3D technology in the cultural heritage and education context

Eva Milkova, Martina Manenova, Lenka Chadimova and Klimis Ntalianis

***Abstract*—**Modern technologies are getting involved in most spheres of human activities, they play an important role also in cultural heritage care. These technologies are used when research into historical reference is carried out, specifically in case of digitalization. Within the vast framework of cultural heritage, this paper deals with using 3D technologies suitable for digitalization of cultural heritage and utilization of its results in education. Firstly, the text focuses on basic criteria selecting a software appropriate for creation of a digital 3D model of a historical building and its implementation into a serious game. The second focus is on possible ways in which 3D technologies can impact the process of teaching history to elementary school pupils.

***Keywords*—**3D technology, cultural heritage, serious game, cultural heritage education.

I. Introduction

FROM the historical point of view, the 2D and 3D technologies are used for re-constructing and preserving historical monuments. The 2D technologies are most frequently used for digitalization of archival documents, they are also used when preparing documentation for 3D virtual reconstructions of historical sites. Another convenient use of the created 3D digital models is their inclusion into an interactive application, which then mediates information on historical and architectonic development of objects. Such an interactive application can be a useful complement of history knowledge source; it can be used in the teaching process as well as it can be placed into permanent expositions of historic objects and this way they can offer a new kind of insight into history to the visitors.

In the Czech Republic, there is only one doctoral study program aimed at preparing specialists in the field of information and communication technologies in education. The preparation includes independent creative work in science, research and development with a high potential to develop the field. *The ICT in Education* study program is provided by a consortium of four Czech universities, one of which is the University of Hradec Kralove. The graduates complete their undergraduate studies with more detailed knowledge of the content and methods of some informatics sub-disciplines, especially theoretical foundations, and enrich their knowledge of new directions in the field of education and psychology. They master methodological foundations of educational research in order to design and conduct their own research. They acquire an overview of the use of information technologies in education, theoretical background and practical applications in our country and abroad. They are well informed about contemporary views on informatics education and the possibilities of introducing ICT into the curriculum of all subjects [1].

The dissertation thesis written by the third author of this text (it was called *Využití 3D technologií a interaktivních prezentací pro poznávání českého kulturního dědictví pro žáky základních škol)* focuses on the implementation of 3D digital models into a serious game suitable for elementary school pupils. Such a kind of interconnecting of technologies and ways of teaching is very attractive for these i-kids (cf. [2], [3]). Recent research has shown that serious games included into educational process have positive effects on students learning and their motivation (see [4] - [8]). The main aim of the mentioned dissertation thesis is utilization of a serious game in the process of teaching history at elementary school. Specifically, the most interesting issues for us are the impact on communication between a teacher and his/her pupil (cf. [9], [10]), and the impact on pupils´ activation and motivation (see [11]) which are brought if serious games are applied through interactive boards.

A very thorough analysis is essential when the final choice of the 3D program convenient for the 3D models creation is being made. A possible way of selecting a 3D software appropriate for creation of a digital 3D model of a historical building was the aim of the paper presented at the APSAC conference 2018 (see [12]. This paper deals with and refers to that part of the above-mentioned dissertation thesis which is devoted to the research dealing with the issue of how 3D technologies can influence pedagogical communication and interaction.

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II. 3D MODELING OF HISTORIC BUILDINGS

Firstly, some parts of the APSAC paper [1].

3D modelling is a process during which a virtual spatial model is being created on the basis of certain template. This template can have the form of scheme documentation, photographs, pictures, vedutas, or just a written or oral description. In this way it is possible to reconstruct the earlier form of the chosen template and also its historical development. If this method is applied, also a simplified image of an object (even with important elements highlighted) can be created in a relatively short time. In case of building monuments, modelling on the basis of the scheme documentation and construction-historical research is applied. If such a kind of documentation is not available, then modelling is based on photographs and sketches (if there are some) and on written and oral descriptions. In case of historic buildings which no more exist or which have been damaged too much, the 3D modelling is the only possibility of digitalization or the only possibility of reconstruction (if a paper model variety is ignored). Most frequently, castles´ or forts´ ruins are concerned whose walls´ remains do not exist anymore, or places at which the original historic building has been replaced by other building development. Then a virtual 3D modelling can be carried out merely on the basis of extant historical sources, such as vedutas and descriptions of the buildings presented in documents from the given time period, and also on the basis of analogies with still existing buildings of the same type.

