CONTENT DEVELOPMENT FOR TEACHING AND LEARNING IT IN A VIRTUAL 3D ENVIRONMENT

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In recent years, interest in effective digital learning materials has grown significantly in almost all disciplines, fuelled by the rapid expansion of distance learning in the wake of the worldwide coronavirus pandemic. In our study, we would like to present a new and hopefully promising technology, through the development of an IT e-learning material, which offers an easy-to-use 3D virtual environment for the content to be displayed. This project is based on the use of the Maxwhere system for educational purposes. The MaxWhere environment is a 3D presentation tool developed a few years ago that can be used as an excellent tool for the development and presentation of e-learning materials in both teaching and learning environments.

In the development of the curriculum, special attention was dedicated to the content composition from a network-theoretic point of view, focusing on the relationships between the elementary units as hubs and the integration of each hub into the curriculum system. In addition to this, the data content of the resulting curriculum was also analysed from a scale-free perspective. It is assumed that the structure of the curriculum can theoretically be viewed as a network of relevant cognitive units (e.g. chapters, subchapters, pictorial illustrations, etc.) and that the curriculum is likely to be more effective if the interconnection of the individual information units follows the scale-free pattern that has been identified in many networks. It is thus safe to assume that when new knowledge is integrated (i.e. when the material is being learned), the pattern of connections established by the participants in their own cognitive knowledge systems will be similar. Consequently, the brain pattern of memorized information inherits many of the good properties of scale-free networks (e.g. robustness).

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INTRODUCTION

The need for effective electronic curricular material in teaching and learning has recently significantly increased in almost all areas of science and knowledge. This is due, mostly, to the digital education introduced as a consequence of the pandemic Covid 19. In the current study, a new promising technology for developing and presenting e-material adaptable in different instructive and learning environments will be introduced.

The MaxWhere Seminar System is a 3D presentation tool developed in Hungary some years ago that offers as a frame a spectacular, easily usable 3D virtual environment for the contents to be presented (MaxWhere 2021). The system, after its installation on the client machine, can be used for developing, presenting, and browsing e-materials in the areas of teaching and individual learning alike. The MaxWhere environment can be manifoldly used beyond the educational area, e.g. in marketing or the economy, for presentations or introductions, etc.

The following from among the basic functions of the MaxWhere environment must be emphasized:

- 3D space: moving freely in the space within the environment (left and right, forward and backward, up and down as well as turn horizontally or vertically) that suits the simulation of virtual presence.
- the possibility of vertical guiding: basically with the mouse or the keyboard but can also be used with VR tools.
- information can be presented as in an exhibition on the so-called smartboards (i.e. on interactive browsing windows) in the 3D space.
- wide range compatibility with various offline and

online, static and dynamic contents.
- preparation of presentation, projection with automatic gear, and the possibility of a survey, from multiple viewpoints.
- textual content, videos, web pages, web applications as well as various collaborative tools, and even polling systems or video conferences can be presented on smartboard tables.
- it is possible to choose from a number of formerly prepared, different-looking virtual spaces, according to topic or taste.

LEARNING AND NETWORK THEORY

In the process of learning when viewed in the light of network theory one can see that on one hand new nodes are added to the existing knowledge system, while at the same time new edges are formed. It is an open question whether from a network theory point of view the strength between the nodes should be noticed. If the metaphor of "neural network" or "deep learning" etc. is applied connectionwise to the human brain, the answer is yes but if the metaphor of a computer system or network (internet, web) is applied, then the answer is no. Within the verbally organized knowledge network, the nodes are those units that are more or less meaningful (e.g. data, concepts, expressions, sentences, texts, etc., or verbally expressible pictures, sounds etc) The edges between the nodes are simply those connections that have meaning-organizing functions (semantic, coreferential, intertextual, etc.) as well as branching associative links. By learning the knowledge network is continuously built and restored. A contrary process is forgetting when the number of connections decreases (or fades away) or entirely stops.

