

# MaxWhere VR-Learning Improves Effectiveness over Classical Tools of e-learning

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*Abstract: The paper investigates how workflows can be communicated and shared through linguistic descriptions, digital content and technological tools. We focus primarily on the content and digital tools of e-learning and VR learning. However, the results of the paper can be applied to collaborative workflows in general. The paper compares the effectiveness of three techniques, ranging from well-known to radically new: classical e-mail / attachment based sharing, sharing through web interfaces (through a Moodle frontend), and sharing through a VR interface provided by a recently developed VR engine called MaxWhere. To this end, the paper introduces new methods and a new set of concepts for the purposes of benchmarking digital capabilities and user effectiveness within the domain of workflow sharing. The paper applies these concepts and methods to compare the use of the above listed technologies with the participation of 379 test subjects. Tests show that the users were able to complete the required workflow at least 50% faster in the MaxWhere 3D environment than in all other competing cases. The paper also proves that 3D environments are capable of providing users with a much higher level of comprehension when it comes to sharing and interpreting digital workflows.*

*Keywords: VR-learning; e-learning; Cognitive Infocommunications*

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## 1 Introduction

In the past decade, the everyday use of the Internet has become widespread in all areas of life, including education. However, the question of which digital tools can be used most effectively in education is still open to debate.

Many educators share their curriculum and learning material using e-learning tools, which can also be accessed by students having the required access privileges. Others prefer to simply share the learning materials through e-mail.

In the past few years, VR applications have been used in education primarily as tools for visualization. The MaxWhere VR platform for education was first released in 2016. Besides serving visualization purposes, MaxWhere's strength lies in its ability to present complete electronic notes on smart slides in 3D space. Through MaxWhere, a powerful combination of interactive 3D visualization, working environments fit to specific workflows and e-learning can be achieved.

The topic of the paper belongs to Cognitive Infocommunications [1, 2], where the blended cognitive capabilities of Human and IT solutions are investigated. Within this topic the paper focus in the research direction of VR-learning and papers investigating user experience in virtual 3D environments [3, 4,...,25].

The goal of this paper is to provide a systematic comparison among the three aforementioned techniques in education and in the sharing of collaborative workflows.

## 2 Properties and Definitions of Workflow and Digital Content Sharing

In this section, we provide definitions of key concepts relevant to digital content: its comprehensibility and accessibility as well as the various forms in which it can be shared. Further sections of the paper will provide evaluations of various digital tools and methodologies based on this nomenclature.

### **Definition 1: Digital element (DE)**

*A digital element is taken to mean a unit that has to be opened or loaded separately, in itself with an appropriate software.*

**Example 1:** PDF files, PPT presentations, video files, content accessed through a specific URL (as a Moodle test or Google form), web apps (e.g. Octave Online), or source files that can be opened using an editor or IDE are all examples of digital elements. In the experiments described in the paper, the following digital elements will be used:

doc1.pdf, doc2.pdf, doc3.pdf

home page 1 at www.hp1.com

pres1.ppt, pres2.ppt

test1 at url www.test1.com es test2 at url www.test2.com

video1.avi,

### **Definition 2: Digital content**

*Digital content are defined as a set of digital elements. Digital content can be quantified based on the number of digital elements contained in the content.*

**Example 2:** If we consider the digital elements listed in example 1.1. to be the building blocks of a digital content, the size of the content will be 9 DEs.

**Definition 3: Digital fragmentation (DF)**

*Digital fragmentation is a property of digital content that shows how many different formats are represented by the digital elements forming the content - i.e. how many different software tools are required to open or load them.*

Remark: we regard digital elements that can be accessed on the web through a url as being different formats, even though all of them can be loaded using a web browser. For example, a web page or a Google Drive document or a Moodle test are three different formats, not one. The reason for this is that although all of the examples can be opened using a web browser, separate web apps are required to open all of them.

**Example 3:** The digital content referred to in the previous examples have a digital fragmentation of 5 DFs.

**Definition 4: Digital project**

*A digital project is a set of tasks that are to be carried out on a digital content.*

**Example 4:** Consider the 5DF, 9DE digital content referred to in the previous examples. The tasks in a digital project associated with that content might be to fill out two questionnaires based on the information contained in the digital elements forming the content.

**Definition 5: Digital workflow (DW)**

*Digital workflows determine the order in which individual digital elements are to be accessed or processed during the course of a digital project. We distinguish among the following types of digital workflows:*

*1st order (linear): The digital elements are to be accessed in a static and sequential order, one after the other*

*2nd order (loopy): There are loops in the order in which the digital elements are to be accessed, so that individual elements, or smaller sequences thereof, are to be accessed repetitively. Such loops can be characterized by length and number of repetitions.*

*3rd order (networked): Digital elements accessed during the project are structured as hierarchical loops, so that the project may contain subprojects of subprojects, and / or the ordering of digital elements may be different upon different repetitions of the loops.*

*4th order (algorithmic): It is possible that the project contains branches, so that different digital elements are accessed dynamically in an order that depends on information obtained during the project.*

**Example 5.1:** The digital workflow is of the 1st order if the order in which the digital elements are accessed is static and sequential, e.g.:

```
doc1.pdf -- doc2.pdf -- pres1.ppt -- test1 -- doc3.pdf -- video1.avi -- pres2.ppt --
test2 -- homepage1
```