If the 3D modelling of historic buildings is to be carried out, it is essential to select proper software. Being aware of a big amount of the 3D software available, we could come to the conclusion that the 3D programs designed for architects and builders (e.g. ArchiCAD or Autodes Revit) are suitable for digital reconstruction of historical buildings. However, it is necessary to realize that these modelling tools are designed for the current architecture which is based on simple geometrical shapes. The current architecture is plain, full of pure lines and without “useless” decorative elements. On the contrary, historic buildings have a lot of decorative elements, internal and external vaulted arches, and frequent irregularities (especially in case of castles, forts and similar types of buildings). Then it is obvious that the 3D programs designed for builders and architects are not convenient for modelling of historic buildings.

On the contrary, programs designed for polygonal graphics, which are primarily developed for entertainment industry, in which irregularities and decorative elements are “not missing”, offer suitable solutions. We are talking about the 3D modelling programs which do not work with precise parameters (like CAD or parametric systems) but focus on possibilities of comfortable creating of complicated and non-typical shapes. The most important issue about the digital reconstruction of historical buildings which is carried out through the 3D modelling is the resulting form. The virtual model of the given historical building should be as close to the original form as possible, it needn´t be “millimetre-precise“.

The amount of the 3D modelling tools available on market is enormous. Usually the following basic criteria for selecting a software suitable for the 3D modelling of historic building monuments are considered.

Licence

Programs with the OpenSource licence are available free of charge even if used for commercial purposes.

Paid professional licences are related to professional programs. Concerning the financial demands, some companies offer various versions of their paid software – the lite version, in which mostly just basic or the most frequently used tool are available or in which not all the transfer formats are supported; the full version without plug-in modules, which can be, however, additionally purchased; and the complete version. If the institution involved in care of the given building monument is an educational institution or if it closely cooperates with and educational institution, an education (edu/student) licence can be considered.

Galleries of tools and options of additional modules

It can be generally claimed that the range of modelling tools and possibilities of their extension through plug-in modules (plug-ins) depend on the licence of the chosen software. This choice is connected mainly with the user´s “professional level“ and the needed detailed preciseness of the processing of the 3D model. It is obvious that the extent of the galleries of the 3D software tools for complete beginners (which are generally free or very lowly charged) will be different from the extent of a fully professional OpenSource licensed software program. And obviously, it is important to know what the modeller will focus on and how much detailed 3D models s/he will want to create. If s/he wants to create simple models, then the basic tools will be sufficient, in case of creation of 3D models processed in detail, the extended gallery of tools will be needed.

Options of import and export

For further work with the 3D model or potential inclusion of another (already created) model into the setting, formats for data transfer are needed – those for both the data imported and the data exported. Therefore, it is important to consider which input data will be processed and which further operations will be carried with the model, that means the purpose of the designed 3D model, its inclusion into the interactive application, additional elements of the 3D model created by other technologies, etc.

If the chosen 3D modelling software does not support the needed import or export format, other software can be used for the format conversion. This “intermediate stage“, however, increases the risk of damaging or unwanted deforming of the converted 3D model, including the texturing or animation.

User comfort

If more software applications are available, then obviously the one which is the closest to and the most convenient and pleasant for the user is chosen.

III. Materials and Methods

Nowadays, children are surrounded by modern technology since their early childhood, they spend most of their spare time on playing computer games. That is why they are familiar with the virtual environment, and they are able to remember information better when they get it from this environment than when they get it from the classical sources. Therefore, it is suitable to convey the information to pupils also in this way. The study carried out in 2014 - 2017 was focused on a long-term research concerning the use of the 3D technologies when presenting the issue of the cultural heritage of the Czech Republic to elementary school pupils.

A. Research objective

The main objective was to find out how the 3D technologies can affect the process of education when teaching history to 4th and 5th grade elementary school pupils.

Generally, the following research questions were asked:

- Do the 3D technologies have an impact on the pedagogical communication and interaction?
- Do the elements of gamification have an impact on the pupils´ knowledge?
- Do the elements of gamification have an impact on the permanence of pupils´ knowledge?
- Do the elements of gamification have an impact on pupils´ motivation?

In the paper we deal only with the first research question – Do the 3D technologies have an impact on the pedagogical communication and interaction?

B. Interactive application

The interactive application containing the 3D models of historical objects used the 3DS MAX (edu/student version) software by Autodesk company. This software had been selected on the basis of financial options and the above mentioned criteria (see [12] for more).

