3D MODELLING AND ITS USE IN EDUCATION

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Abstract: Technology surrounds us in everyday life and its control is becoming not only a social but also a necessity of life. One of the manifestations of these trends is the growing interest in 3D modelling, which is becoming an integral part of the curriculum in some primary schools. The inclusion of 3D modelling followed by 3D printing represents an innovative way of using modern information and communication technologies in education. Its impact can positively influence the development of key learning activities for primary school pupils where such a focus is implemented. The aim of the research work carried out in this paper was to map out the use and benefits of 3D modelling in selected primary schools, including a systematic description of specific tools for the implementation of such focused teaching, based on pedagogical research methods.

Keywords: innovation in education, primary schools, technical education, 3D modelling.

1 Introduction

Technology is part of our lives, it is all around us. It can be stated that a person without the necessary basic technical knowledge and skills would not be able to perform his social function and lead a full life (Dostál, 2019; Dixon, 2013; Zubatá, Plishke, Kropáč, 2011 and others). Therefore, the education system must make elementary technical knowledge and skills available to the entire population, not only to students of technically oriented schools. In developed school systems, this elementary technical education is an integral part of the basic general education that takes place in primary and secondary schools. This is done by means of teaching subjects which, both at home and abroad, have not only different names (work education, work education, technical education, technical practice, technical work, technology, practical activities, technology, etc.) but also different scope and content. In recent years, the term "technical education" is often used in the literature (Idrus, Mond, & Abdullah, 2015). Through them, students are equipped not only with theoretical knowledge but also with elementary work skills. The emphasis is usually on technical creative activities according to the pupil's interest (predominant in elective subjects). In spite of the rapid development of digital technologies, elementary manual work activities of a technical nature (woodworking, metalworking, working with tools and simple machines, electrical work, etc.) are maintained in all educational systems of developed countries, but increasingly we see a combination of both areas. The aim of technical or polytechnic education and training is to develop the learners' skills in handling tools and machines, to acquire a working culture and to acquaint them with the scientific principles of contemporary production, rules of work safety, etc. (Mojžíšek, 1981). Today, these objectives are further developed to include the use of digital technologies to support these activities, as these technologies now cover or support a significant part of industrial production. In technically oriented subjects, when there is a combination of the two segments of the objectives mentioned above, this task can be well fulfilled, their content and procedural aspect being close to the performance of many professions, today not only professions referred to as technical (Manullang, Kons, 2012).

Thus, it is becoming a natural and common phenomenon that many designers, engineers and scientists from various fields, need to use 3D modeling in their work. Even younger children are beginning to use different kinds of technology (Klement, Klementova, 2015). Thus, it is not surprising that in some primary schools there is already a tendency to start introducing 3D modelling and 3D printing software into the curriculum (Bai et al., 2021). This is also due to the fact that a number of software companies have opted for favourable licensing policies for educational purposes. Some applications are completely free, some are even available online, and are web browser based. In some cases, pupils, students and educators can learn to work with the same version of the software on which professionals create their products. Even for primary school children, working with 3D modelling can be beneficial and bring many benefits (Klement, 2017; Atkinson, 2012). There are modelling programs that are very intuitive and easy to understand, in addition to giving children a great experience of their own creation. Children are getting beyond just simple drawing. 3D modelling in conjunction with 3D printing is a good way to motivate children to create a variety of objects and stimulate their creativity. The programmes target all children - boys and girls. It creates good conditions for both groups to realise their ideas. The fact that they strongly encourage girls in particular is an important and very good input for the future - for example, for choosing a profession (Bybee, 2019).

2 Possibilities of using 3D modelling in primary school

For young children (first grade), it is necessary to start with programs that have a simple and appealing interface, are easy to understand, intuitive. Fortunately, there are also such solutions on offer. Especially suitable for a class of first grade children are online applications. Many programs also offer an "EDU educational version" that helps students and teachers communicate about the project (Ertmer, 2020). These versions allow teachers to monitor students' work. For upper grade students, it may be appropriate in some cases to reach for basic versions of more complex 3D modelling programs with more sophisticated editing tools. Although most pupils are unlikely to become industrial designers, understanding the basic elements and principles of 3D modelling and 3D printing is important for pupils and can be used in practical life. It is noticeable that more and more disciplines are using 3D visualisation or 3D modelling. The basic knowledge gained from creative experiments with these programs in primary school can subsequently direct pupils to further study in specialized fields in secondary schools, or will be of great benefit in the workplace (Dostál, 2019; Klement, 2017).