**Example 5.2:** The digital workflow is of the 2nd order if the order in which the digital elements are accessed has repetitions, loops, e.g.:

```
doc1.pdf -- doc2.pdf -- pres1.ppt -- test1 -- doc2.pdf -- pres1.ppt - test1 --
doc3.pdf -- video1.avi -- pres2.ppt -- test2 -- pres2.ppt -- test2 -- homepage1
```

akkor ezt a digitalis workflow-t 2 rendunek nevezzük

**Example 5.3:** The digital workflow is of the 3rd order if the order in which the digital elements are accessed has hierarchical, embedded loops, e.g.:

```
doc1.pdf -- [doc2.pdf -- pres1.ppt -- test1] -- [doc2.pdf -- pres1.ppt - test1] --
(doc3.pdf -- video1.avi -- {pres2.ppt -- test2} -- {pres2.ppt -- test2} - [doc2.pdf --
pres1.ppt -- test1] -- [doc2.pdf -- pres1.ppt - test1] -- doc3.pdf -- video1.avi --{
pres2.ppt -- test2 }-- {pres2.ppt -- test2} - [doc2.pdf -- pres1.ppt -- test1 ] --
[doc2.pdf -- pres1.ppt - test1 ]--) -- [doc2.pdf -- pres1.ppt -- test1] -- doc3.pdf --
video1.avi --{ pres2.ppt -- test2} --{ pres2.ppt -- test2} - [ doc2.pdf -- pres1.ppt --
test1] --[ doc2.pdf -- pres1.ppt - test1] -- homepage1
```

where in reality

```
[doc2.pdf -- pres1.ppt -- test1]
```

and

```
{pres2.ppt -- test2}
```

can also be regarded as subprojects

Based on the definition, the workflow is also of the 3rd order if the repeating loops are not always the same

```
doc1.pdf -- doc2.pdf -- pres1.ppt -- test1 -- doc2.pdf -- pres1.ppt - test1 --
doc2.pdf -- -- test1 -- pres1.ppt - test1 -- doc3.pdf -- video1.avi -- pres2.ppt --
test2 -- pres2.ppt -- test2 -- homepage1
```

**Example 5.4:** if the order of access of digital elements depends on information obtained during the workflow (i.e. there are branches in determining access to digital elements), then the workflow is of the 4th order, as in the following case:

```
doc1.pdf -- doc2.pdf -- pres1.ppt -- test1
```

```
if test 1 was successful then -- doc3.pdf -- video1.avi -- pres2.ppt -- test2 --
homepage1
```

```
if test 1 was NOT successful then -- homepage1
```

we may have a further branch at test 2 that leads to an even more complicated chain.

Through examples 5.1 - 5.4, it is clear that as the order of the workflows grows, so it becomes more difficult to represent them. For example, the workflow in example 5.1 can be expressed as a list:

Step 1 -- doc1.pdf - click here to open

Step 2 -- doc2.pdf - click here to open

Step 3 -- pres 1.ppt - click here to open

Step 4 test1 - click here to open

step 5 doc3.pdf - click here to open

step 6 video1.avi - click here to open

step 7 pres2.ppt - click here to open

step 8 test2 - click here to open

step 9 homepage1 - click here to open

However, the workflows in examples 5.2 and 5.3 are already very difficult to convey using text, which makes the execution of such workflows even more difficult than purely justifiable by their order. In such cases, representation through a dashboard or 2D graphical UI can help a lot (see Figures 1-3).

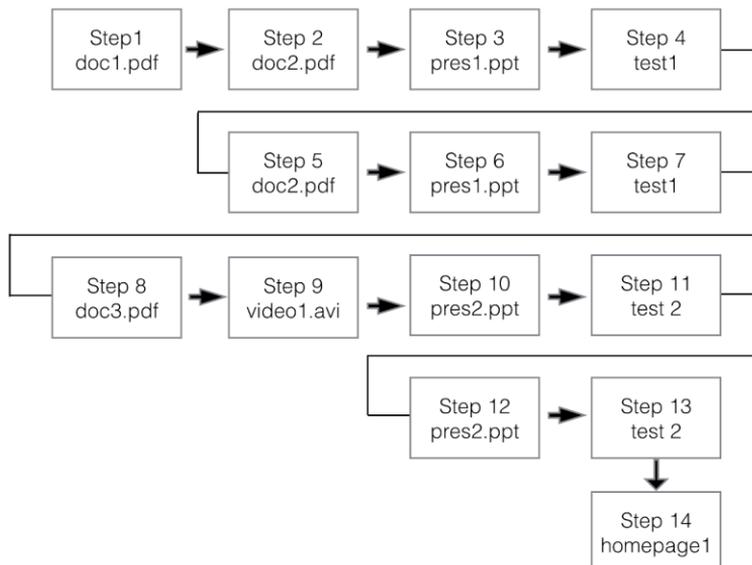


Figure 1

Workflow of the 2nd order, from example 5.2, as expressed using a process diagram

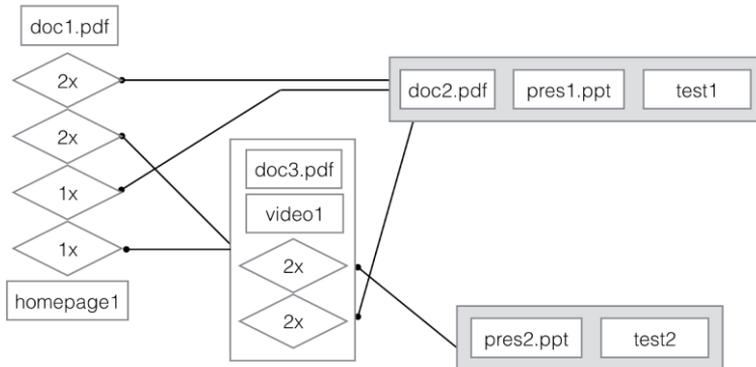


Figure 2

Workflow of the 3rd order, from example 5.3

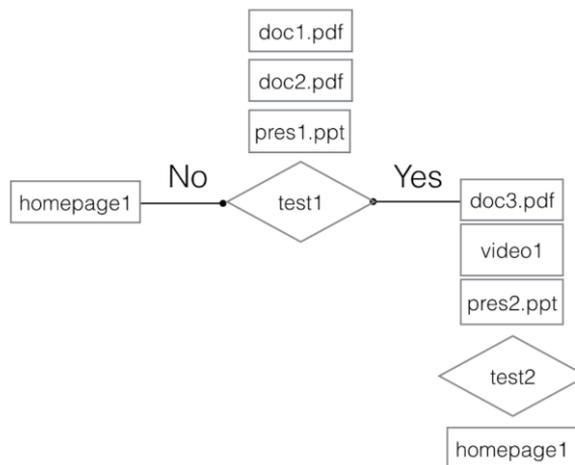


Figure 3

Workflow of the 4th order, from example 5.4, expressed using a process diagram

Based on the following, we make the following remarks in terms of accessibility and comprehensibility.

