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Distance Learning: Should We Go Interactive At Any Cost?*

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The need for successful self-directed distance learning is not a new construct in education. However, the circumstances surrounding the emergence of the COVID-19 pandemic have emphasized the weaknesses of distance learning. The transition of students to distance learning has become inevitable. In current times, educators' task is to ensure the same quality of distance learning as in-person learning. The present paper contributes to our understanding of this task by examining good practice recommendations in instructional design. The experiment's focus is the effectiveness of interactive 3D learning tools in engineering studies depending on the level of study, i.e., prior knowledge of the students. Two separate experiments were conducted with 138 first-year and final-year university students studying the same material in three different instructional designs: interactive animation, continuous video and images. All three groups received textual information through identical narration. The results showed statistical significance among the lower prior knowledge students regarding knowledge transfer issues, while there was no statistically significant difference among the respondents with higher prior knowledge. These results suggest that substantial financial resources and time can be saved in preparing materials for various degrees in higher education.

Keywords: distance education; instructional design; technology-enhanced learning; *prior knowledge*

1. Introduction

Today's students are so-called digital natives who started using technological gadgets before they could walk. Their brains have grown accustomed to speed, hypertext, interactivity, and shared attention, which led to cognitive changes reflected in their way of learning [1]. Not only do they search for information and solve problems online, but they also manipulate digital content in online exercises, simulations, games and virtual worlds. They are not mere observers but active participants who control learning materials and manage their own time and pace of learning, achieving self-agency and autonomy, solving problems, and avoiding distractions [2]. Therefore, instructional designs should continually develop new digital products and experiences which enhance the interaction between a user and online learning tools, providing more opportunities for students to learn actively and develop creative competence [3].

However, instructional design is aimed at a wider group of people, people of all ages, who might not be as adept at technology as younger generations. In such cases, technology might hinder learning. To avoid this, actions performed in learning tools should be logical, i.e., intuitive. When an instructional design is intuitive and aligned with the educator's instructions, it is more likely to contribute to active learning [4, 5]. Technology-assisted learning must be active and more effective than conventional learning because it does not allow direct contact with the lecturer, further explaining the issue with his comments [6].

To justify the additional time and costs invested in developing sophisticated learning management systems, the confirmation of their effectiveness must be explicit and concrete. Experiments with actual learning tools are of particular importance [7–12]. In their work, Zepke and Leach (2010) argue that investing educators' time and institutional resources will have positive outcomes, as technology-assisted learning encourages students' motivation for active learning, which leads to long-term knowledge. In addition, Nelson, Laird and Kuh (2005) concluded that there is a positive correlation between technology-based learning and active learning because of collaboration among students and between students and teachers, even in remote locations. Thus, institutional support should be provided to develop new learning methods that will be active, collaborative, and foster learning.

Despite a large amount of research in this field, more research is needed to show what methods have the most effect. While some authors claim that one of the most significant advantages of e-learning is that students can control the intensity of learning [13], for others, the availability of lessons is essential for learning [14]. Such divergences indicate that it is not enough only to provide students with information. It is also necessary to create a learning environment that engages and motivates students to examine the material and actively participate in the learning process even outside the classroom.

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Therefore, to enable easier acquisition of knowledge, educators should search for new ways to teach with modern technology support.

As part of a 2-year-long research covering different generations of students (first and final year), this paper seeks to explore the effectiveness of interactive learning tools in engineering studies depending on prior knowledge of the students. The article starts by laying out the theoretical foundations of previous findings of Cognitive Load Theory (CLT) and other relevant conclusions regarding the learning process and efficient instructional design. Secondly, the methods and experiments are presented. The final sections show the results and discuss findings based on which we offer practical implications for further development of learning tools.

2. Learning Process

It is necessary to understand and master the learning process to provide learning tools that will be useful to students. Kirschner, Ayres and Chandler (2011) write about the importance of understanding the cognitive system, i.e., its capacity during the learning process. According to Kirschner, the architecture of the cognitive system, the learning environment, as well as the interactions between the two, must be clear, adaptive and balanced. Cognitive Load Theory (CLT) is based on existing knowledge about the structure of the human cognitive system and complex cognitive processes in which cognitive load control is crucial for effective learning. Cognitive processes involve two additional elements: effective unlimited long-term memory and working memory (WM), which is limited in capacity and duration [15] and is composed of partially independent processors connected to our senses [16].