There are different perspectives among educators and parents on the question: when should a child actually start using 3D modelling programs? One group is more conservative and leans towards the student learning to draw in the hand first. Using traditional tools such as: pencil, compass, ruler, they take the view that a person's basic literacy includes the ability to express oneself graphically without a computer (Granath, 2003). When drawing in the hand, there is a richer development of sensitivity, perception, psychomotor skills. Children then better understand the continuity with the work of previous generations (draughtsmen, graphic artists, etc.) who did not have 3D modelling programs. The second group classifies these listed aspects as rather secondary, and does not prevent pupils from using technology to start drawing and expressing their ideas. A similar analogy can be seen, for example, in the disagreement amongst graphologists as to whether to persist with stick writing or to try to introduce a font closer to print - that is, a more legible font such as (for example) Comenia Script.

Thus, the question of when to start drawing and graphing with 3D modelling software cannot be answered in a clear and decisive way (Hallstörm et al., 2013). In our opinion, it is not even relevant whether or not the child first has to learn to draw so-called "by hand". What is essential is that one or the other form of skill is not completely eliminated from his or her 'journey of discovery'. It is also good to take into account the experience of some designers and architects that the initial idea, the idea that stands at the start of a work or project, usually comes to them on a walk in the woods or on a plane journey. Other key factors that need to be addressed and given equal importance when teaching at primary school are the choice of a suitable 3D modelling program and its use for subsequent 3D printing.

3 3D modelling programs suitable for primary schools

From an educational perspective, 3D modelling and printing can be seen as tools that, through play, engage children in learning without their primary awareness. 3D modelling and printing fit into the concept of STEM/STEAM education (Wang et al., 2018). The aim of this concept is to create a better relationship with STEM subjects (science, technology, engineering and mathematics) in students so that an increasing percentage of graduates choose careers and professional life in this field. This concept began in the US in the 1980s, was strongly supported (also financially) during the Obama administration, and is still promoted significantly today (Sanders, 2015). Fortunately, European countries have also caught this current and have understood the warnings of economic experts, who consistently point out that not being educated in STEM will lead to a loss of competitiveness in the market and will have an adverse effect on the development of the future economy. It is a known fact that even the unemployment rate of graduates in STEM fields is significantly lower than that of graduates in other fields (Mansour, 2014).

STEM education should be tailored to each age group. Already for first grade children it is advisable to apply this type of education because they are exposed to various technologies at an early age. They start to learn about science and technology and develop their creative thinking. Pupils can use both analytical and creative parts of the brain. STEAM engages creativity and new ways of looking at technical subjects. It also addresses the issue of how to address the shortcomings of the current gender disparity in technical careers. At a younger age, social stereotypes are not yet ingrained in children. The STEM/ STEAM programme seeks to address this as well. For example, it uses celebrities - famous women in the field - to show that they really belong in the world of technology. It picks up on the fact that in modern companies the female element is increasingly needed and sought after (Siekman, 2016).

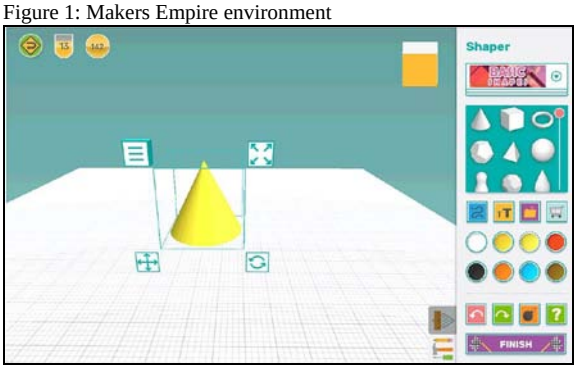
Educators in STEM fields are aware of this fact and are trying to capture innovations and issues from science and technology. Increasingly, schools are using special educational tools, educational toys, electronic building blocks, special 3D modelling programs and 3D printing in their teaching. Several such programs that can be used appropriately in the educational process in primary school computer science classes will be described in the following sections. These applications can also be used for the STEAM education concept.