**Lemma 1:** Digital workflows of the 1st order can be conveyed well using text alone. Digital workflows of the 2nd order can be conveyed using text, but are better conveyed using a graphical process diagram. Digital workflows of the 3rd order are very difficult - if not impossible - to convey using text, depending on the complexity of the workflow. In more complex cases, the paths guiding the

workflow may even intersect and become entangled on the process diagram, making it difficult for humans to comprehend the diagram (see Figure 4, which shows that in such cases spatial diagrams may be used to good effect). In the case of digital workflows of the 4th order, where the workflows, in addition to being characterized by complex paths between the digital elements to be accessed, are also dynamic, no 2D graphical representation can be expected to work well, aside from the simplest of cases.

All of the above observations are summarized in Table 1.

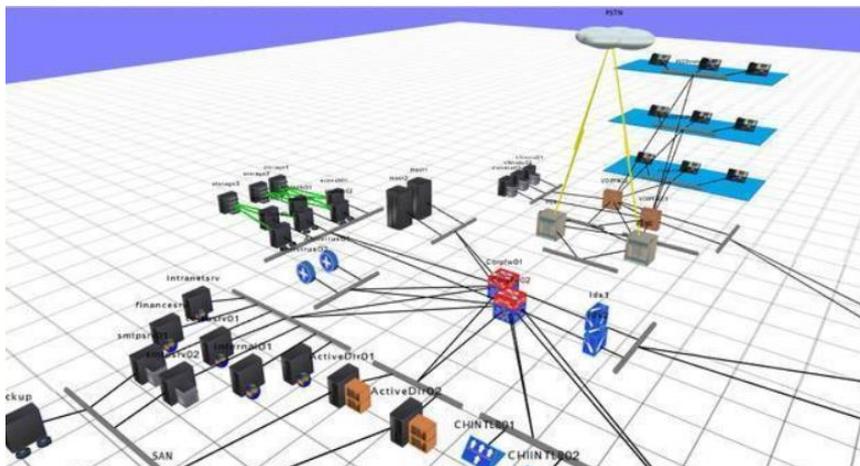


Figure 4

In more complex cases, loops in the workflow can better be represented in 3D space

Table 1

In the table, a value of 1 means that a digital workflow of the given order can be well represented in the given representation. A value of 0.5 means that although a digital workflow of the given order may be represented using the given representation, in more complex cases the representation cannot be expected to be effective. The letter X in the table symbolizes the fact that the given representation is not effective or cannot be used at all for a digital workflow of the given order.

DW	1	2	3	4
text based description	1	0,5	x	x
2D description	1	1	0,5	x
3D description	1	1	1	1

The comprehensibility of a digital workflow can be improved if the blocks in its representation can be clicked on and the corresponding digital elements open or load accordingly (or are already displayed alongside the blocks to begin with). The reason for this is that any ordering (even alphabetical ordering) of the digital elements that are independent of the representation itself will lead to the user

having to continually search for the element that needs to be accessed - a task that can be tedious and error-prone. Thus, it is worth distinguishing between representations in which the digital elements are embedded into the representation and those, in which, that are not.

**Definition 6: Linked Digital Element (LDE)**

*A digital element is referred to as a Linked Digital Element (LDE) if it can be accessed by clicking on a link included in the representation (whether text-based or other) of the digital workflow.*

**Definition 7. Embedded Digital Element (EDE)**

*A digital element is referred to as an Embedded Digital Element (EDE) if it can be accessed without any additional interaction, together with the blocks corresponding to the digital elements within the representation of the digital workflow.*

**Example 7:** Figure 5 shows an example of the block diagram with a pdf file, a video and an interactive application (Octave Online) providing real-time graphical output. All of the digital elements in the example are embedded into the representation of the workflow.

Based on the above, the following definition is formulated:

**Definition 8: Digital comprehension (DC)**

*Digital comprehension is a qualitative concept that can be used to describe the quality of a representation with respect to a digital workflow. The following types of digital comprehension can be distinguished:*

*0th order: There is no ordering among the digital elements of the workflow.*

*1st order: There is a linear (sequential) ordering among the digital elements of the workflow, potentially supplemented with text descriptions.*

*2nd order: The linked digital elements of the digital workflow are ordered in 2D using icons on a dashboard. Relationships between the linked digital elements are represented in 2D and the icons representing the digital elements act as links to the elements.*

*3rd order: The order among the linked digital elements within the digital workflow is represented in a 3D space. The icons within the space are representations of the digital elements and links to them at the same time.*

*4th order: The digital elements and their relationships are represented in 3D space in a linked or embedded form - i.e. the digital elements are not only accessible through links but are also displayed continually as part of the visual description of the workflow.*

Remark: there is no such representation as the embedded (EDE) form of 2nd order iconic dashboards. The reason for this is that in such cases, the running (embedded) applications cannot be effectively presented on a 2D monitor, so that the representation itself is already considered to be 3D; even if they are displayed on a flat screen, users need to access them via zoom in / out operations, and on a virtual canvas that is usually much larger than the 2D screen itself (for example, this is how Prezi software is able to call its presentations 3D).

**Example 8:** The text-based description of the digital workflow in example 5.6 has a digital comprehension (DC) of the 1st order. Figures 1, 2 and 3 show workflows of with a DC of the 2nd order. Figure 4 shows an example of a workflow with a DC of the 3rd order.