According to Mayer and Moreno (2003), CLT can be applied to all types of learning: books, the Internet or e-learning through various applications, offers three theoretical assumptions about how a person learns from words and images: the assumption of dual channels, the assumption of limited cognitive capacity, and the assumption of active processing.

In theory, effective long-term memory is associated with the mental schemata by which it functions. Namely, long-term memory uses a schema to store different elements of various information by organizing them into a single component with a specific function [18], allowing students to expand further the ability to process information. A schema can be seen as a stand-alone element that is retrieved from long-term memory to working memory. Despite its complexity, a schema reduces the working memory load because it is perceived as a single element [19]. The term working memory (WM) refers to the short-term memory responsible for managing the information necessary to perform complex cognitive tasks [20]. Working memory, in which cognition occurs, can process a small number of two or three new elements in interaction [21].

As WM is of limited capacity, the closer it is to its maximum, the weaker the task performance [22]. WM load or learning process is limited by cognitive load. Cognitive load is not one element but consists of three different cognitive loads: extraneous, intrinsic and germane. They add up to make a total cognitive load [23]. If the extraneous load is lower, the intrinsic load can be higher while the full cognitive load remains within the optimal range.

Extraneous cognitive load depends on the way the information is presented. If a lesson is presented optimally in terms of format, instructional and information design principles, cognitive processes, the extraneous load will be reduced. In instructional design, we want to minimise extraneous load to save entire cognitive resources [24]. Extraneous cognitive load is caused by the inadequate presentation of material requiring students to perform non-learning activities [16]. It involves the actions that need to be done to the learning tool and do not contribute to learning but reduce the WM capacity available for learning [9].

Intrinsic cognitive load depends on the complexity of the elements that need to be processed simultaneously in the learning process. The greater the number of elements and the complexity of their interconnections, the greater is the intrinsic load. In other words, the lesson's complexity, concerning the students' previous knowledge, determines the intrinsic load. If the student's prior knowledge is higher, the intrinsic load will be lower [16, 23, 25]. Intrinsic cognitive load cannot be reduced by a design of the learning tool [24].

Lastly, germane cognitive load is linked to the creation of schemata that are responsible for long-term memory. The creation of schemata depends on how engaged in the learning activity a student is [24]. Germane load increases the overall cognitive load but also supports the creation of schemata [16] because it arises precisely in the activities required to construct and automate cognitive schemata in long-term memory [9]. Schemata are in charge of the long-term learning process and can be used repeatedly for different types of tasks, thus enabling the transfer of knowledge.

The instructional design should use germane cognitive load to accelerate the creation of mental schemata [16], which allows students to expand further their ability to process information. Corbalan, Kester and J. G. van Merriënboer (2009) state that giving the student control over the learning tool increases germane learning process. Pinćjer, Nedeljković, Dimovski and Adamović (2016) concluded that students with control over learning tools had a better experience than passive video observers [27]. Intrinsic cognitive load adapted to students' previous knowledge allows for germane cognitive load to be increased to its maximum [28]. Consequently, students' prior knowledge plays a significant role in CLT research [29].

The learning process's goal is to acquire necessary complex cognitive skills and knowledge that students can further apply to new situations and fields. Therefore, it is not just about acquiring knowledge, but it is also about transferring knowledge to new problems – knowledge transfer. Knowledge transfer is an indicator of mastering a specific material. However, acquiring the necessary complex cognitive skills to be applied in new situations and new domains is very demanding for students [30].

However, not all researchers came to the same conclusions. Some even concluded that CLT is wrong, i.e. that it gives opposite results than the expected [14]. Similarly, Höffler and Leutner (2007) analysed the advantages of using animation compared to a static image. They found that many papers dealing with this topic had differing, inconsistent, and often contradictory results. Using a meta-analysis of several relevant scientific papers, they concluded that very realistic animations (videos or computer animations) could compensate for the shortcomings of seductive elements that are often the negative consequences of animation. When creating the learning tool used in this experiment, we implemented most of Hoffler and Leutner's positive recommendations.