4 Makers Empire

This programme has been designed specifically for younger primary school pupils. It was named one of the best educational programs in Common Sense Education's Best EdTech competition by a non-profit organization promoting digital literacy. Maker Empire is supported by ministries of education in the US, Australia, Saudi Arabia. It has become part of many educational projects in more than 40 countries. The ME School version includes more than 130 lesson plans aligned to the US Common Core standards, Next Generation Science standards, and the Australian curriculum. The software is available free to students in both desktop and tablet versions. The learning app allows you to develop spatial thinking - learning from real-world examples of architecture and real-world examples. It aims to help pupils develop logic, precision, creative thinking, spatial imagination.

The app supports the creation of 3D models, children can also download models and print objects for 3D printers. The program is also a classroom management tool with integrated assessment. Teacher, has the ability to create materials for lessons, can manage, direct students during the lesson during student work. The program also has a game zone - 3D maze. Finished models can be shared, and it is possible to work in a team on a joint project, make comments, read instructions, teacher's opinion. Every week the creators of Empire prepare a competition for students.

Figure 1: Makers Empire environment



Source: authors

5 SolidWorks Apps for Kids

Dassault Systemes SolidWorks has released some interesting 3D online apps for kids. They run directly in the web browser. It encourages children's enthusiasm for studying engineering in a fun way and helps develop technical thinking. SolidWorks Apps for Kids is aimed at children between the ages of 4 and 14. The collection of five apps allows the design process to be broken down into individual steps with tools for creating, defining style, designing a concept and then presenting and sharing it with others. The apps inspire students and give them the tools to bring their diverse ideas to life. The web-based collection of apps is also available for tablets and other mobile devices. Children can learn about the design process in a fun and exciting way.

After registration, five modules are available on the manufacturer's website: Capture It, Shape It, Style It, Mech It, Print It.

- "Capture it" creates composite images, collages and videos with sound. Children can then show off the results to their classmates.
- "Shape It" creates ideas in 3D designs. Whatever a child imagines, they can create in this intuitive and easy-to-use modelling tool.
- "Style It" adds colors, stickers, backgrounds and other elements to Shape It designs. It even lets you paint directly on the model.
- "Mech it" is used to construct motion mechanisms, including animation and trajectory rendering. It folds individual shapes and allows you to move them around. Touch links make the individual designs lighter and their behaviour matches reality.
- "Print It" prints designs in 2D, 3D or some fun project format.

Figure 2: SolidWorks Apps for Kids modules

Source: authors

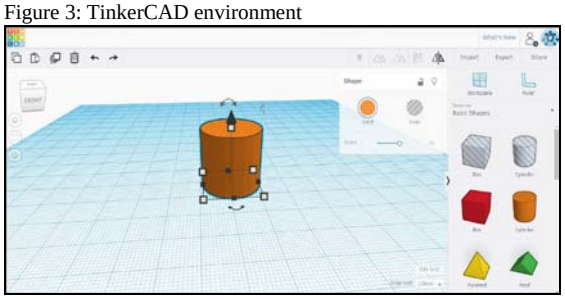
6 TinkerCAD

TinkerCAD is a product of Autodesk (AutoCAD). It is one of the simplest 3D programs that even first grade children can learn to use well. Yet it is not only for them. The software has a clear interface - it is based on creating a design using 3D shapes and solids from a prepared library and combining them (adding or removing shapes) to create the represented model.TinkerCAD is built on a web browser and is completely free. Teachers (or just students) can create an account and invite classmates via a connection code. It also allows students to access their designs outside of school and share their designs with the global TinkerCAD community. Gradually, as children's skills develop and their designs become more and more

complex, it can be interesting and beneficial for pupils to transfer models from TinkerCAD to the professional program Fusion 360 (from the same Autodesk development company). The resulting model that the student creates can be easily exported to STL format and downloaded for printing. TinkerCAD is therefore compatible with 3D printing.