Figure 5

A workflow represented at a DC level of the 4th order, such that the digital elements are presented in 3D via running applications (EDE type elements).

Based on the above, the following relationship can be set up between digital comprehension and digital workflows.

Table 2

In the table, a value of 1 means that a representation with a digital comprehension of the given order can be used to represent a workflow of the given order effectively. A value of 0.5 means that although a representation with a digital comprehension of the given order may be used with respect to a given order of workflow, in more complex cases the representation cannot be expected to be effective. The letter X in the table symbolizes the fact that the given representation is not effective or cannot be used at all for a digital workflow of the given order.

DW	1	2	3	4
1 rendu DC	1	0,5	x	x
2 rendu DC	1	1	0,5	x
3 rendu DC	1	1	1	0,5
4 rendu DC	1	1	1	1

**Definition 9: Digital guidance**

**none:** *no guidance is applicable, or the representation of the digital content doesn't involve embedded digital elements (instead, the elements are provided through separate lists).*

**sequential (DG-S):** *The digital elements are traversed in sequential order. It is thus possible to jump between one element to the next in the context of a digital workflow.*

**random access (DG-R - event/dynamic focus-driven):** *One can switch between sequences of digital elements, and thus follow non-static sequences (for example, in the case of DWs of the 4th order).*

**Example 9:** Consider a DW of the 1st order represented with a DC of order 1, such that the digital elements are embedded using hyperlinks within the text. In this way, one can step forward and backward between digital elements using the page dn / page up keys.

In non-linear cases it is especially effective when users can jump, or branch in a random access fashion within a workflow represented in a 2D or 3D space (DW of the 4th order), such that the jumps are automatically adapted to the workflow.

Similar to table 1 and 2, it is possible to define a relation between digital guidances and digital workflows:

Table 3

Contains the result of comparing in pairs with the final result

DW	1	2	3	4
DG-S	1	1	0,5	x
DG-R	1	1	1	1

To summarize the above tables, it is clearly visible that a platform allowing for Digital Comprehension and Digital Guidance of the 4th order can be expected to be most effective in the transmission of even Digital Workflows of the 4th order, while a system capable of achieving a Digital Comprehension of only the 1st order (text-based) will be very limited in its ability to convey workflows.

For the sake of completeness, it is worth introducing a further two definition.

**Definition 10: Digital complexity**

*Digital complexity describes the complexity of the mapping (“assignment”) between digital elements. For example, if in order to fully interpret a digital element, the user has to access a further digital element, then the two are “assigned” to each other. Three different kinds of assignment can be distinguished:*

- i) one-to-one: refers to pairs of digital elements which are assigned to each other in both directions (i.e. the interpretation of each requires the other).
- ii) one-to-many: refers to digital elements that can be interpreted only in the context of multiple other digital elements.
- iii) many-to-many: refers to groups of digital elements that can be interpreted only in the context of (the same group of) multiple other digital elements.

**Example 10:** if a user needs to consult two digital elements in order to fill out a test, the digital complexity of the test is one-to-many.

#### **Defintion 11**

A digital map is the contextual system underlying digital elements, which in many cases coincides with the digital chain.

### **3 Comparison of Classical, e-learning and MaxWhere VR-based Learning Frameworks**

In the following, we begin by outlining the 3 most common techniques used for sharing digital workflows. We then compare those techniques based on the conceptual framework outlined in earlier sections.

#### *1. Classical - TXT based message*

This technique consists of sending digital elements and digital content to a group of recipients as attachments to a text-based message, or as web links inside a text-based message (e.g. sent via e-mail or any kind of messenger application).

Because of the text-based medium it uses, the classical technique can be regarded as an example of Digital Comprehension of the 1st order. In the case of digital workflows conveyed through text, the associated digital elements cannot be integrated into the text (although links to web-based content can). Therefore, this approach can be referred to as having an LDE of 0.5. Correspondingly, it cannot be a part of a continuous guiding scheme, and therefore can be conceived of as representing a DG level of Not Applicable.

**Lemma 3.1:** The classical approach therefore can be characterized as having a DC of order 0, no EDE, an LDE of 0.5 and a DG of ‘not applicable’.

#### *2. Online interfaces such as Moodle*

This technique consists of helping users access and / or download digital elements and digital content through an on-line web-based interface.

In the simplest of cases, the approach of using online interfaces can be equivalent to the classical approach (with the added quality of being web-based), such that

the task to be carried out is described using text, and the required digital elements are listed in some order at the end of the text.

At the same time, an important advantage of online interfaces is that links embedded into the text can be used to share not only digital elements that have a web-based url, but more generally any kind of digital format (EDE). Thus, the digital elements can be ordered inside the text as required by the digital workflow, and sequential DGs can be conveyed without a problem, as long as the digital elements are ordered and users are able to move between them using a scrolling operation or a specific combination of keys (e.g. page up and page dn).

Online interfaces are not amenable to the presentation of digital elements in a 2D process diagram. Thus, even if a digital workflow is presented through an image or a diagram, this solution can be regarded as only partial in view of the requirements of 2nd order DCs.

**Lemma 3.2:** As a result, online e-learning systems are typically capable of presenting DCs of the 1st order (complemented with LDE, DG-S), and can therefore be used to represent digital workflows of the 1st (and in some cases, 2nd) order.

### 3. The MaxWhere Operating System

From an IT perspective, the MaxWhere OS contains no digital elements. Instead, it gives users access to a single (pack or bundle) file, which can be loaded and which contains references to all of the digital elements that are in turn loaded recursively.

All digital content and elements thereof are displayed in thematic groups in 3D. Digital elements are displayed in smartboards, or opened using browser technology integrated into smartboards, hence the representation of the elements is of type EDE. In contrast, to text-based descriptions, the entire process underlying the workflow is in this case represented spatially, through digital elements that are laid out and opened in space.

