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Utilizing Software for Computer-Aided Design and Construction in Slovenian Educational Institutions

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Abstract

Visualization is crucial in daily life, particularly in fields involving construction or manufacturing. Considering the importance of this topic, we were interested in learning how computer-aided visualisation is presented in Slovenian education. The study's objective was to find out how frequently computer-aided design and construction, or visualization content, is used in Slovenian classrooms. Curricula and knowledge catalogues were analyzed, and the results showed that content is well-represented in educational programs that directly relate to the professional fields of building, designing, and producing models and products; however, these fields are not well-represented in the Slovenian education system. Additionally, a survey was carried out using a sample of 47 Slovenian educators. The results indicated that the primary determinant of the design and construction computer programs teachers select is the software's cost; teachers are primarily self-taught in using the programs; and curricula are well-structured and may contain design and construction content.

Keywords: education, computer-aided design, construction, modelling

1 Introduction

Humans use their senses to perceive the world around them. The eyes are one of the most important input channels for perceiving the environment. Visualisation plays a key role in this process. *"Visualisation is any method of creating images or pictures with the aim of conveying a message. The end product of visualisation is any pictorial information"* (Mancini, 2016, p. 13). Mancini (2016) divides visualisation into two types according to meaning:

1. visualisation created in the brain (visualisation that is felt and transferred to the natural environment, for example in the form of a drawing); and
2. the final visualisation, which results in the creation of something (for example, a product) that we can see.

There are several types of visualisations, but the most interesting for us is 3D visualisation, which is created using computer visualisation software (Stres, n. d.). 3D visualisation, which is often equated with 3D graphics, 3D rendering, 3D design, engineering, modelling, construction, etc., represents the processes that allow us to create graphical content using 3D software. These processes result in visual content in virtual space (What is 3D design?, n. d.). 3D design is a process in which a person designs (visualises in the mind) an image or product, eventually visualises it in the form of a 3D model using a computer software programme, and then can examine and test it in a virtual computer environment. Design thinking and creativity play an important role in this process and are becoming increasingly important problem-solving skills in the 21st century (Novak & Wisdom, 2019). The subject of 3D visualisation is covered in school curricula. These vary in content depending on the specifics of the individual subjects in the education system. One of the guidelines considered by the authors when designing the curricula is the relevance, which is particularly pronounced in the technical education curricula. These are associated with modern technology and typically emphasise the use of technology in various areas of life (Aberšek&Flogie, 2019).

It is therefore foreseen that *"teachers present technology in its historical context, highlighting trends in technical development and linking technology to other natural and social sciences"* (Aberšek&Flogie, 2019, p. 82). One of the current objectives related to the acquisition of current knowledge, which is becoming increasingly important for life in modern society, is 3D visualisation, which is taught in most technical education curricula using various engineering and design software. There are many ways to teach 3D visualisation, and here are two of the most common. The first is the traditional teaching system, where students first learn the basics of engineering drawing and then learn to draw using spatial modelling software. The second approach is the reverse, where students first learn to model with 3D visualisation software and then gradually learn other skills in this area (Kuna et al., 2018).

1.1 Overview of the curriculum

Since civil engineering is only covered in engineering and technology classes in primary school, the curricula for this subject were analysed (Curriculum. Primary school programme. Engineering and technology, 2011). As presented below, significantly more content of construction and modelling with computer programs is covered in secondary school education. We have focused on technical programmes in secondary vocational and vocational-technical education, which *"are intended for students who have completed primary school or a lower vocational education programme"* (cpi.si, n. d.). The programmes cover general education subjects such as mother tongue (Slovene), mathematics, biology, geography, etc., as well as various vocational subjects, depending on the programme. They usually also include computer-aided design and construction.

The curricula and skills catalogues of vocational school programmes in Slovenia have been reviewed. Table 1 lists the training programmes covering computer-aided design and construction and the objectives of the programmes relating to computer-aided design and construction.