Another feature crucial for successful active learning is interactivity. Nevertheless, interactivity should not increase the extraneous cognitive load. When used in moderation, it can be beneficial and can enhance learning [31]. Tversky points out that interaction can be crucial in reversing animation's harmful effects (too much information) because students can choose to watch only the parts of the animation they need without reviewing the details they already understand. Similarly, according to CLT, while specific actions that do not contribute directly to learning may be detrimental to the initial learning process, they may still lead to improved long-term memory. The so-called desirable difficulties can contribute to superior long-term memory [32].

3. Methodology

The main CLT guidelines were considered to make learning tools as efficient as possible. Namely, the modality principle was applied, which states that the lesson's text should be presented in a spoken format when combined with images or animation [33]. In this way, the mental load is divided between different working memory subsystems – auditory and visual. Learning through two sensory modalities reduces the cognitive load caused by instructional design [14, 17].

The lesson that the students did in the experiment was presented by applying new technologies and creating virtual spaces (Fig. 1), thus enabling the creation of an environment in which the user of the online course is immersed in computer-generated reality [34]. The lesson is part of a virtual laboratory, created within the more extensive Learning Management System [27]. In the virtual space, the student is isolated, which allows for maximum concentration on a particular subject. 3D visualisation was chosen to present the lesson since immersive experience in 3D visualisation reduces interference and increases the focus on the study [35].

The lesson was also designed in such a way to enable long-term retention. The relevant literature proposes increasing processing depth, or the so-called Type II processing, which involves further, more in-depth analysis of the stimulus and leads to a more durable trace [36]. Schweppe and Rummer (2016) also suggest introducing specific difficulties, which will prevent students from merely skimming material superficially. They argue that a written text is a desirable difficulty that reduces the benefits that multimedia learning brings. In its experimental part, the present paper explores desirable difficulties that will enable the full potential of multimedia presentations.

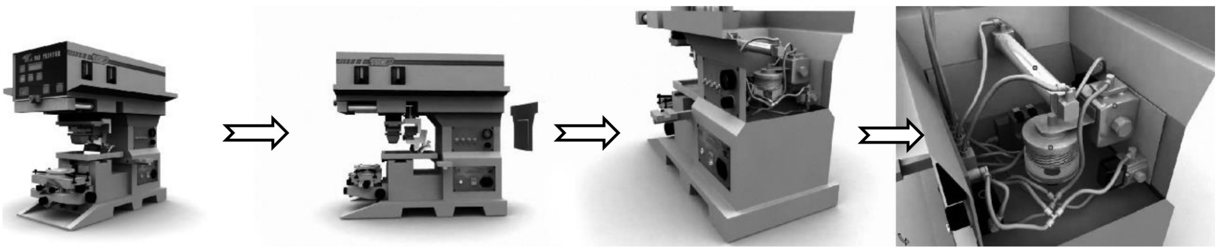

Fig. 1. Animation sequences of the interactive learning tool show how participants could rotate the virtual pad printing machine and see inside its components in virtual 3D space.

The instructional design enabled the students in the experiment to control the lesson, enhancing germane learning process [26]. Just watching recorded video material with its monotonous linearity can overwhelm the viewer with unnecessary information. A well-designed application will enable each student to explore the information which they find the most desirable at the time that is most convenient for them. This kind of interactivity is recommended to overcome the disadvantages of animation and emphasise its advantages [31].

Another variable studied in this experiment is prior knowledge. The experiment was conducted with two separate groups of students with different levels of prior knowledge, which is crucial for information selection and perceptual processing [24]. According to theory, students with more prior knowledge have less intrinsic load and can thus learn more. On the other hand, the intrinsic load adjusted to the learners' prior knowledge allows for the maximum germane load [16].

3.1 Participants and Context

Participants (n = 138) were first-year and final-year students of the Faculty of Technical Sciences. The number of first-year students was 56, while the number of final-year students who participated in the experiment was 82. The difference in the year of study was intentional as we wanted to have the broadest possible difference between the two groups in terms of the level of prior knowledge in the field of technical sciences. The students' lesson in the experiment was new to both groups, and both groups had enough prior knowledge to master it.