In this perspective, it is obvious that the nodes of a network that have few connections (links) can be easily damaged ("discarded"), i.e. disappear in the shadow of forgetting. On the other hand, those nodes which have many (multiple or redundant) connections are far more resistant to the injuries of the connections (which may result in forgetting). As an example learning by heart (memorizing) as a form of learning should be mentioned where the student makes an attempt to remember certain units of information from the learning material in such a way that it is hardly or not at all connected to existing knowledge. It is known that such knowledge does not persist in the long run and is said to be injurious because there is no or little connection between the memorized units of information.

With mindful learning a so-called cognitive excess is created in the brain. It is assumed that in the case of SM patients education can, in some degree, protect from decline (Esem.hu 2021/1/2). Investigations have proved that forgetting does not mean the loss of information or data but rather the lack of capability to obtain information.

Nobel prize winner biologist Tonegawa and his team have managed to revitalize forgotten memories in mice, which proves that not the memories are injured in the brain, but rather their recall capability (Ramirez et al. 2013). According to these investigations retrograde amnesia due to brain injury, stress, or Alzheimer's disease is caused by the memories' recall problems (Ryan et al. 2015). With these results in hand, it can be assumed that the nodes representing „forgotten" information do not become deleted from the brain, only those routes are lost or injured through which they become available. (This is supported by the fact that in the case of retrograde amnesia the temporarily forgotten memories can later reappear.)

When learning takes place in a virtual 3D environment it is assumed that learning translates the virtual environment that is used into the student's mental and cognitive system. When the curriculum was planned it required a network model which gives meaning to the nodes and edges of the knowledge system and describes in one way or another the network architecture in question. A similar model is outlined below.

Network-based learning or connectivity is a learning theory based on the works of George Siemens and Stephen Downes and is placed on the meeting point of three areas and these are informatics, pedagogy, and network research. Network-based learning means network theories employed in pedagogy (Bates 2019). Information coming from curricular material and forwarded by a connecting way, which e.g. may play a part while memorizing certain units, can be significant from the point of view of the methodology of learning in a virtual 3D environment. In the current study, however, the emphasis is not on methodological questions but rather on effective curriculum development. A starting point in this can be the organization of the internet and its abstraction, the theory of scale-free networks. The internet is a spontaneously organized information network and its development marks the appearance and disappearance of nodes (i.e. web pages) as well as connections or edges (i.e. links). In this network that is organized both verbally and multimedially the nodes represent those units that have meaning (e.g. numeric and textual data, verbal and multimedia texts, pictures, videos, etc.) – while the edges between the nodes show branching (semantic, associative) connections which make it possible to search the information stored in the nodes. The spontaneous organization, however, does not mean that the web is randomly organized. There are so-called "small-worlds" on the internet (e.g. the pages on Wikipedia) which are nodes where numerous mutual relationships can be found; and there are "hubs" (or central points like the internet searchers such as Google) that command an extremely high number of links and connect the "small-worlds" too. Generally speaking, the centers establish short routes between any two points of a system (cf. Barabasi 2013: 72). If the number of incoming or outgoing links to a web page is named degree number then the number of web pages with a given degree number follows power function ($N(k) \sim k^{-\gamma}$). It has happened in the case of several big networks that the distribution of nodes can only be described with power function and the degree number is in each case unique and in most systems falls between two and three (Barabasi op. cit. 78). Let us note that such systems are called scale-free networks.

When developing an e-curriculum certain units are regarded as nodes and the connections or links between them edges; and they form a knowledge network. If the internet is regarded as a metaphor for a knowledge network created through a learning process then learning can be viewed as a mental activity that helps build and restore the knowledge network. In this regard, learning translates the e-curriculum into the student's cognitive system, which means the mental creation of the curriculum within the human long-term memory. This, however, does not mean a one-to-one correspondence since the created knowledge when linked with further knowledge (e.g. background knowledge) stored in the memory adds other nodes to the system and creates new links (while the existing knowledge settles in). It is also possible that the student fully or partially reinterprets or rejects certain knowledge units. All this can be reintroduced into curriculum development (e.g. through permanent contact with the students) and the content and effectivity of the e-curriculum can be continuously developed.

LEARNING IN THE 3D VIRTUAL ENVIRONMENT

Some positive features of the 3D environment should be presented concerning the presentation, organization, and use of the curricular material.

