it is flexible, can be individually scheduled, saves time because there is no travel time, learning can take place anywhere and at any time, modern learning materials are interactive and experiential, and is cheaper than traditional forms of learning. The disadvantages are that good digital learning materials are time-consuming and require specific expertise to produce, there is no real interaction between the teacher and the student, students are less motivated because they spend less time learning due to too much freedom and e-learning materials do not always fit the individual learning needs of students.²²

M-learning (mobile learning)

It involves learning and teaching processes using mobile technology (mobile phones, e-book readers, laptops, portable media players), thus mobilising not only the learning but also the learner. Mobile learning means using handheld IT devices while learning is mostly fast, mostly at leisure, allowing learners to move at their own learning pace, at their own convenience, which can increase the effectiveness of learning. It has the advantage of enabling students to access learning materials from anywhere and at any time, providing the opportunity for interactive and personalised learning, and increasing motivation to learn. Mobile learning is more than just the use of technological devices, it also represents a new way of teaching. It allows students to communicate easily and quickly with each other and to work on group tasks. Mobile technology can automate repetitive tasks, allowing students to focus their cognitive energy on the more important elements of the learning process, access the latest information and content, and stay up-to-date in their field.²³

²¹ ADY–TERPECZ 2018: 124.

²² MRÁZIK 2021.

²³ KÓRÖSI et al. 2015; BÓNUS–KOROM 2022.

Printed and non-printed teaching materials

The media to be used in education will determine what best suits the educational purpose, content, target group and conditions, whether the medium is provided for the students and whether the students have the learning habits to use the medium. In recent decades, the most commonly used educational tool has been the printed course material. In education, electronic tools and printed learning materials co-exist well and complement each other. Printed learning materials have many advantages, i.e. they are easy to handle and transport, relatively cheap to produce, small in size, can be read twice or three times faster than listening to the same text, encourage the learner to take notes, highlight, underline, and have a “bookish/papery smell”, which is an important consideration for many people. Of course, the printed courseware also has disadvantages, e.g. it is linear and difficult to present knowledge that requires a global understanding, it is less interactive, it has limited remote control, i.e. the self-tests included in the printed courseware can only contain closed questions, while on the computer you can also give open questions. Some of the learning and teaching functions can also be implemented with non-printed learning materials, such as slides, audio cassettes, audio CDs, films, video cassettes, computer-based tutorials, multimedia-based tutorials, digital whiteboards.

Slide films, audio cassettes, video cassettes have been out of use for a number of years, because it is useless to have this form of teaching material if you do not have the equipment to play it. It is also true that CDs and DVDs are hardly usable, because over time these media have become obsolete, and many new computers nowadays do not even have a drive. Multimedia-based teaching materials are good because they take into account the learning needs of students, but they are very time-consuming to produce and therefore relatively few are available. The objective of computer-based instruction is to adapt to the learning needs of students, but also to give them sufficient autonomy. With new digital tools, the focus should not be on the impact of the new tool on education, but on how education can make better use of the new technologies. New innovative technologies complement traditional teaching methods and provide a new pedagogical approach to the educational process.

With a digital whiteboard (interactive whiteboard), a projector and a computer installed in a stable way, we get a teaching system that is in itself just a technical background on which to project and write. This system can only be exploited if the appropriate teaching material accompanies the technical background. The interactive system helps to motivate the student, maintaining interest and increasing the effectiveness of classroom teaching. The use of interactive whiteboards allows students to participate visually and actively in learning at the same time, and is an effective tool for presenting the material and maintaining attention during lessons. You can write or draw in the projected diagrams, pictures and tables to make the teaching even more visual. At any time during the presentation, you can save or even print out the information on the whiteboard. The order in which the material is presented during the lesson is not fixed and does not have to be presented in a linear way, making it easier to adapt to the groups of students and to move at the pace and in the way that best suits them. Multimedia tutorials can be multi-purpose, they can be given to the students, but they can also be used by the teacher for classroom

work and even include self-tests. The only limits to the production of a courseware are time and programming skills, but with the right routine, it takes little more time to produce a multimedia courseware than a well-edited presentation.

Changes in teaching techniques due to 3D printing

The development of educational technology is closely linked to technological progress. The advent of digital technology, the internet, virtual reality and new media, as well as 3D printing, have changed teaching methods and teaching tools.

3D printing provides students with an interactive way to learn about the subject matter, concepts and theories (Figure 1).



Figure 1: Using 3D printed illustrative objects in the classroom

Source: photo taken by the authors

Turning them into tangible objects not only enhances the learning experience, but also helps students to understand complex concepts in more depth. Students can make their own models in or out of class, so they not only learn in theory but also apply their knowledge in practice (Figure 2). The integration of 3D printing into education also allows for project-based learning, where students can find solutions to real problems.

This not only develops their creativity, but also their critical thinking and teamwork. Students are able to implement their own ideas, which can encourage them to research and innovate.