C. Research methodology

Our basic research method was the method of structured observation, specifically the modified Flanders´ interactive analysis [9].

The categories of recording the pupils´ activities are much less structuralized in Flanders´ original system (FIAS) than the categories recording the teacher´s activities. Due to this, we applied the modified version of this FIAS method which was extended by T. Svatos and J. Dolezalova [13] in the sphere of pupils´ activity categories so that the observed parameters were balanced. Svatoš and Doležalová present seven categories of the teacher´s activities (similarly to Flanders), and the number of pupils´ activities has been increased to seven as well. Based on our experience with observing class lessons, we can claim that group work is frequently applied at elementary schools. That is why we included also this form of interaction and communication into the observed pupils´ activities, which means that we observed eight categories in total. In our modified FIAS method, labelled as MFIAS, the individual categories of the teacher´s and the pupils´ activities are specified as follows:

U1 – The teacher accepts the pupil's feelings and behavior, tries to show sympathy in a constructive way.
U2 – The teacher evaluates the pupils in a positive way, expresses favourable opinions of their work, answers, actions or behaviour, s/he is encouraging, makes jokes, generally values achievement.
U3 – The teacher uses, elucidates, develops, or accepts the pupils´ opinions, repeats the pupils' statements in order to stress their value so that the others can remember them, the teacher paraphrases or modifies answers or comments on the task.
U4 – The teacher summarizes and makes responses more precise, compares the pupils´ statements.
U5 – The teacher asks questions about the task, methods of working or organization of the lesson, s/he expects answers and asks questions to stimulate the pupils.
U6 – The teacher explains, informs, introduces own his/her own opinion, acquaints pupil with his/her own attitudes and values, elucidates or glosses the subject matter (we include the use of video and sound recordings here, as it is the teacher who selects them).
U7 – The teacher gives instructions or orders, criticises the outputs, answers, actions or behaviour, gives reasons for his/her own methods, explains why particular approaches or actions are necessary, establishes rules, enforces authority, tries to change the pupils' unsuitable behavior or actions.
Z1 – The pupil asks questions, seeks help and support from the teacher.
Z2 – The pupil asks questions, seeks help and support from the other pupils.
Z3 – The pupil states, explains and introduces his/her own opinions when pressured or influenced by the teacher, answers when being called to do so rather than raising his/her hand first.
Z4 – The pupil states, explains and introduces his/her own opinions arising from his/her own actions or motivation, raising his/her hand when answering questions or spontaneously referring to his/her own experience or opinion.
Z5 – The pupil directs or modifies actions of the others, offers them help (we include here any presentation by the pupil, such as use of the blackboard when 'teaching' the other pupils).
Z6 – Group work, communication between the pupils during a team activity.
Z7 – The whole class discussion.
Z8 – Pupils pursues individual learning activity without visible interaction.
O1 – Silence or confusion, the work is stopped, communication is indistinct.

The data which were obtained from the structured observation, were evaluated from two viewpoints. The first one was the compilation of classical quantitative surveys (in the graphs and tables). These surveys expressed absolute and relative frequency of the shares of separate activity categories in relation to the whole content. (cf [11])

The second viewpoint on the obtained data was aimed at grouping of the individual activities carried out by the teacher and the pupils into the activity „bunches". They created, after the statistical processing, separate indexes, with which the level of communication and interaction in the observed lessons could be described. The following combined and partial indexes are concerned [13]:

Ii = Az/Au

where:

Ii – the combined index of interaction;
Az – the index of the pupil´s activity (*Zo+Za+Zp*);
Au – the index of the teacherś activity (*Ua+Uv+Ur*);
K – the total number of coding categories O1;
Zo – the index of the pupil's seeking for help and support (Z1+Z2)/*K*;
Za – the index of the pupil's activity (Z3+Z4+Z8)/*K*;
Zp – the index of the pupil´s moving towards teaching the others (Z5+Z6+Z7)/*K*;
Ua – the index of the teacher's acceptance of the pupils (U1+U2+U3)/*K*;
Uv – the index of the teacher's active teaching (U4+U5)/*K*;
Ur – the index of the teacher's dominant role in teaching (U6+U7)/*K*.

It could be generally stated that if the index of the interaction is equal to 1, then the lesson from the side of a teacher and even pupils was balanced. If the index of the interaction is higher than 1, it testifies a bigger activity by the pupils, if the index of the interaction is smaller than 1, it is a case of a dominant share of the teacher in the mutual communication and interaction. Svatoš and Doležalová [13] add that the indexing of the interaction can be applied also to time cuts and these can be mutually complained if the changes in the interaction during the individual phases of the teaching process are in the centre of our attention.