In general, it can be said that a 3D environment can have several significant advantages concerning e-curricular material. The following should be emphasized:

- In terms of segmentation, organization, and content division the virtual 3D space has different and more varied possibilities compared with the 2D environments (like e.g. printed books or e-books, web pages e-learning, or LMS systems, etc.) due to the "one plus" dimension.
- Presentation of the curricular material in a 3D environment is more exciting and therefore more easily digestible for the average student as opposed to the usual most often unilateral content offered by traditional media.
- The proper organization and presentation of the material in a 3D space can greatly help orientation and the cognitive process of learning, e.g.
    - perception of essential and emphatic information which makes easier the interpretation of the material;
    - there are several possibilities to mark links or correlations among content units simultaneously presented in a 3D space (such as organization and grouping of content units, shape, colour, measure, of the units or their certain parts etc.) which would greatly help shape the feedback concerning interpretation;
    - visual fixation of curricular material as a presentation (in a classroom, lecture hall, library, or museum exhibition space) can be an automatic process.
- Increased visual delight can particularly influence members of the "new" young generations (e.g. net generation, Z generation, generation of cognitive entities) to spend their time with learning (instead of spending their time on social media content).
- In theory the structure of the learning material can be studied as a network of relevant cognitive units (e.g. chapters, paragraphs, diagrams, etc.). From this point of view, the more connected the single information units of the curricular material are to each other, in either explicit or implicit way, the more connections can the receivers create in their own cognitive systems.
- Consequently, the synthesis preservation and recall of the memorized information can be far more effective when the number of connections between single units or parts (knowledge links interpretation bonds) is higher and the routes between

the units to be memorized are shorter. It can be assumed that the visual picture and the presented structure of the learning material become the basis of a cognitive picture fixed in the brain (which routinely happens when an infographic is perceived). This shows that the 3D learning material content offers really big possibilities.

DEVELOPMENT OF CURRICULAR MATERIAL IN A 3D ENVIRONMENT

The current study aims at demonstrating the possibilities for the development and presentation of the learning material through the elaboration of a selected informatics topic in the 3D virtual environment of a MaxWhere seminar system (Figure 1).

The selected topic is the curricular material developed by the Department of Mathematics and Informatics of the Ferenc Kölcsey Teachers Institute at the Debrecen Reformed Theological University and is part of the instruction network of the informatics educational field. The title of the subject is History of Informatics and Hardware Knowledge. The content of the subject has formerly existed in electronic form as an MS PPT presentation. To be installed in a MaxWhere 3D system first the original material has had to be transformed into a hypertext (HTML/CCS) form which means that it has gone over from the offline space in the online world.

With this development, 26 chapters of the material have been prepared for a web page, in HTML format, with search windows (Figures 2 and 3). Presentation in MaxWhere does not necessarily require an HTML format in the background, since the frame makes possible the presentation of files with different extensions on smartboards within the virtual 3D space. This makes possible a direct PPT presentation as well. The extra work effort to develop the web page is justified for two reasons. One is that the HTML pages are easily, without a time limit, accessible for those interested (e.g. the students), and the online content developed in this form can be changed at any time, independently from the 3D environment. This way the user has access to the most up-to-date information. In case he does not have the hardware or software required for the presentation of the MaxWhere 3D environment he can nevertheless have access to the curricular material on the web (2D), even on a cellphone. Another reason is that the real or one might say full interactivity of the MaxWhere virtual environment can be mostly used with the interactive possibilities of the web pages (beyond hypertext links, e.g. Javascript programs).