**Lemma 3.3** In summary, MaxWhere has the capability to represent workflows with a DC of the 4th order, with EDEs and DG-R - hence, it is suitable for the effective execution of DWs of the 4th order.

The following table summarizes the capabilities of classical, online web-based (e-learning) and MaxWhere operating system based approaches:

Table 4  
Capabilities of classical, online web-based (e-learning) and MaxWhere operating system based approaches

DW	1	2	3	4	EDR	EDE
Classical	1	0.5	x	x	0.5	x
e-learning	1	1	0.5	x	1	x
MaxWhere	1	1	1	1	1	1

## 4 Experimental Evaluation of User Effectiveness

In this chapter, results of experimental evaluations are provided. The goal of these experiments was to investigate the effectiveness with which users can execute digital workflows shared through classical approaches, online interfaces and MaxWhere. The digital workflow used in the experiments was of the 1st order, with 11 DEs and a DC of type 5DF. The experiments were carried out on 379 students.

### 4.1 Digital Content

The digital content was comprised of 1 PowerPoint file, 1 PDF file, 1 video file, 4 webpages and a further 4 tests. From the point of view of digital complexity, the task involved both one-to-one and one-to-many relationships. Specifically, 1 (separate) test was to be filled out in the context of the PowerPoint file, the PDF file and the video file, respectively. A final test was given to users in the context of the 4 webpages. Therefore, the last test was characterized by a one-to-many relationship.

### 4.2 Digital Workflow

The key to solving the digital workflow effectively was the appropriate organization of the digital elements. Thus, users had to make sure that they could answer the questions on the first three tests based on the information contained in the PowerPoint file, the PDF file and the video file, respectively; and that they could answer the questions on the final test based on all 4 webpages provided to them in the context of that test. Since the task could be carried out by considering the digital elements in sequential order, the DW can be regarded as being of the 1st order. Naturally, the fact that in specific cases users could decide to go back to the previous digital elements for clarification does not mean that they are required to do so, and does not increase the order of the DW.

### 4.3 Sharing of the DW

**Classic:** one group of users received the DW based on the classical approach, through e-mail. The body of the email contained a textual description of the workflow, and the digital elements required for the workflow were attached to the e-mail. Finally, the webpages and tests were included as links at the end of the body of the email. The naming of the attachments and links were chosen to reflect the identity of the digital elements well.

**Online interface:** A second group of users received the DW on through the Moodle platform. Similar to the classic approach, the description of the workflow was text-based in this case as well. However, a simple form of digital guidance was also available to users in this case, given that each step within the description of the workflow included an embedded reference to the digital elements required for that step. As a result, users were able to perform the workflow step by step instead of first having to obtain a holistic overview of the workflow. In effect, the users' ability to scroll through the steps guaranteed a DG of type S in this case.

**MaxWhere:** Regardless of whether this group of users received the workflow on an online surface or through the classical approach, they could import the digital elements into MaxWhere, which then provided a spatial arrangement of EDEs in smartboards. In the case of the PowerPoint file, each slide was added to a separate smartboard. The tests were loaded in smartboards that were closest to the digital elements related to them. The MaxWhere Operating System also had built-in functionalities for S and R type DG, which could be made use of by the test subjects.

## 4.4 Experimental Procedure

In the classic case, test subjects received the workflow via e-mail or Facebook. The measurement of time to complete the workflow began when the e-mail or Facebook message was opened. In the case of the Moodle-based approach, the measurement of time began when the module for the workflow was opened. Finally, the same approach was used in the MaxWhere condition: the measurement of time began when users opened the e-mail containing the pack file for the workflow.

## 4.5 Details of Workflow Transmission

### 4.5.1 In the Classic Case, Test Subjects Received the Following e-mail

-----  
Dear Students,

Please take a look at the material listed under point A), and fill out the tests under point B) based on the material.

A. Materials on Google Drive and other webpages:

a. Click here:

<https://drive.google.com/open?id=0By19Pc3VT68aOUZ2bGtKMGNSRzQ>

1. Diasor.pptx
2. PDF-dokumentum.pdf
3. Video.mp4

b. Webpages:

- <https://drive.google.com/open?id=0By19Pc3VT68aNHRFY2Q2dUkzLU0>
2. <https://drive.google.com/open?id=0By19Pc3VT68abEIyWjJDblVytW8>
  3. <https://drive.google.com/open?id=0By19Pc3VT68aY21yWU0zc0FIc1U>
  4. <https://drive.google.com/open?id=0By19Pc3VT68aLWRLUFBCZDI2dFE>

B. Test forms:

- [https://docs.google.com/forms/d/e/1FAIpQLSdd8tF1R9pwmmwc-GqNrQvirnog8IgvTJmBbbrq90tBGbu8uw/viewform?usp=sf\\_link](https://docs.google.com/forms/d/e/1FAIpQLSdd8tF1R9pwmmwc-GqNrQvirnog8IgvTJmBbbrq90tBGbu8uw/viewform?usp=sf_link)
- [https://docs.google.com/forms/d/e/1FAIpQLScNGnvtAEard6yfdpXGMw2lj6cG MoawZJ6kCvIriXUgseQG5A/viewform?usp=sf\\_link](https://docs.google.com/forms/d/e/1FAIpQLScNGnvtAEard6yfdpXGMw2lj6cG MoawZJ6kCvIriXUgseQG5A/viewform?usp=sf_link)
- [https://docs.google.com/forms/d/e/1FAIpQLSdmeMFNDEFRTLEdfK5PTIy7uwZbQTwmKKddiYn9\\_q7\\_9X\\_CQg/viewform?usp=sf\\_link](https://docs.google.com/forms/d/e/1FAIpQLSdmeMFNDEFRTLEdfK5PTIy7uwZbQTwmKKddiYn9_q7_9X_CQg/viewform?usp=sf_link)
- [https://docs.google.com/forms/d/e/1FAIpQLScEflnfw8bfla0Tw3gpY-kJATTOo1TvqVXLK5ng7rY0NWYGcg/viewform?usp=sf\\_l](https://docs.google.com/forms/d/e/1FAIpQLScEflnfw8bfla0Tw3gpY-kJATTOo1TvqVXLK5ng7rY0NWYGcg/viewform?usp=sf_l)

Sincerely, ...