The experiment was first conducted with the final-year students (n = 82). They independently used a learning tool to learn about a pad printing machine's functioning, which they had not learned about before. The students were randomly divided into three groups to which the material was presented in different forms. After completing the lesson and answering the lesson's questions, students fill out the questionnaire to evaluate the presented material.

The same experiment was done with the first-year students. A total of 56 students attending the first year of study participated in this experiment. As this was a group of students who were at the end of the first year, it was assumed they had sufficient prior knowledge of basic concepts related to printing processes and graphic engineering to be able to understand the lesson. Students were also randomly divided into three groups to which the same content was presented in three different ways, as given below.

3.2 Stimuli

The multimedia instructions (Fig. 2) were part of the LMS developed at the Faculty of Technical Sciences, and various papers were published describing the development process [27, 37, 38]. Instructions were prepared in three different versions.

Version 1 (V1): Interactive animation + audio: This stimulus consisted of interactive animation accompanied by adequate audio content that describes the printing processes presented in the animation. The animation is interactive, so students had to choose the system elements they were interested in by clicking on them. The click was a signal for the system to launch an action together with the accompanying spoken text linked to that segment.

Version 2 (V2): Video + audio: This stimulus consisted of a video with an accompanying audio explanation. Students had the option to replay the

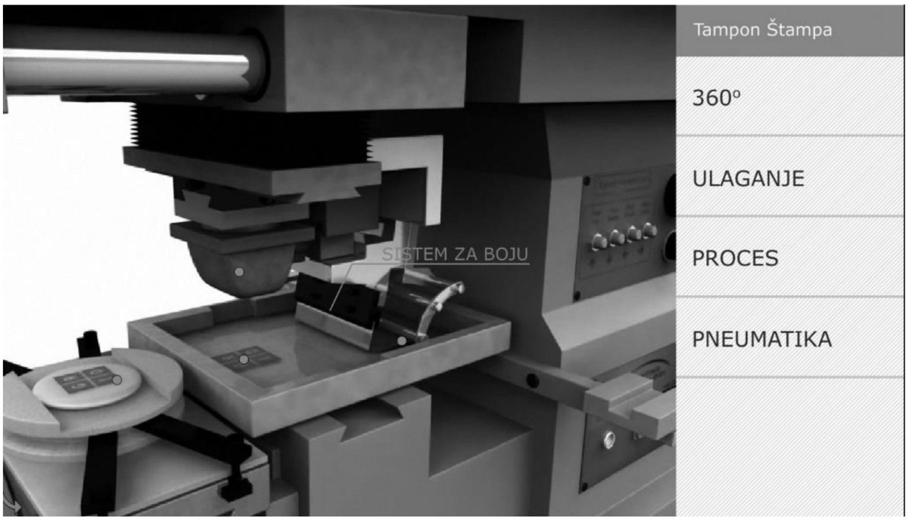

Fig. 2. Screenshot of a learning tool. All critical elements of the learning tool are interactive and marked with circles.

video but did not have the option to select individual video segments, i.e., had less possibility to interact.

Version 3 (V3): Images + audio: In the third stimulus, the material was presented in the form of 25 images that alternate and are accompanied by audio.

The same narrative content was used in all three stimuli. The total duration of the experiment was about 20 minutes. Each student watched the lesson in the format of their group on their computer, using headphones.

3.3 Procedure

The experiment was divided into three phases. Before listening to the lesson, students were given a pretest consisting of five questions related to the printing process to check students' prior knowledge on the topic. After the pretest, students had 20 minutes to listen to the lesson using the learning tool, and they could do it more than once. Next, the students were given a posttest consisting of eleven questions divided into three groups or subtests: recall, visual memory and knowledge transfer test [8].

After the posttest, students were asked to subjectively assess the quality of the presented content by filling out a questionnaire on the quality of the presented information and interface, i.e., the learning tool. The questions, shown in Table 1. were adapted from the IBM Computer System Questionnaire. Respondents were asked to evaluate the claims related to the information and the interface. A 7-point Likert scale was used.