Hypertextuality has already provided the original raw material with a new dimension because instead of originally "passive" content pages, hypertext with interactive links and pictures (or generally, with multimedia content) have been created. Through the links, the content units of the curricular material are connected and beyond that several supplementary bits of

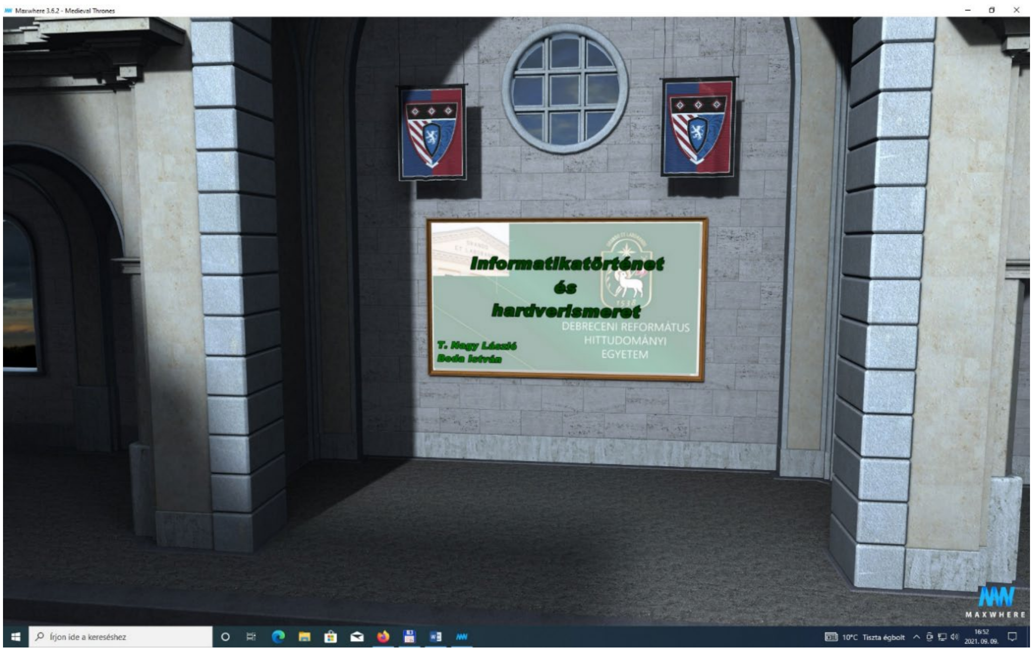

Figure 1 The starting screen of the informatics learning material developed in MaxWhere virtual 3D environment

information and metadata have become available.
Considering that the chapters of the curricular material are the *nodes* of a network it is possible to analyze the hypertext links between them from the viewpoint of network science focusing on the scale-free characteristics of the developed material. In the first phase of developing the material, the main chapters ('n' pieces) are connected to the index page, and certain subchapters ('m' pieces) to the main chapters as well as to the index page. Both to the main chapters and the subchapters belongs rich illustrative picture material ('p' pieces; note that this number might as well include audio material, animation, videos, etc.). The pictures, diagrams, etc. can be presented on separate pages which means that they can be also considered network nodes. In this particular form, the curricular material to be prepared is still hierarchical. Let us try to determine, still in this phase, the basic characteristics of the network. For a starter, it must be noted that the pictures are the "leaf nodes" of the created link structure, i.e. they are referred to from the chapters while they do not refer to further units. Let each picture as a leaf node has exactly one connection (k=1). If we would like to get a scale-free network then the number of nodes having exactly 'k' links is described by a power law function

$N(k)=c*k^{-\gamma}$

(cf. Barabási 2013: 77 et passim). If it is assumed that beside the pictures every node is referred to and every node contains at least one reference to another node, then only the pictures can be considered as leaf nodes each of which having exactly one link.
Then due to N(k)=p and k=1 we get

$p=c$

(currently p=c=114). On the other hand, a link points to every chapter and subchapter from the index page of the curricular material which results in k=m+n links altogether. If it is assumed that every single chapter or subchapter contains less number of links, then because of N(k)=1 and k=n+m the relation

$1=c*(n+m)^{-\gamma}$

is valid (currently n+m=26). If we take the logarithm of both sides and arrange the equation we get