-----

It is clear based on the above that the relationships between digital elements are not at all transparent. We used two different ways to add the digital content to the e-mail. In the first case we attached all files to the e-mail. In second case we put the link of the content located on the Google drive.

#### **4.5.2 In the Case of the Online Interface, Test Subjects had to Open the Following Page**

-----

Dear Students,  
Diasor

Please click on the "Diasor" link above, take a look at the slides and then answer the test questions that can be accessed through the following link:

[https://docs.google.com/forms/d/e/1FAIpQLSdd8tF1R9pwmmwc-GqNrQvirnog8IgvTJmBbbrq90tBGbu8uw/viewform?usp=sf\\_link](https://docs.google.com/forms/d/e/1FAIpQLSdd8tF1R9pwmmwc-GqNrQvirnog8IgvTJmBbbrq90tBGbu8uw/viewform?usp=sf_link)

#### PDF documentum

Please click on the "PDF-dokumentum" link above, take a look at the pdf file and then answer the test questions that can be accessed through the following link:

[https://docs.google.com/forms/d/e/1FAIpQLScNGnvtAEard6yfdpXGMw2lj6cG MoawZJ6kCvIriXUgseQG5A/viewform?usp=sf\\_link](https://docs.google.com/forms/d/e/1FAIpQLScNGnvtAEard6yfdpXGMw2lj6cG MoawZJ6kCvIriXUgseQG5A/viewform?usp=sf_link)

#### Video

Please click on the "Video" link above, watch the video and then answer the test questions that can be accessed through the following link:

[https://docs.google.com/forms/d/e/1FAIpQLSdmeMFNDEFRTLEdfK5PTIy7uwZbQTwmKKddiYn9\\_q7\\_9X\\_CQg/viewform?usp=sf\\_link](https://docs.google.com/forms/d/e/1FAIpQLSdmeMFNDEFRTLEdfK5PTIy7uwZbQTwmKKddiYn9_q7_9X_CQg/viewform?usp=sf_link)

Please take a look at the following webpages:

<https://drive.google.com/open?id=0By19Pc3VT68aNHRFY2Q2dUkzLU0>

2. <https://drive.google.com/open?id=0By19Pc3VT68abEIyWjJDbIVyTW8>

3. <https://drive.google.com/open?id=0By19Pc3VT68aY21yWU0zc0Fic1U>

4. <https://drive.google.com/open?id=0By19Pc3VT68aLWRLUFBCZDI2dFE>

Afterwards, please answer the test questions that can be accessed through the following link:

[https://docs.google.com/forms/d/e/1FAIpQLScEflnfw8bfla0Tw3gpY-kJATTOo1TvqVXLK5ng7rY0NWyGcg/viewform?usp=sf\\_l](https://docs.google.com/forms/d/e/1FAIpQLScEflnfw8bfla0Tw3gpY-kJATTOo1TvqVXLK5ng7rY0NWyGcg/viewform?usp=sf_l)

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In this case, the order in which the sub-tasks were to be completed and the relevant digital elements to each sub-task were clearly delineated, therefore the workflow was supported by a DG of type S.

### 4.5.3 In the MaxWhere Case, Test Subjects Received the Following e-mail

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Dear Students,

Please open the following pack file using MaxWhere, and go through the space using the guiding functionality of MaxWhere. While doing so, please fill out the 4 tests included in the pack.

Sincerely,

-----

## 4.6 Details of the Digital Elements

The PowerPoint file contained 14 slides. Each slide contained an image of a cat or a dog (see Appendix 1).

The PDF file contained 3 pages, each showing images of either a cat or a dog (see Appendix 2).

The video (30sec) contained a sequence of 5 static images, with one of them showing a dog (see Appendix 3).

Finally, each of the 4 webpages contained an image of a single animal -- either a cat or a dog (see Appendix 4).

## 4.7 Results of the Experiment

The number of students tested using the classical e-mail with attached content and with linked content, online platform and MaxWhere-based approach were 115, 77, 97 and 90 respectively.

Figures 6, 7 and 8 show the results of the test. The horizontal axes represent the time required to complete the test. The vertical axes represent the percentage of users corresponding to the given number of minutes.

The average and standard deviation of the time required to complete the workflow in each of the cases were:

E-mail with attachment:	average: 6:42, standard deviation: 3:02
E-mail with Google Drive links:	average: 5:54, standard deviation: 1:39
Moodle	average: 6:42, standard deviation: 3:03
MaxWhere	average: 3:11, standard deviation: 0:46

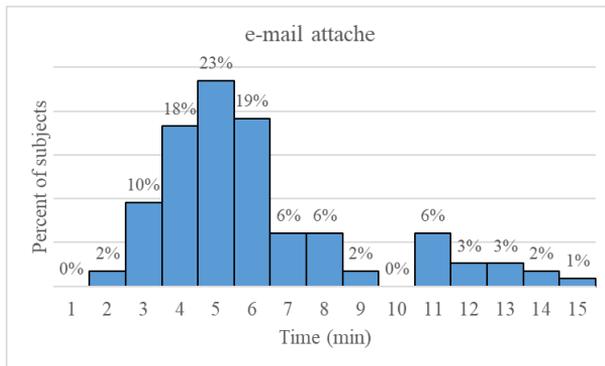


Figure 6

Test in which files were sent via e-mail attachment.