Research questions (RQ) based on the principles of cognitive load theory are as follows:

RQ1: How do version 1 of the lesson affect the recall, visual memory, and knowledge transfer test results?

RQ2: How effective is version 2 of the lesson, compared to version 3, due to the process's dynamic visualisation?

RQ3: What is the impact of prior knowledge on student questionnaire responses?

4. Results

4.1 High Pre-Knowledge Students Test

The first presented results refer to the experiment conducted with final-year students. Table 2 shows the results for all three versions of the lesson as well as the pretest, recall, visual memory and knowledge transfer test results.

One-factor analysis of variance was used to examine whether there was a statistically significant difference between the three groups of respondents regarding the pretest, recall test, visual memory test and knowledge transfer test. Statistical significance is above the critical value of *0.05*, so we concluded that there is no statistically significant difference between the three different groups.

The pretest shows that all respondents form one homogeneous structure when it comes to prior knowledge and that the groups, although random, were well divided. In addition to the overall results, the analysed results fall into three categories: recall test, visual memory test and knowledge transfer

Table 1. The questionnaire the students completed after the lesson

Information quality	1. The amount of information presented is adequate. 2. The content of the learning tool is easy to understand. 3. The presentation and selection of information enable easy memorising. 4. Sequence and organisation of information is adequate.
Interface quality	5. The interface of the learning tool is pleasant. 6. The interface of the learning tool is easy to use. 7. The interface of the learning tool enables efficient memorizing. 8. The interface of the learning tool makes learning easier. 9. Generally, I am satisfied with the learning tool.

Table 2. Integrated results for Experiment 1

Group		**Pretest**	**Recall Test**	**Visual test**	**Knowledge transfer test**
V1	M	**4.115**	**7.115**	**3.923**	**3.192**
	SD	1.583	1.904	0.271	1.442
V2	M	**4.285**	**6.321**	**3.928**	**3.035**
	SD	1.560	2.126	0.377	1.400
V3	M	**3.964**	**6.607**	**3.928**	**2.928**
	SD	1.731	1.523	0.377	1.152
Total	M	**4.122**	**6.670**	**3.926**	**3.048**
	SD	1.613	1.872	0.343	1.323
F		0.273	1.243	0.002	0.265
p		0.762	0.294	0.998	0.768

test. By analysing the parameters from Table 1, it can be concluded that when it comes to knowledge test results, the first group (V1) scored best with a mean value of 7.1154 (SD: 1.9) points, and is closely followed by the third group (V3) with a mean value of 6.6071 (SD: 1.52362) points. However, the third group showed a lower standard deviation, which tells us that more students were closer to the average value than in the interactive presentation group (V1). The worst group was the video group (V2), with a mean score of 6.3214 and with the highest standard deviation (SD: 2.12661). The visual memory test shows uniform results for all three lesson formats, which can be easily seen in Graph 1. In the transfer test, interactive presentation (M: 3.1923 SD: 1.4427) has a slight advantage over video (M: 3.0357 SD: 1.4) and images (M: 2.9286 SD: 1, 1524).

Such results are expected from this group of respondents. If we analyse their common characteristic, we can conclude that all the respondents from this group had a high level of prior knowledge in engineering and that the benefits of interactive animation were not significant.

4.2 Low Pre-Knowledge Students Test

Fifty-six first-year students participated in the low pre-knowledge students' test. We assumed that the first-year students have less prior knowledge than the final-year students, which can be confirmed by observing the test results for the first (M: 0.946 SD: 0.862) and final year of study (M: 4.1220 SD: 1.6131). It is useless to compare two groups that are so statistically different directly, but it is interesting to look at the test results within these two groups. In this second test, the subjects were divided into three groups with the same lesson formats as in the high pre-knowledge test. Table 3 shows the results for all three versions of the lesson as well as the results of pretest, recall, visual memory and knowledge transfer test.

Based on the data in Table 3, all three groups of respondents have similar prior knowledge regarding the lesson and can, therefore, be considered a homogeneous sample.