Another nice feature of TinkerCAD is that it offers the Circuits feature. This allows you to design, work, build and understand the principles of electrical circuits. Or at least it can become an interesting didactic tool for pupils in the highest year of primary school. Pupils can design various circuits, program microcontrollers and incorporate electronics directly into their 3D designs.

Figure 3: TinkerCAD environment



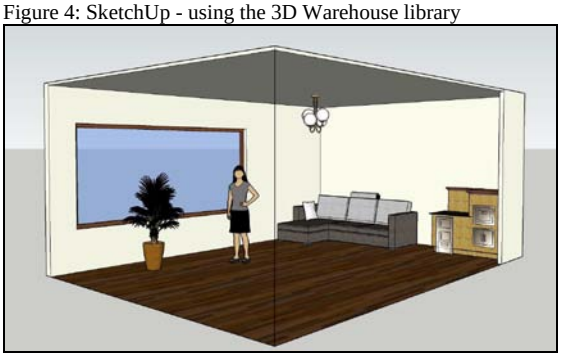
Source: authors

7 SketchUp

SketchUp is one of the most widely used 3D drawing programs. It impresses with its simplicity and user-friendly interface. Unlike most CAD programs (such as AutoCAD), it works directly in 3D space. It finds its application not only among amateurs, but also in the world of architects, interior designers, furniture makers, model makers and anyone who needs to quickly prepare a 3D design or just capture an idea and sketch. Today there is a desktop version of SkatchUp Pro and also a simplified online version of SketchUp Free. Even the Free version is quite sufficient in scope for pedagogical purposes beyond elementary school. The advantage of the online version, apart from its price, is that it is continuously updated, has support for the Trimble Connect cloud service - projects are stored directly on the web. This way, students can have their projects available at school, on their home computer, or show off their creations on any device that is equipped with a WebGL-enabled web browser. SketchUp's strengths are its wide range of Import and Export features. Models can be converted from AutoCAD, for example, or exported to a 3D printer.

The first version of the program was introduced in 2000 by the American company @Last Software. In the same year it won the Community Choice Award. SketchUp was presented as an easy-to-use 3D tool for creating 3D models with an intuitive user interface. The program gained great popularity due to the short time required to learn and understand the features. The next evolutionary step for SketchUp was the change of ownership in 2006. Google bought @Last Software and released a free downloadable version of "Google SketchUp" in addition to the commercial version. This already included the Google 3D Warehouse. Google 3DWarehouse is a huge repository of models made in SketchUp by users. The vast majority of models are available for free. In 2012, SketchUp was purchased by Trimble Navigation and released SketchUp Pro 2013. In parallel, SketchUp Make 2013 was introduced, which is completely free for non-commercial use. The latest version is the desktop version SketchUp Pro 2020 and the web browser version SketchUp Free.

Figure 4: SketchUp - using the 3D Warehouse library



Source: authors

8 3D modelling from the perspective of primary school pupils - a research probe

As mentioned in the previous text, there are a variety of tools on the market for implementing 3D modelling-focused learning. 3D modelling and printing fit into the concept of STEM/STEAM education (Wang et al., 2018). The aim of this concept is to create a better relationship with STEM subjects (science, technology, engineering and mathematics) in students so that an increasing percentage of graduates choose a career and professional life in this field. For this reason, this issue is also taught in some schools within the Olomouc region, which, in line with the modernisation of teaching in technical and computer science subjects, include the issue of 3D modelling and 3D printing in their teaching.

The contact with these schools occurs within the framework of joint cooperation within the Summer Schools of Computer Science or within the framework of the European-wide activity CodeWeek, which pupils and teachers of selected schools attend and which the author's workplace provides to schools and their pupils and teachers. Within the framework of this mutual cooperation, a request was made by these schools, a total of 8 primary schools within the Olomouc region, to carry out a joint research investigation that would map the benefits or negatives of the inclusion of 3D modelling and 3D printing from the perspective of the pupils of these schools. The contacted teachers therefore promised the necessary cooperation in making the necessary research tool, a structured questionnaire, available to their pupils. The research was carried out from September 2021 to November 2021 and during this period a total of 237 respondents - pupils of primary school level 2 - benefited from the research. This period was followed by the processing and evaluation of the responses.