$\gamma=\log(c)/\log(n+m)$

and substituting the current values, for the γ parameter of the power function

$\gamma\approx1.45$

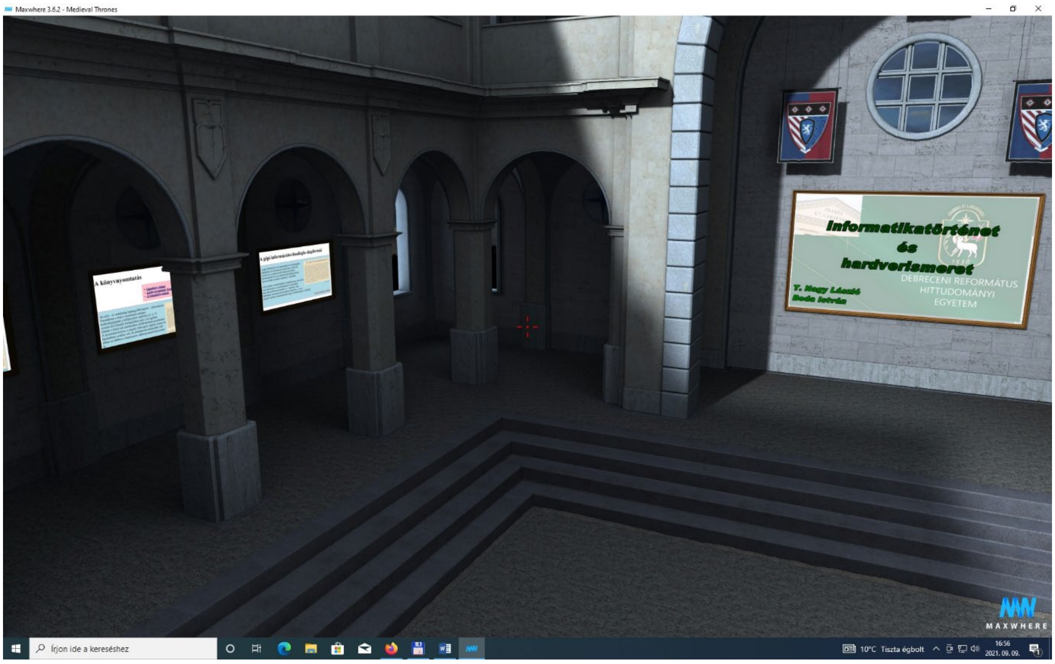

Figure 2 Two chapters of the informatics curricular material developed in MaxWhere virtual environment shown on the ground level aisle left to the starting screen

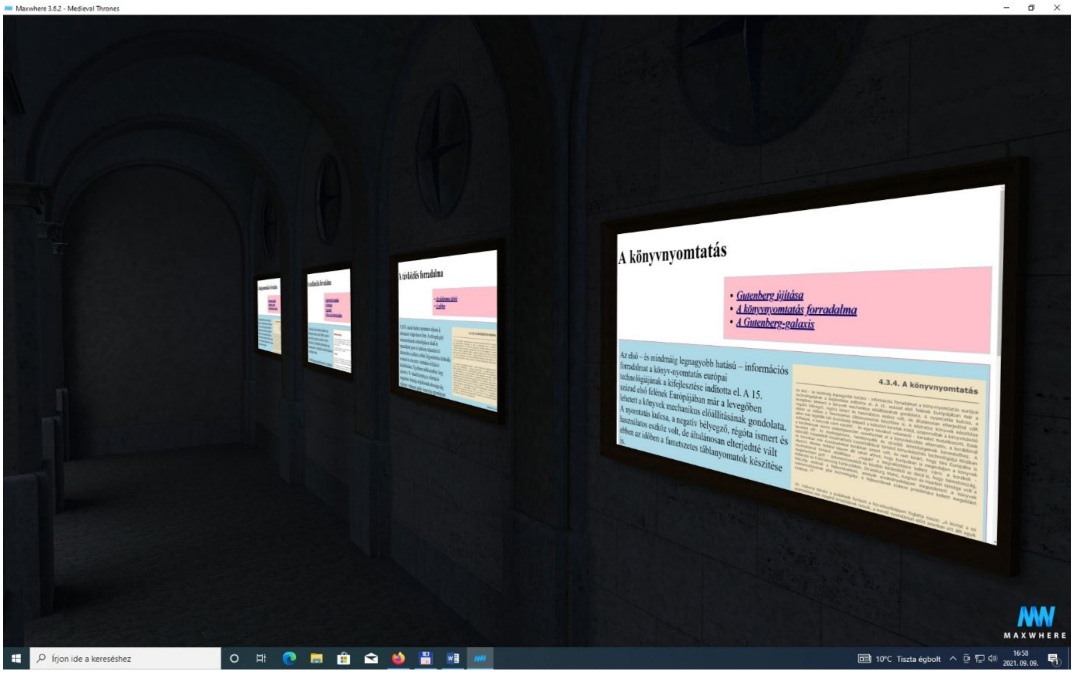

Figure 3 Four chapters of the informatics curricular material developed in MaxWhere 3D environment shown on the ground level aisle from another perspective