Table 1:Overview of design and construction topics in Slovenian schools

Name of the programme	Contents of Computer-aided design and construction in the curriculum
Elementary school	The curriculum has only one (optional) objective, which requires students to draw a picture of an object in space using a computer graphics programme.
Construction technician	The aim is for students to use a computer programme to design and dimension simple structural parts of buildings. In doing so, they will learn about the usefulness of computer programmes in the field of drawing and computer programmes for drawing reinforcement. They will also use drawing programmes on the computer and learn about the basic software tool for drawing 3D plans.
Marine engineering technician	Students learn how to use computer technologies to model raw materials and workpieces. They learn about CAD programmes for 3D modelling of components, which they use the computer to model and assemble into assemblies and products. They also learn how to produce a technical drawing based on a computer model. One of the objectives is to create 3D computer models of a product using add and subtract building blocks.
Woodworking technician	Students are expected to use modern information and communication technology in their work (3D drawing, activity planner, presentation software, etc.). Among other things, they have to produce all the design technology documentation of the product. They learn how to draw wood ties and simple products using a computer, and they also learn the commands to produce a 3D drawing.
Environmental technician	Students review applications for computer-aided drafting.
Mechanical technician	Students learn how to use CAD computer technologies and programmes for modelling raw materials and workpieces and learn advanced spatial modelling techniques. The aim is to be able to use a computer to produce a technical drawing based on a computer model. Create a 3D computer model of a product using add and subtract building blocks.
Mechatronics technician	The objectives only include that students learn how to model products using CAD software.
Design Technician	Students learn how to prepare various graphics and how to draw up a technical plan, instructions and layout of cut-outs or 3D models in the material.
Technical Gymnasium (Laboratory exercises Mechanics and Mechanical Engineering - compulsory subject)	Students learn how to use modelling and design software tools in practice, and how to design and manufacture products and prototypes in a modern, well-equipped company.
Technical Gymnasium (Descriptive Geometry - optional)	Students draw individual drawings from a template and are systematically introduced to 3D drawing tools, with an emphasis on mastering quick transitions between views and projections. (There are 50 hours of content, with special mention of the computer drawing programme Auto-CAD among the content skills.)
Technical Gymnasium (Mechanical Engineering - optional)	By the end of the course, students are able to use computer-aided drafting software packages and acquire a sense of how to design devices.

1.2 Research Aim and Research Questions

With the new industrial revolution (Industry 4.0) and the new societal form of Society 5.0, the world is evolving and changing rapidly. Schools and the content that is part of the school curriculum will have to follow these changes. In some areas, the content of the curriculum is already being adapted accordingly, in particular in engineering and technology (Zemljak&Aberšek, 2020; Zemljak, Dolenc&Aberšek, 2021). The research aims to find out how well spatial modelling is represented in the curriculum and whether there are any changes and adaptations in this area due to an ever-changing world. In this context, we were interested in what influences the choice of software, how access to software is regulated and how the learning objectives of spatial modelling are linked to the needs of the economy or Industry 4.0. The following hypotheses were formulated:

- Hypothesis 1: Spatial modelling is strongly represented in curricula and skills catalogues.
- Hypothesis 2: The choice of software is most influenced by the price of the software.
- Hypothesis 3: Teachers are trained to use the software.
- Hypothesis 4: Curricula allow the integration of computer modelling software in the classroom.

2 Research Methodology

To confirm or reject the hypotheses, a questionnaire was developed. The questions included were designed in such a way that the results could be analysed to confirm or refute the hypotheses. Only the first hypothesis was confirmed or refuted independently of the questionnaire. For the first hypothesis, a detailed analysis of the curricula used in education in the Slovenian school environment was carried out.52 participants started the survey, 5 of whom did not complete it. Thus, the analysis was carried out on 47 (n = 47) responses from teachers from different parts of Slovenia, 42 % of whom came from primary schools.The questionnaire consisted of 20 questions, which were divided into two sets. The first set of questions related to spatial modelling and the use of related computer programmes, while the second set consisted of demographic questions. The survey was conducted from July to September 2021. The online questionnaire was developed using the open-source online survey application 1ka.si. The link was posted on the community forum of teachers participating in the national project on innovative learning environments. Priority was given to teachers teaching 3D modelling. Before completing the survey, participants were informed that participation in the survey was completely anonymous.

Descriptive statistical analysis was carried out. Percentages of individual responses, medians and standard deviations were calculated. The explanations of the survey participants' answers were analysed and grouped according to frequency.

3 Research Results

A review of the content of the curricula shows that design and construction are represented quite differently. In primary school, where there is little emphasis on designing and constructing with computers, there is only one goal in the curriculum, and even this is not a mandatory goal that the teacher must achieve in teaching. There is considerably more content relating to design and modelling in the upper secondary curricula. In particular, the following programmes stand out: *Construction technician, Marine engineering technician, Woodworking technician* and *Mechanical technician*. These programmes include specific modules dedicated exclusively to computer-aided design and construction. Computer-aided design and construction is significantly less covered in the *Mechatronics technician* and *Design Technician*. In these programmes, students are mostly only introduced to design and construction software and try their hand at working with it. However, the content covered is only a small proportion, which is not comparable to that of the above-mentioned training programmes. The programme covers the least amount of computer-aided design and construction *Environmental technician*. This can be compared with the primary school subject Engineering and Technology, as students only look at modelling and design applications.