As a research tool for data collection we chose an online questionnaire of our own design. This choice was based on the need to reach the pupils of the selected primary schools during the period of limited contact teaching caused by the pandemic situation of Covid-19. For this reason, we evaluated the use of an electronic questionnaire as the most appropriate form, because the questionnaire could be easily distributed, filled in by the respondents and evaluated electronically. In designing the questionnaire, consideration was given to adhering to the basic requirements and characteristics outlined by Chráska (2016, pp. 164-165). The questionnaire was distributed via email or the school's information system, which, in addition to the accompanying message text, also contained a link through which respondents could access the questionnaire. The questionnaire was anonymous, and it was used to elicit pupils' opinions or attitudes towards teaching focused on the use of 3D modelling software. The pupils of the selected primary schools were therefore able to fill in the questionnaire anonymously and thus record their opinions and attitudes on the individual questions. They could express their opinion by ticking YES or NO, according to their personal preferences or opinions. A description of the research sample is given in Table 1 below.

Tab. 1: Structure of the research sample

Gender	Number of respondents	Number of respondents in %
Boys	112	47.3%
Girls	125	52.7%
Total	237	100.0%

Source: authors

As the main method to evaluate the acquired research data, chi-square test (Chráska, 2016) was used to determine the dependence of the results on a certain significant characteristic of the group of respondents, which was gender. Basic descriptive statistics and their visualization using tables were used to determine the power of each group of respondents who answered in the same way. Statistica 14 statistical system was used for the calculation (Meloun, Militky, & Hill, 2017). In the following, some partial results of the conducted research investigation are presented, which aimed to find out the opinions and attitudes of the students of the selected schools towards the teaching focused on the use of 3D modelling software, and its real impact on the educational process in these schools.

9 Partial outputs of the implemented research probe

In the following, the outputs of the research investigation are presented in five separate areas. Each analysis involved the calculation of a contingency table, the calculation of percentages and the assessment of the dependence of the result on the gender of the respondents. For simplicity and clarity, all three analyses are included in one table.

The first area examined was whether students were interested in 3D modelling software. Thus, pupils were able to give their opinion on whether they found learning 3D modelling programs interesting and creating 3D computer models beneficial from their point of view. A summary of the results of their responses is demonstrated in Table 2 below.

Table 2: Interest in learning 3D modelling

Contingency table for: n = 237 Pearson chi-square: p = 0.00546 **Are you interested in 3D modelling?**			
Gender of respondents	**Boys**	**Girls**	**Line totals**
No - frequency	37	83	120
No - %	15.7%	34.8%	50.5%
Yes - frequency	54	63	117
Yes - %	22.8%	26.7%	49.5%
All groups - frequency	112	125	237
All groups - %	47.3%	52.7%	100.0%

Source: authors

According to the results shown in Table 2, it can be stated that almost half of the students of the selected primary schools, namely 49.5%, were interested in learning 3D modelling. Thus, the initial assumption that the inclusion of this educational content would be interesting and beneficial for the pupils was confirmed.

Furthermore, it can be stated that there is a statistically significant difference (p=0.00546) between the response rates of girls and boys. Boys were demonstrably more interested in 3D modelling than girls, which is a normal result and not out of line with the usual average, given the generally higher popularity of technically oriented activities among boys.

Another area investigated was whether pupils found learning 3D modelling difficult or more difficult than other technically oriented activities. Pupils were therefore able to give their opinion on whether they found teaching this subject more difficult than other subjects taught in technology or practical activities. A summary of the results of their answers is shown in Table 3 below.

Tab. 3: Level of subjective difficulty of learning 3D modelling

Contingency table for: n = 237 Pearson chi-square: p = 0.00061 **Did you find learning 3D modelling difficult?**			
Gender of respondents	**Boys**	**Girls**	**Line totals**
No - frequency	51	108	159
No - %	21.5%	45.5%	67.0%
Yes - frequency	40	38	78
Yes - %	17.1%	15.9%	33.0%
All groups - frequency	112	125	237
All groups - %	47.3%	52.7%	100.0%

Source: authors

According to the results shown in Table 3, it is quite obvious that the vast majority of primary school pupils (67.0% overall) do not find the teaching of 3D modelling difficult, or more difficult than other thematic units focused on technology or practical activities. This result indicates, among other things, that the general popularity of technically oriented subjects is high and that pupils therefore welcome other ways to enrich their learning, which was also confirmed in this case.