The MFIAS method was used for coding of video recordings and for coding directly during the classroom lessons.

D. Research sample and its characteristic

Eight teaching units in the third grade of the elementary school were analysed in total. The 3D models of historical objects were implemented in ordinary classroom lessons as e.g. St. George´s Rotund on Říp mountain – Fig. 1.

These models were enriched by gamification elements, which can be considered as the interactive 3D applications. The teachers then used these applications in their teaching process. The individual classroom lessons were taught by different teachers. The interactive application was involved in the motivating or fixing phase of the lesson.

IV. Research Results

In this secton let us introduce the results gained for the question dealing with the 3D technologies impact on the pedagogical communication and interaction.

Tab. 1 describes individual classroom lessons on the basis of the acitivity categories. The number of the recorded time periods (3 seconds long) was in the range from 494 to 616.

Fig. 1: Texturised 3D model. Source: by L. Chadimova

Tab. 1 Detailed analysis of individual classroom lessons carried out on the basis of the activity categories

	L1	L2	L3	L4	L5	L6	L7	L8
U1_acceptance	2	7	4	2	2	0	1	2
U2_praise-approval	10	18	12	12	11	10	13	16
U3_pupils' ideas	1	0	3	1	0	0	2	4
U4_questions	14	22	26	24	8	17	10	15
U5_communicates	10	18	15	20	15	20	19	23
U6_guidance-organization	139	117	125	141	123	146	118	106
U7_change student behaviour	2	1	1	1	1	1	0	1
Z1_seeking support from teachers	8	3	3	1	0	0	1	2
Z2_looking for support from pupils	11	0	0	0	1	0	3	4
Z3_student interprets the teacher's instructions	9	3	4	3	1	4	4	5
Z4_student actively communicates	226	246	168	167	209	196	231	218
Z5_student directs the activities of other students	20	43	54	50	81	57	62	59
Z6_group work	24	55	20	34	29	40	38	41
Z7_all class activity	42	49	28	32	48	36	46	48
Z8_separate activity	14	33	31	29	63	31	53	50
unproductive silence	1	1	0	0	0	0	0	0
Total	**533**	**616**	**494**	**517**	**592**	**558**	**601**	**594**