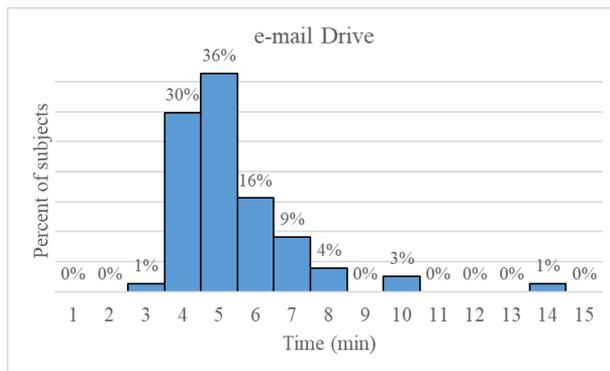


Figure 7

Test in which digital content was sent through Google Drive links via e-mail

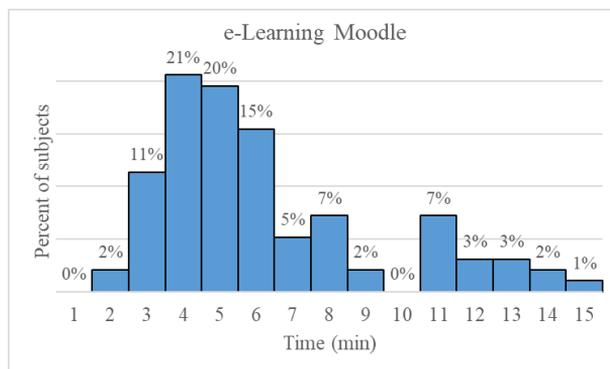


Figure 8

Test in which the digital workflow and digital content was shared through the Moodle e-learning framework

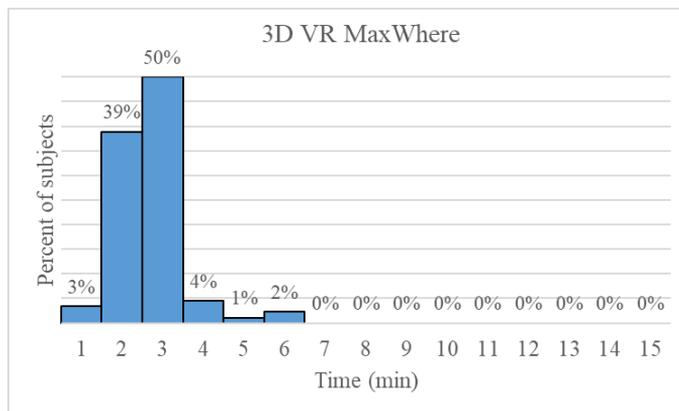


Figure 9

Test in which the digital workflow and digital content was shared through the MaxWhere 3D environment

## Conclusions

This paper investigated how workflows can be communicated and shared through linguistic descriptions, digital content and technological tools. We focused primarily on the content and digital tools of e-learning and VR learning. However, the results of the paper can be applied to collaborative workflows in general. The results of the paper show that users of the MaxWhere VR environment could complete digital workflows in considerably less time (i.e., 50% faster) than using the more traditional (e-mail based and content management system based) approaches. It is also remarkable that the standard deviations of completion times are considerably smaller in the case where the MaxWhere-based approach was used. Although the reasons behind this observation may need to be clarified through further investigations, it nevertheless points to the conclusion that the whole process of comprehension is rendered clearer than usual in 3D environments capable of representing 4<sup>th</sup> order digital workflows with automatic guiding, as pointed out in the paper.

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## References

- [1] P. Baranyi, A. Csapo, Gy. Sallai, “Cognitive Infocommunications (CogInfoCom)”, *Springer International Publishing* Switzerland, p. 191. (978-3-319-19607-7), 19607, <http://www.springer.com/us/book/9783319196077#aboutBook>

- [2] P. Baranyi, Á. Csapó, "Definition and synergies of cognitive infocommunications." *Acta Polytechnica Hungarica* 9.1 (2012): 67-83
- [3] I. Horvath, "The edu-coaching method in the service of efficient teaching of disruptive technologies," *Springer book chapter, Cognitive Infocommunications and computing, in the Series of Topics in Intelligent Engineering and informatics*. Accepted
- [4] M. Akçayır és G. Akçayır, „Advantages and challenges associated with augmented reality for education: A systematic review of the literature,” *Educational Research Review*, , pp. 1-11, 2017
- [5] L. J. Ausburn és F. B. Ausburn, „Technical perspectives on theory in screen-based virtual reality environments: Leading from the future in VHRD,” *Advances in Developing Human Resources*, pp. 371-390, 2014
- [6] E. Z. Borba és M. K. Zuffo, „Advertising Perception with Immersive Virtual Reality Devices,” in *IEEE Virtual Reality (VR)*, 2017
- [7] T. Griffin, J. Giberson, S. H. M. Lee, D. Guttentag, M. Kandaurova, K. Sergueeva és F. Dimanche, „Virtual Reality and Implications for Destination Marketing,” in *Tourism Travel and Research Association: Advancing Tourism Research Globally*, 2017
- [8] I. Horváth, „Innovative Engineering Education in the Cooperative VR Environment,” *Cognitive Infocommunications (CogInfoCom), 2016 7th IEEE International Conference*, pp. 359-364, 2016
- [9] S. Jang, J. M. Vitale, R. W. Jyung és J. B. Black, „Direct manipulation is better than passive viewing for learning anatomy in a three-dimensional virtual reality environment,” *Computers & Education*, pp. 150-165, 2017
- [10] H. Van Kerrebroeck, M. Brengman és K. Willems, „When Brands Come to Life: Experimental Research on the Vividness Effect of Virtual Reality in Transformational Marketing Communications,” *Virtual Reality*, pp. 177-191, 2017
- [11] X. Zhang, S. Jiang, P. Ordóñez de Pablos, M. D. Lytras és Y. Sun, „How virtual reality affects perceived learning effectiveness: a task–technology fit perspective,” *Behaviour & Information Technology*, pp. 1-9, 2017
- [12] J. Katona and A. Kovari, "A Brain–Computer Interface Project Applied in Computer Engineering," in *IEEE Transactions on Education*, Vol. 59, no. 4, pp. 319-326, Nov. 2016, doi: 10.1109/TE.2016.2558163
- [13] T. Ujbanyi, J. Katona, G. Sziladi and A. Kovari, "Eye-tracking analysis of