When mean values from Table 3 are analysed, it can be seen that the result for the knowledge transfer test falls below the critical value of 0.05 (F = 3.46, p = 0.039). The respondents who watched the V1 version of the lesson had the most points (M = 1.66 SD: 2.37). They are followed by the group that watched the V3 version (M = 0.76 SD: 1.82), while the respondents who studied the V2 version of the lesson had the least points (M = 0.23 SD: 0.44). Interestingly, the V2 group, which observed continuous video, had the worst results. There is no statistically significant difference in achievement between the three groups of respondents regarding questions in recall and visual memory test, with the V1 group standing out slightly.

4.3 Questionnaire

After completing the lessons, first and graduate year students filled out questionnaires about the quality of the information presented and the interface's quality. The t-test for large independent samples was used to examine whether there was a statistically significant difference between the two groups of respondents regarding the quality assessment. Statistical significance below the critical value of 0.05 was noted on almost all the questions except Q5. Respondents of the final year rated the lesson better in all questions for which there is a statistically significant difference (Fig. 3). Fig. 3. shows mean values and standard deviation of student's scores.

5. Discussion

The results of both experiments conducted in this study show that students' manipulation of digital content has a positive effect on learning results. Previous research [27] showed that the quality of learning is better assessed by students if they have a higher level of control over the lesson. By analysing the test results and positive student responses to the questionnaire, it can be concluded that the students

Table 3. Integrated results for Experiment 2

Group		**Pretest**	**Recall Test**	**Visual test**	**Knowledge transfer test**
V1	**M**	**0.833**	**3.500**	**1.556**	**1.667**
	SD	0.857	1.249	1.423	2.376
V2	**M**	**1.238**	**3.286**	**1.143**	**0.238**
	SD	0.831	1.454	1.276	0.436
V3	**M**	**0.706**	**2.882**	**0.941**	**0.765**
	SD	0.849	1.536	1.197	1.821
Total	**M**	**0.946**	**3.232**	**1.214**	**0.857**
	SD	0.862	1.414	1.303	1.773
F		2.101	0.853	1.023	3.465
p		0.132	0.432	0.367	***0.039***

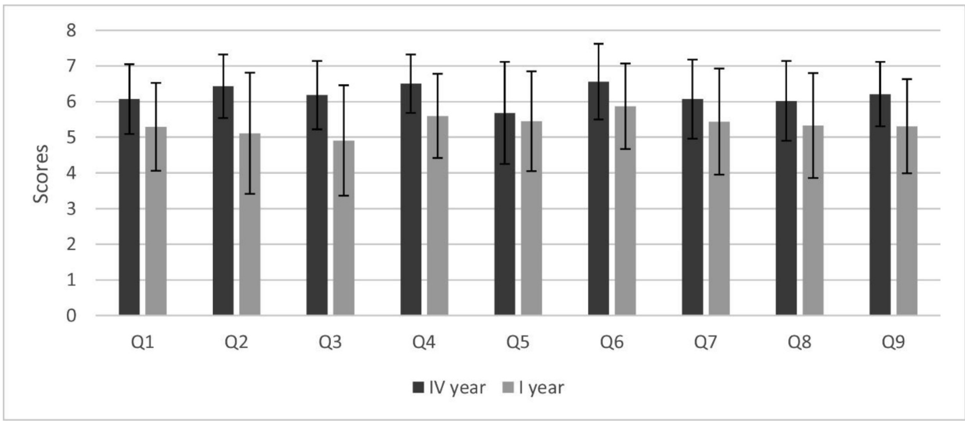

Fig. 3. Mean and standard deviation values of the scores given by the first and final-year students regarding the quality of the presented information and the quality of the interface.

who mastered the lesson better were more satisfied with the learning tool.

Observing the results of Low and High pre-knowledge tests, we can see that prior knowledge significantly impacts how students master a new lesson. Therefore, whether instructional design features are positive or negative, and whether they enhance or hinder learning, depends on prior knowledge.