comes. With this, both parameters of the power function are given and actual meaning is allocated to them as follows: 'c' equals the number of pictures, and calculating the value of 'γ' requires the division of the logarithm of the number of pictures by the logarithm of the number of chapters and subchapters.

The definition of the basic parameters makes it possible to follow the steps necessary to create a scale-free network. For example, it is possible to refer to single subchapters both from the index page and from a certain main chapter and if it is assumed that a subchapter contains an average of two pictures, then we get k=2+2=4 links for each subchapter. Therefore we get for the number of subchapters

$N(k)=114*4^{-1.45}\approx15$

which is close to the real m=16 value. Similarly, from the index page there is one link to each main chapter, and from each main chapter there is one link to each subchapter (in average there are two subchapters that belong to each main chapter). Let's assume that as an average there are two links pointing to the corresponding pictures from each main chapter (note that the pictures must be different). What follows is that one main chapter has k=1+2+2=5 links as an average. Therefore we get for the number of the main chapters

$N(k)=114*5-1.45\approx11$

which is close to the real n=10 value. It is clear that the characteristics obtained this way are only approximations. But the obtained values show what procedure is to be followed when developing a curricular material having scale-free characteristic.

The curricular material is mapped sequentially by the order of the content pages and follows the suggested learning order but the material itself can be, at least theoretically, mapped and used in random order. The latter is useful if the user would like to supplement the earlier acquired material with additional information as well as with new connections between the information units. This makes it possible to shape new knowledge units and knowledge links in his own cognitive system. This increases the effectiveness of learning and knowledge acquired by learning since the knowledge network shaped by learning is the stronger the more redundancy can be detected.

SUMMARY AND CONCLUSIONS

When development of a curricular material is in question the starting point is a metaphor called knowledge network that compares the organization of human (subjective) knowledge with the organization of complex, scale-free networks similar to the internet. Based on this metaphor learning can be conceived as similar to the knowledge network of the brain where new knowledge units and links are added to the existing system which connects them with the already existing units while new links can build up between the already existing nodes as well. In the course of developing a curricular material, this can be considered as an attempt to develop a system that follows the above pattern. The complex networks organized in a scale-free way are rather resistant when certain units or links are randomly removed (cf. Barabási 2013: 217). Therefore when in the course of learning a similar structure appears in the brain it can be safely assumed that the acquired knowledge strongly resists forgetting. Therefore it is patently important to establish as many as possible relevant connections between the knowledge units within the curricular material:

The simplest and most often used pointer which describes best the structure of the network is called density. The density of a network indicates the rate of actual connections between the points within the network compared to the overall number of possible connections (...) The bigger the density of a network, i.e. the more connections there are within the network the easier the units of the network connect with each other. So the stream of information becomes easier, too. (Juhász et al. 2016)

Virtual 3D spaces have knowledge-deepening and learning-stimulating effects and have been investigated in many ways by many. Of these, there must be mentioned Edgar Dale's Cone of Experience, i.e. the knowledge or learning pyramid which has often been referred to and often appears in the investigations of the theme. In this model, those experience-acquiring forms that become available during knowledge acquisition (teaching, learning) are depicted like a pyramid, according to how close the experience-acquisition of the receiver is to the actual reality or on the contrary how abstract it is (Dale 1969). Virtual reality may appear as a particularly valuable form in the coordinate system of this method because stemming from its characteristics it connects virtually direct experience acquisition with the verbal and multimedia display of abstract contents. This way, based on the model, it is possible to consider virtual reality as an extremely effective system, both from the viewpoint of knowledge transfer and from information preservation.

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■ Článok bol recenzovaný