- computer networks exam question besides different skilled groups," *2016 7th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, Wroclaw, 2016, pp. 000277-000282., doi: 10.1109/CogInfoCom.2016.7804561
- [14] J. Katona, T. Ujbanyi, A. Kovari, "Investigation of the Correspondence between Problems Solving Based on Cognitive Psychology Tests and Programming Course Results," in *International Journal of Emerging Technologies in Learning*, Vol. 10, No. 3, pp. 62-65, 2015, doi: 10.3991/ijet.v10i3.4511
- [15] J. Katona, A. Kovari, "EEG-based Computer Control Interface for Brain-Machine Interaction," in *International Journal of Online Engineering*, Vol. 11, No. 6, pp. 43-48, 2015., doi: 10.3991/ijoe.v11i6.5119
- [16] J. Katona, T. Ujbanyi, G. Sziladi, A. Kovari, "Speed control of Festo Robotino mobile robot using NeuroSky MindWave EEG headset based Brain-Computer Interface," *2016 7th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, Wroclaw, 2016, pp. 000251-000257, doi: 10.1109/CogInfoCom.2016.7804557
- [17] J. Katona, D. Peter, T. Ujbanyi and A. Kovari, "Control of incoming calls by a windows phone based brain computer interface," *2014 IEEE 15th International Symposium on Computational Intelligence and Informatics (CINTI)*, Budapest, 2014, pp. 121-125, doi: 10.1109/CINTI.2014.7028661
- [18] G. Sziládi, T. Ujbányi, J. Katona, "Cost-effective hand gesture computer control interface," *2016 7th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, Wroclaw, 2016, pp. 000239-000243, doi: 10.1109/CogInfoCom.2016.7804555
- [19] J. Katona, "Examination and comparison of the EEG based Attention Test with CPT and T.O.V.A.," *2014 IEEE 15th International Symposium on Computational Intelligence and Informatics (CINTI)*, Budapest, 2014, pp. 117-120, doi: 10.1109/CINTI.2014.7028659
- [20] J. Katona, " Evaluation of The Neurosky MindFlex EEG Headset Brain Waves Data," *2014 IEEE 12th International Symposium on Applied Machine Intelligence and Informatics (SAMI)* Herl'any, Slovakia, 2014, pp. 91-94, doi: 10.1109/SAMI.2014.6822382
- [21] I. Horváth, "The IT device demand of the edu-coaching method in the education of engineering," *8th IEEE Conference on Cognitive Infocommunications (CogInfoCom 2017)* pp. 000379-000384
- [22] I. Horváth, "Innovative engineering training, *Australian Journal of Intelligent*

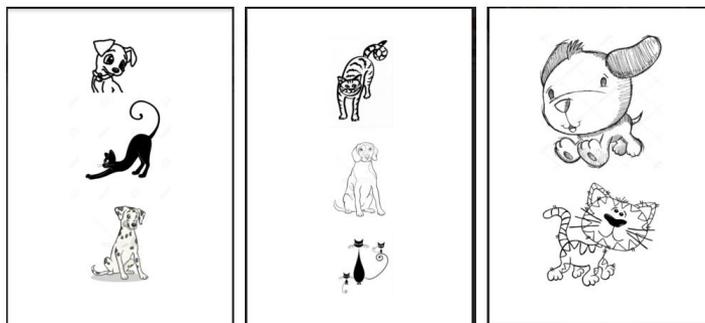
*Information Processing System*, Vol. 14, No. 4

- [23] I. Horváth, “Disruptive technologies in higher education,” *7<sup>th</sup> IEEE Conference on Cognitive Infocommunications (CogInfoCom 2016)* 16-18 October, 10.1109/CogInfoCom.2016.7804574
- [24] I. Horváth, “Digital Life,” *IEEE Conference on Cognitive Infocommunications (CogInfoCom 2016)* 16-18 October, 10.1109/CogInfoCom.2016.7804575
- [25] I. Horváth, “Innovative engineering education in the cooperative VR environment,” (*CogInfoCom 2016*), 16-18 October, Wroclaw, Poland, pp. 000359-000364, doi: 10.1109/CogInfoCom.2016.7804576

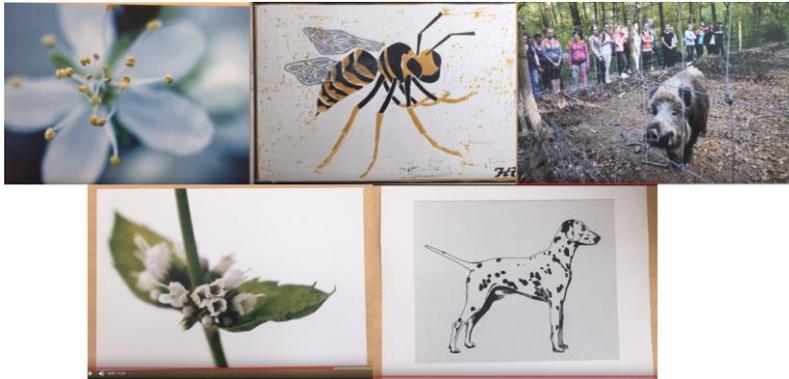
## Appendix



Appendix 1. Slides



Appendix 2. Pages of the PDF file



Appendix 3. Content on the Video



Appendix 4. Webpages