5.1 High Pre-Knowledge Students

Students with higher prior knowledge were less responsive to different instructional designs, which is reflected in the absence of any data with statistical significance. Such results are consistent with those of [39]. The adverse effects of watching a continuous video in the V2 group are also mitigated. Still, they do occur on recall test questions, where better results were achieved by students who listened to the lesson with images. Although a higher extraneous cognitive load could be expected in the lesson with images because the students had to supplement the movements between the pictures mentally, this was not a problem because they had less intrinsic cognitive load when following the lesson.

On the other hand, when watching a monotonous video, students superficially follow the lesson and thus later have difficulty remembering the material. Also, a video can contain a large amount of unnecessary information that increases the extraneous cognitive load. So, as working memory load increases, student performance weakens [22]. Finally, student satisfaction with the presentation of the lesson was high in both groups of students. However, high pre-knowledge students gave higher ratings than low pre-knowledge students.

5.2 Low Pre-Knowledge Students

Low pre-knowledge students test confirmed that students with lower prior knowledge are more susceptible to instructional design quality. So instructional design has a more significant impact on the learning outcomes of first-year students. The instructional design's positive features were confirmed with statistical significance in the experiment with students who had less prior knowledge. The V1 group again achieved the best results. However, the V2 group had better knowledge test results than the V3 group. There was a more significant cognitive load among students who learned the lesson through pictures because they found it difficult to mentally recreate the missing movements between static images since they lacked prior knowledge. The most considerable difference in the results with statistical significance ($F = 3.46$; $p = 0.0039$) occurred in knowledge transfer test questions. Knowledge transfer is associated with the germane cognitive load so that if knowledge transfer increases for a particular lesson, the design of that lesson had a positive effect on germane cognitive load. These results confirm the research results by Corbalan, Kester and J. G. van Merriënboer (2009), who found that if students can control the lesson, germane learning process is accelerated. It can be concluded that the element in the instructional design allowing students to interact with the interface by selecting and replaying a part of the lesson represents a desirable difficulty, which activates germane learning process by creating a more engaging experience. Without students' interaction and active manipulation of the lesson, their engagement is lower, and the lesson might not be completed, and material not retained. Desirable difficulties "remind" the student of what he should do and do not allow him to "wander off" in the process of completing and learning the lesson. These results confirmed Prensky's (2001) finding that continuous video is too monotonous for today's generations of students because they are used to respond to various stimuli continually.

The difference in results that occurs with different

Table 4. Recommendations for instructional design with respect to students' prior knowledge

Both groups	Allow students to manipulate content. Introduce desirable difficulties into lessons, requiring some student intervention. Divide the lesson into smaller units separately accessible.
Low prior knowledge students	If 3D animations are not available, provide interaction through hyperlinks. Pay more attention to instructional design. Use realistic visualization to reduce cognitive load.
High prior knowledge students	Reduce design complexity using traditional learning methods. Use still images instead of video. Avoid long linear video.

prior knowledge students can be theoretically explained by the fact that students with less prior knowledge have a higher intrinsic cognitive load. The lesson design itself plays a larger role because it directly affects the amount of extraneous cognitive load. The instructional design should reduce the workload of working memory by creating content that will not require students to create the missing images by themselves mentally, but the lesson itself should already contain them.

We would also like to underline that high prior knowledge students do not need impressive visualisations because they have built mental schemata that simplify their mental load and enable more accessible learning by building on the existing schema. On the other hand, low prior knowledge students have to create new schemata, so their working memory must be as unburdened as possible to make room for germane cognitive load, which should create new schemata when triggered by desirable difficulties.

Contrary to expectations, students who watched the video presentation (V2) in both groups had unexpectedly low results. The reason for this may be the combination of insufficient involvement in the lesson and the large amount of information that such a video presentation contains.

5.3 Questionnaire Survey

The difference between students with high and low prior knowledge is visible in answers regarding the quality of the information and the learning tool. Students who had more prior knowledge and mastered the lesson had much more praise for the learning tool than their younger counterparts. The only question they answered the same is question number 5, which reads – Evaluate the teaching unit's interface (p: 0, 357 t: 0,924), which is logical because the interface was the same. However, when it comes to the quality of information and how much it helped them in mastering the material, the final year students were more satisfied.

Results' analysis allows us to answer the research questions.