The research also focused on the question of what most influences the choice of computer software and how much price influences the choice. The results show that almost half of the teachers consider price to be a very important factor in the choice of a computer program, and overall, practically the majority consider price to play an important role in the choice. The results in Table 2 also show that the tradition of use of the software is also important for teachers, while the needs of the curriculum and the needs of the economy are less influential on the choice. Recommendations from colleagues and Slovenian school organisations are also less important factors in the choice.

Table 2: Influences on the choice of modelling software (n = 47)

	Price		Tradition of use		Curriculum needs		Business needs		Recommendations from			
									eColleagues		Slovenian school organisations	
	f	f%	f	f%	f	f%	f	f%	f	f%	f	f%
1 – Very important	22	47	8	17	2	4	7	15	4	9	4	9
2 - Important	8	17	16	34	10	21	4	9	3	6	6	13
3 - more importantly	5	21	8	17	15	32	7	15	10	21	2	4
4 – more irrelevant	1	2	9	19	10	21	9	19	10	21	8	17
5 - irrelevant	3	6	4	9	6	13	10	21	10	21	14	30
6 – very irrelevant	8	17	2	4	4	9	10	21	10	21	13	28
Mean	2.6		2.6		3.4		3.9		4.0		4.3	
Std. Deviation	1.93		1.39		1.31		1.71		1.53		1.64	

The survey also asked whether and how teachers are provided with training on how to use the software. The results show that training is overwhelmingly not provided and that teachers have to train themselves to use the software (f % = 96). The remaining responses are presented in Table 3.

Table 3: Training methods for using the programmes

	Independently	Knowledge transfer, cooperation between teachers at school	Knowledge transfer, cooperation between teachers from different schools	Training is part of the licence purchase	Training organised by a company from the business sector	Training in various institutions
f	43	19	6	2	3	8
f%	96	42	13	4	7	18

The purpose of the research was also to find out whether teachers who deal with curriculum content and programmes on a daily basis believe that the curricula in Slovenian schools allow for the adequate and sufficiently frequent integration of computer programmes in the curriculum. The results for the question, if the curricula enable the integration of modern computer programs in the classroom are as follows (n = 47): YES (f = 43, f% = 81) and NO (f = 4, f% = 6).

4 Discussion

It is noticeable that the specific training programmes cover the areas of computer-aided design and construction quite well. To a greater extent, these are programmes that directly train for occupations where employees need to demonstrate and apply design and construction skills. The catalogues of these programmes thus contain objectives that provide students with basic and (in some cases) advanced knowledge in these areas, thus empowering them to work independently in design and construction when they are employed. When analysing and reviewing the objectives of curricula and skills catalogues, we found that there are relatively few such programmes. This suggests that design and construction content is only well represented in Slovenian schools when it relates to specific educational programmes. If we look at the representation in general, i.e. in the context of all educational programmes available in Slovenia, it is possible to determine that these contents are poorly represented, and therefore we can only partially confirm the first hypothesis, while concluding that it would be worthwhile to consider how to introduce these contents to the wider population. These contents are therefore poorly represented (only as an optional objective) in primary school, which leads us to conclude that individuals only encounter computer-aided design and construction in secondary school, and the majority of the population does not do so even then, as those who opt for general secondary education or secondary vocational education in the social sciences, humanities, economics and other non-technical subjects do not receive these contents. Thus, many students are not exposed to these subjects until they are at university, if at all. This is because visualisation using computer-aided design and construction software is part of a broader process of digitisation, which takes place at various levels, from mapping the environment (maps), to monitoring the current state of play (environmental sensors, satellite images, etc.), to monitoring people and modelling their habits, and, as a result, to adapting the environment, habits, and the automation and robotisation of various works. Modern technology allows simulations and tests to be carried out in a digital twin, and the findings and lessons learned from these simulations can be transferred to the real world in a much faster time with less cost and risk. The key to successfully integrating the real and digital worlds, reaping the benefits of the digital twin, and leading to a thriving society is unambiguous and quality communication with the digital twin. How to communicate with the digital twin is no longer a matter of language, but rather a way of expressing oneself and thinking, of which computational thinking is a central part. The encounter with the use of design and construction software, even in non-strictly professional contexts, is a step towards understanding the digital world. Given the situation in Slovenian schools, we assumed that the price of the software is the most important factor in the choice of software. Only one curriculum mentioned a specific computer-aided drafting programme (Auto-CAD), which means that teachers have a lot of freedom and responsibility in this area. The results of the survey showed that price is one of the most important factors in decision-making, with almost all teachers expressing that price is important in their choice, confirming Hypothesis 2. There are probably many reasons why price is such an important factor, the most important of which would be financial constraints. School institutions are generally financially constrained and purchasing (even more expensive) equipment can be a problem for a school. This should not neglect the subsequent renewal of software licences. It is worth noting that schools have to divide the financial resources available to them between different costs, which means that it is difficult to allocate a large part of the money to the purchase of software for specific subjects or modules, as there are many of them. A lot also depends on the goodwill of the head teacher, especially in primary schools where it is an optional objective. Among the possible solutions for schools to reduce the impact of price in the decision to purchase software, we see various forms:

- linking schools together at national level to jointly submit an intention to select and purchase specific software, which would (probably) allow them to lower the purchase price due to the volume of the order;
- the creation of a specific fund at national level (e.g. the Ministry of Education and Science) from which schools could easily apply for funding for the purchase of specific software;
- networking with economic operators from the environment who employ students from the schools and should therefore have an interest in being trained to handle specific software.

61 % of teachers expressed the opinion that the needs of the economy in terms of software procurement are less or very unimportant. This, coupled with the fact that they rarely consider the recommendations of colleagues or professional and development institutions, shows that teachers are quite isolated and even self-sufficient, unwilling to step out of their comfort zone and use certain software because they are used to it. It can even be assumed that some schools, for example, are willing to spend more money on software simply because they have been using it for a long time and are not prepared to adopt other, similar and possibly cheaper software. It can also be concluded that the attachment to a software is related

to the time and energy that teachers should invest in training to use it in a meaningful way. The results on teacher training showed that teachers are mostly left to their own devices in training, so Hypothesis 3 cannot be confirmed. To a fairly large extent, teachers also exchange knowledge about the software among themselves, but only within their own school. We believe that things should be changed in this area, as training within development institutions is only in third place. Part of the reason for this is that the software is purchased by the schools themselves, which is probably why it varies and makes it difficult to provide uniform training. Perhaps the development institutions could play a role here as a facilitator and facilitator of the emergence of a professional learning community of teachers who teach computer-aided design and construction at regional and national level. Not only would this reduce the time teachers spend on their own training, but it would also mean the creation of a community where teachers in the profession could exchange information and good practice, both on the technical features of using specific software and on didactical approaches and ideas. Institutionally organised training would also have clear objectives, which would contribute to the acquisition of the relevant knowledge needed by the teacher to work with the software and to teach computer-aided design and construction effectively. Such organised training would be particularly effective if it were carried out in cooperation with stakeholders in industry or even software developers.

Although the results of the survey showed that teachers mostly consider that the curricula allow for the integration of modern design and construction software into the curriculum content, which supports hypothesis 4, it is questionable (given the influence of price and tradition in equipment habits) to what extent they actually do so. Curricula and knowledge catalogues are clearly broad enough to keep pace with the demands of rapid changes in technology and society.

5 Conclusions and Implications

The research carried out has provided a deeper insight into the use of computer programmes in the field of design and construction. It showed that the areas of design and construction are mainly covered by those educational programmes that are directly linked to professional fields where this type of knowledge is indispensable. In general, design and construction subjects are under-represented in Slovenian education. Teachers believe that the curricula in Slovenia are adequately oriented as regards the possibilities of integrating design and construction software into teaching, although we expected the survey results to be lower, as we initially felt that the use of computer software was not fully developed. The results showed that price, rather than the needs of the pupils or the environment (e.g. the economy), plays a major role in the choice of software. We also found that teachers are mostly trained to use the software they use on their own, at most in collaboration with colleagues from the same school. As this is a subject that is taught only in a few specific programmes and in a relatively limited number of schools, we believe that schools (or teachers) should be better connected to each other and should be adequately supported by the institutions in charge. We suggest that the field should be addressed in a holistic way and that it should be linked to the economy and that additional funding should be made available at national level for the purchase of the relevant software. It would also be important to provide training for teachers, and the curricula should be continuously upgraded and adapted to the realities and needs of the economy in these areas. In future research, it would be useful to compare the integration of these subjects in curricula internationally, and to include economic operators and their needs in the curricula.

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