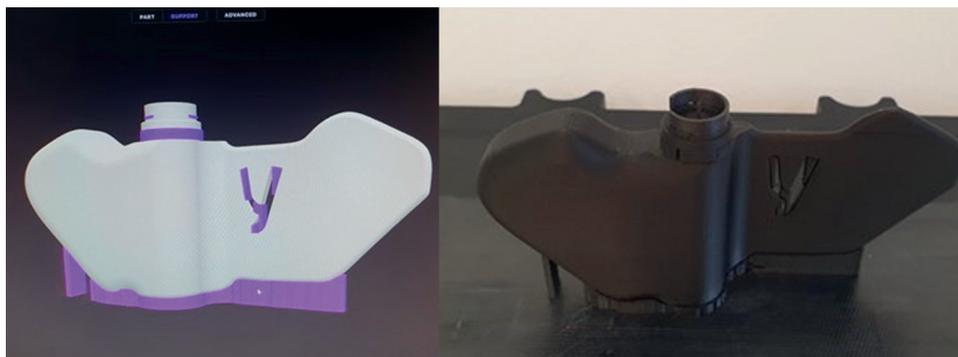


Figure 2: Computer drawing of a landmine (left) and the 3D-printed result (right)

Source: photos taken by the authors

The emergence of 3D printing in education could change the current practice of frontal classroom work and the spread of learning models based on active participation and student autonomy, such as flipped classrooms, where students learn new skills at home, usually through videos or online materials. In the classroom, students actively apply this knowledge, working on practical tasks and learning from each other under the guidance of teachers. This approach has many advantages, giving students the opportunity to move at their own pace, to revisit the material and to master it better.

On the other hand, the time spent in the classroom allows for deeper interaction with the teacher and fellow students, which helps to develop problem-solving skills and collaborative work. The introduction of a flipped classroom can also present challenges, for example in terms of students' attitudes towards independent work and the availability of IT tools. If implemented well, that highly effective teaching method contributes to active students' participation and deeper understanding of knowledge.

3D printing can help students not only during lessons, but also during home learning, where they can create different 3D models for the classroom and present them later. This method emphasises the importance of research and presentation, which helps students to go deeper into the topic of their interest. While 3D printing and technological advances offer great potential for education, they also present a number of challenges, one of which is accessibility. Not all schools have the tools and resources to integrate 3D printing and other advanced technologies. Another challenge is that teachers need significant training to be able to use these new technologies effectively. The training of teachers is key to ensuring that 3D printing and other technological tools are truly useful to students.

The Ludovika University of Public Service is a unique knowledge centre that offers modern education, competitive knowledge and a specific profession. The training courses offered at the university faculties enable talented young people who are committed to public service to find the career that best suits them. The main task of the Faculty of Military Science and Officer Training is to train military officers for the military organisations of the Hungarian Defence Forces, and also deals with other undergraduate and master's degree programmes, as well as course and advanced training. The Faculty has two doctoral schools for the implementation of scientific research, the Doctoral School

of Military Sciences and the Doctoral School of Military Engineering. In addition to theoretical education, great emphasis is placed on practical education during the training of future military officers, and accordingly, training takes place in classrooms, simulation centres, training areas and at military units.

The use of additive manufacturing and objects produced by this process in education/training has already begun in several areas of military training. Various illustrative tools made with 3D printing bring the textual and graphic information found in textbooks to a “tangible proximity” for officer candidates (students), which helps them understand it more easily and develops their logical thinking and creativity.

Our “digital warehouse” also makes it easier to provide the necessary logistical background for the sessions. There is no need to store, move, periodically count, or transport various materials and tools to and from the practice area in an actual, real warehouse. Instead, according to educational needs, at the right time, based on the blueprints stored in the “warehouse” (design programme), the illustrative/practice objects to be used need to be printed in the required number, size and material (Figure 3).



Figure 3: Printing a 3D object before class

Source: photo taken by the authors

Overall, it can be stated that we can expect the appearance and spread of additive manufacturing technology in all areas of life in the future – including education and training. Various illustrative and practice tools made of plastic or metal using 3D printing make it easier to master complex knowledge and practical skills, thus making military training more effective.

Summary

3D printing has become an important part of everyday life today, as a wide range of users have access to an affordable printer that best suits their needs, which also has many advantages over traditional manufacturing processes.

Even more complicated and complex structures can be manufactured quickly, efficiently and at a reasonable price, in material quality that meets the requirements.

In order to meet the objectives of the military development strategy regarding personnel, we recommend that 3D printing technology education be included in the training system, both in the framework of BSc- and MSc-level training, as well as in specialised courses.

In our opinion, the development of 3D printing capabilities and the creation of closely related educational conditions can contribute to the development of a defence industry that meets the requirements of the time, as well as a modern Hungarian Defence Forces with a high degree of responsiveness.

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