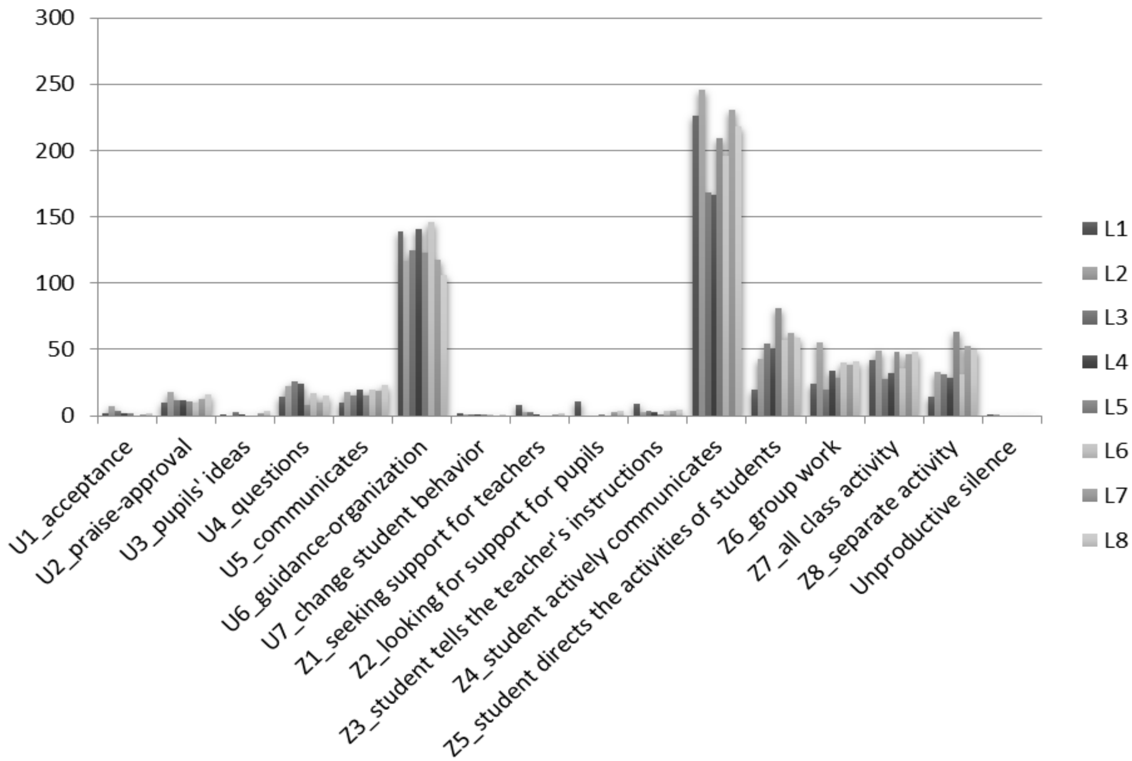

Fig. 2: Graph of overall evaluation of the activity categories in individual classroom lessons

The description of the teaching and learning process based on the frequency of the activity categories is given in the graph, see Fig 2. It is clear that the learners´ activities were prevailing in total (Z4, Z5, Z6 a Z7). The teacher prevailingly organized the pupils´ activities (U6).

On the basis of the detailed analysis of the teacher´s and the pupils´ activities, the indexes of the interaction in individual classroom lessons were calculated, see Tab. 2.

Tab. 2 Indexes of the interaction in individual classroom lessons

	L1	L2	L3	L4	L5	L6	L7	L8
Ua	13	25	19	15	13	10	16	22
Uv	24	40	41	44	23	37	29	38
Ur	141	118	126	142	124	147	118	107
Zo	19	3	3	1	1	0	4	6
Za	249	282	203	199	273	231	288	273
Zp	86	147	102	116	158	133	146	148
Au	178	183	186	201	160	194	163	167
Az	354	432	308	316	432	364	438	427
Ii	**2,0**	**2,4**	**1,7**	**1,6**	**2,7**	**1,9**	**2,7**	**2,6**

We can come to the conclusion that no interaction index is lower than 1, which means that the pupils were prevailingly active during the observed classroom lessons.

I. Discussion

The interviews with the teachers have revealed that the use of the interactive 3D application was a kind of challenge, especially from the point of view of the correct methodological use of the application. The teachers claimed that they such reviving of class lessons is welcomed in spite of the needed concentration on the correct methodological use of the 3D application. The interactive application was included into the fixing phase of the class lesson and as a motivating element. During the observed class lessons, the pupils were able to very quickly learn how to work with the application and how to use its available possibilities (e.g. a possibility of looking up specific architectural elements present in a 3D model of a castle). From the teachers´ reactions it is clear that the given topic was presented in a more illustrative and better perceivable way. The pupils´ increased activity, which was evident in the observed classroom lessons, proves the pupils´ increased motivation for studying.

II. Conclusion and Future Work

Information and communication technology has changed many things in the world and has substantially influenced also education. Demonstration and visualization using suitable multimedia applications make the subject much clearer and comprehensible [14].

Within the framework of the dissertation thesis, using of a serious game in the process of teaching history at elementary school is being observed. Possibilities of involving of serious games into the educative process were recorded already ten years ago, when e.g. Tüzün et al. [15] applied serious games into geography teaching. Their results confirm an increased motivation of the pupils.

Within the framework of our research, the 3D technologies, serious games and their applying to presentations of the cultural heritage were involved in the interconnected ways. Although the research sample was small, it is clear from it that this interconnection can have a positive impact on the educative process.

Our research has revealed that the involvement of serious games enriched by the 3D models into teaching history at elementary school results in a bigger activation and motivation of the pupils. Also other two research questions “Do the elements of gamification have an impact on the permanence of pupils´ knowledge?” and “Do the elements of gamification have an impact on pupils´ motivation?” were answered positively.

In our future studies, more gamification elements [16] will be tested in the teaching process. We will also examine students’ comprehension and satisfaction. Additionally, semi-automatic segmentation of 3D objects could also be considered [17]. In this scenario students will be able to segment and manipulate real world objects, through stereoscopic headsets. Finally, the proposed model could also be extended to be tested as Assistive Technology. Assistive Technologies help people with disabilities to communicate with others and to provide means of access to information. Thus serious games enriched with 3D models could be integrated with Assistive Technologies, to enable new learning ways e.g. for the deaf [18].

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