Furthermore, it can be noted that there is a statistically significant difference (p=0.00061) between the frequencies of girls' and boys' responses, where girls were statistically significantly more likely to welcome the inclusion of this learning content in their lessons because they found its difficulty lower.

The third area examined was whether students would welcome the opportunity to further their education in 3D modelling, both guided and independent. Pupils were therefore able to express their views on whether they found the subject so engaging and developmental that they would like to pursue it in the future. A summary of the results of their responses is demonstrated in Table 4 below.

Tab. 4: Interest in further use of 3D modelling

Contingency table for: n = 237 Pearson chi-square: p = 0.00135 **Do you want to continue to pursue 3D modelling?**			
Gender of respondents	**Boys**	**Girls**	**Line totals**
No - frequency	67	128	195
No - %	28.2%	54.2%	82.4%
Yes - frequency	24	18	42
Yes - %	10.0%	7.5%	17.6%
All groups - frequency	112	125	237
All groups - %	47.3%	52.7%	100.0%

Source: authors

According to the results shown in Table 4, it is clear that only less than one fifth of the pupils of the selected primary schools, namely 17.55%, would like to be further educated in 3D modelling. Although this result is in contradiction with the first analysis presented above regarding the interest in this learning, it can be explained by the fact that the general level of intentionality in education is currently lower and therefore further education is rejected from the pupils' point of view.
Furthermore, it can be noted that there is a statistically significant difference (p=0.00135) between the response rates of girls and boys, with girls rejecting further education in 3D modelling more often than boys. This result is also not unusual and is related to the generally lower popularity of technically and science oriented subjects among girls.

The fifth, and final, area investigated here was whether the students would use the acquired 3D modelling competences in their future lives. This question was again related, albeit indirectly, to the further career orientation of primary school pupils and their interest in further work in technical sectors.

A summary of the results of their answers is demonstrated in Table 5 below.

Tab. 5: Interest in further use of 3D modelling

Contingency table for: n = 237 Pearson chi-square: p = 0.00565 **Do you think that 3D modelling will be beneficial for your future life?**			
Gender of respondents	**Boys**	**Girls**	**Line totals**
No - frequency	50	102	152
No - %	21.2%	43.0%	64.2%
Yes - frequency	42	43	85
Yes - %	17.5%	18.3%	35.8%
All groups - frequency	112	125	237
All groups - %	47.3%	52.7%	100.0%

Source: authors

According to the results found in Table 5, it is clear that the students of the selected primary schools understand the need for 3D modelling education, as almost 36% of them stated that they will use the outcomes of this education in their future life.

Although there is a statistically significant difference (p=0.00565) between the response frequencies of girls and boys, overall, both girls and boys think that the application of 3D modelling is not beneficial to their future life, so boys are significantly more likely to admit that 3D modelling will be beneficial to them.

10 Conclusion

The inclusion of 3D modelling and the subsequent 3D printing is an innovative way of using modern information and communication technologies in education. Its impact, as revealed by the research investigation described above, has positively influenced the formation of key learning activities for pupils in selected primary schools where such a focus is implemented. Thus, the teaching of 3D modelling to primary school pupils offers the opportunity to learn about and improve the issues of creating 3D drawings and to develop individual skills in a new way, including the opportunity to solve tasks in an engaging and independent way in relation to individual knowledge of working with technical means and digital technologies. All these competences together can contribute significantly to the wider adaptability of pupils in further education.

On the basis of the conducted research investigation, which aimed at exploring the current level of awareness and practical experience of pupils with 3D modelling, we can draw some conclusions. An important conclusion is the fact that 3D modelling is perceived positively by pupils interested in the subject. Although there are some gender differences, even at a statistically significant level, these cannot universally point to a lower interest of female primary school pupils in technical education, but only to a lower interest in the issue of 3D modelling. Here we must also draw attention to the fact that, with regard to the total number of female primary school pupils, this is certainly not a significantly representative research sample, but it does provide at least an indicative approximation of the issues under study.

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