RQ1: The interactive version of the lesson (V1) gave the best results on both experiments' knowledge and knowledge transfer test. However, V1 lesson format does not give better results than V2 or V3 on the High pre-knowledge student's visual memory test.

RQ2: The experiment showed that even though V2 format includes dynamic visualisation of the process, it is not superior to V3. Nevertheless, it does give slightly better results for lessons intended for students with lower prior knowledge.

RQ3: The results show that prior knowledge affects students' level of satisfaction with the presentation as students with higher prior knowledge rate the learning tool better than students with less prior knowledge.

This experiment's results and review of theoretical assumptions indicate that extraneous cognitive load can be used as a germane cognitive load and initiate the storage of information in schemata through desirable difficulties. Learning material should be organized so that we can use germane cognitive load to define the beginning of the creation of a new schema.

After the discussion a list of recommendations can be proposed, facilitating the preparation of learning material following the student's prior knowledge. They are summarized in Table 4.

6. Conclusion

This study's findings are in line with other studies presented in the literature review in this paper and provide several practical implications for optimising instructional design during various kinds of emergencies when face-to-face lectures are not possible.

Firstly, CLT assumptions are supported by the current results, which show that the instructional design with animation, narration and a higher degree of interface control by students has an advantage over other analysed form of instruction designs. This advantage is reflected in the higher scores obtained in the posttest, especially on knowledge transfer issues.

This research also supports the idea that prior knowledge plays an essential role in instructional design. A direct application of this finding is that the lecture design complexity can be significantly reduced if it is intended for students with higher prior knowledge in a given field. Instead of complex photorealistic 3D interactive lessons, only images and text can be used without lowering knowledge acquisition quality. This is a significant saving both in financial terms and in the time required to prepare the lesson. In a crisis, these savings become even more critical.

The advantage of simple instructional design is reflected in its availability in remote locations, which have slow or limited Internet access due to emergency or low technological development. Lessons created as images and text take up much less memory and can be transported and downloaded faster. In addition, lessons can be learned on the simplest technological devices. If students are more satisfied with understanding the material, their assessment of the learning tool is better.

Furthermore, the findings that can be applied in instructional design are as follows: the best results were obtained by students who had the lesson divided into phases (confirming Mayer's segmentation principle) and the ability to listen only to the desired part (confirming signalling and multimedia principles). Such interaction can be achieved even with a low technology-based lesson (ordinary text and images) using hypertext. A lesson would be less linear with hypertext. Also, a lesson should be divided into smaller units, and students must be enabled to consciously and independently activate these units (desirable difficulties) to complete them. By activating the desired part of the lesson, students start creating mental schemata that ends when they exit that selected part of the lesson. In this way, during the transfer of knowledge, the student shifts the schema, which behaves as a whole, into the working memory, thus reducing the cognitive load during the demanding process of knowledge transfer. Desirable difficulties can help avoid superficial watching of the video and provide a pleasant feeling of interaction with the learning tool and speed up the creation of mental schemata.

Institutional support in the production of new learning tools is needed to cover the high costs of developing new learning materials. However, the unnecessary spending of funds on learning tools that will not fulfil the purpose is a problem nowadays when funds are redirected to crisis management. This experiment has shown that students with a higher level of prior knowledge do not need realistic visualisation to understand and retain new learning material. A good and worthwhile design will consider the level of prior knowledge and implement signalling and segmentation in the form of desirable difficulties. Desirable difficulties will enhance germane cognitive learning, i.e., schema acquisition. These desirable difficulties should be as simple as possible because otherwise, it can increase the extraneous cognitive load.

Except in emergencies, the research results are applicable in the blended learning environments, which is a combination of online and face-to-face learning [6]. In a blended classroom, traditional education is supplemented with online content, which helps students expand their theoretical knowledge. Recommendations from this paper are also suitable for other neoteric learning methods such as "flipped classroom" [13], in which theoretical parts of the learning material are accessed independently outside the classroom. We believe that the methods developed in the remote learning environments will most certainly play their role in the conventional teaching practices in the near future, either as a supplement to face-to-face learning or as separate tools designed to help students understand better the learning content.

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