Spaced Learning Solution in the e-Learning Environment

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Abstract: The objective of the transdisciplinary research is to find the most effective solutions for spaced learning in the e-learning environment and to create an information system for the implementation of spaced e-learning in the learning management system (LMS). The method is based on short breaks (spaces) between repetitions acquiring the learning content in the e-environment. During breaks, students disconnect from the learning by watching engaging alternative content. During the research, the first prototype of spaced e-learning solution was implemented in the LMS OpenEdX and brought into action with bachelor level students. Experience from the first prototype showed the effectiveness of the method and advantages of personalization of the content of spaces. Research showed the need to take personal interests into account for spaces' content personalization to motivate students to use the method in the learning process. In the light of the data obtained, an information system (IS) for the personalization of the method was developed for use in several kinds of LMS.

1 INTRODUCTION

The contemporary paradigm of education has demonstrated serious changes during the last decades. Increase of the importance of e-learning and blended learning takes place during COVID-19 crisis. These changes have caused serious technological developments, challenges for motivation, and improvements of cognitive solutions by new pedagogical approaches to e-learning. The creation of the "charisma" of learning management systems (LMS) has become one of the most pressing needs for e-learning designers, leading to the search for new learning methods in digitalized education. One of such methods is spaced e-learning, based on the use of repetition effect.

Spaced learning is a pedagogical approach based on the positive learning effect from spaced repeating the learning content in different forms several times - as text, video, multimedia, exercises, educational games, and others. The first research on the spacing effect was published by psychologist H. Ebbinghaus (Ebbinghaus, 1885). Delays between repetition in Ebbinghaus's research increased as follows: the first repetition was included after 1 hour, the second after 5 hours, the third after 1 day, the fourth after 3 days, and so on, the tenth repetition after eight months. Ebbinghaus found the spaced approach more effective than massive repetition of the learning content (Ebbinghaus, 1885). Many studies support these findings (Pashler, Rohrer, Cepeda, & Carpenter, 2007; Quinn, 2011; Carpenter, Cepeda, Rohrer, Kang, & Pashler, 2012; Kang, 2016). Typically, the spacing approach takes a long time for learning. Research showed a strong relationship between duration of spaces and knowledge retention time (Cepeda, Vul, Rohrer, Wixted, & Pashler, 2008). Suspending the spaced learning study time by shortening the duration of breaks becomes as essential challenge for spaced e-learning design. The latest research showed the effectiveness of short spaces (Kelley & Whatson, 2013). It is important that during spaces learners are offered with alternative engaging content allowing to disconnect from the study subject.

Implementation of the spaced learning e-learning practice has created new challenges for learning methods and the design of LMS.

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2 EFFECTIVENESS OF THE SPACED LEARNING

2.1 Neuroscience Considerations on the Spaced Learning

Neuroscience findings support the spaced learning methodology. Research shows interconnections between the acquisition of new information and the activation of several brain systems. Initially it was considered that the dopamine system is a transmitter for good feelings and euphoria, because the use of drugs causes an increase of the dopamine level in particular segments of the brain. In general, the dopamine system is a group of nerve cells, most of which are located deep in the midbrain. The neurotransmitter dopamine is sent across the brain. Following research shows that dopamine's presence in the brain cells is essential for the regulation of movement, attention, motivation and emotional responses (Roediger & Karpicke, 2006), including learning and memory (Poldrack, 2010). Dopamine secretions help to improve the function of the working memory, because the main part of the brain – the prefrontal cortex is associated with higher-ordered thinking. The dopamine level in the prefrontal cortex is extremely delicate and slight increases or decreases of the level comparing to the normal level may cause a significant impact on the memory (Roffman et al., 2016).

2.2 Cognitive Sciences on the Spaced Learning

The positive cognitive effect of spaced e-learning is supported by cognitive neuroscience findings. Repetition of the stimuli, separated by timed spaces without stimuli can initiate long-term potentiation and long-term memory encoding in the human brain (Kelley & Whatson, 2013). Long-term potentiation in neuroscience is defined as persistent strengthening of synapses, based on recent patterns of activity. These are patterns of synaptic activity that produce a long-lasting increase in signal transmission between two neurons. Long-term potentiation is widely considered as one of the major cellular mechanisms that underlie learning and memory (Cooke & Bliss, 2006). According to the Atkinson-Siffrin memory model (Atkinson & Shiffrin, 1968), at the beginning of the learning process information is processed by the sensory memory – something is perceived through senses, as sight, hearing, sensations. Then it is transferred to the short-term memory or forgotten, depending on how much attention this information is given. From the short-term memory, information is encoded to long-term memory or forgotten, if the encoding is not carried out. Continued rehearsal of information strengthens the memory trace and prevents from forgetting.

P. Smolen et.al. (Smolen, Zhang, & Byrne, 2016) summarizes traditional cognitive theories – encoding variability theory, study-phase retrieval theory, and deficient-processing theory in the context of spaced learning. Encoding variability theory interprets the effect of spacing so that a variety of information, stored with spaced presentations, results in a bigger variety of information retrieval routes, considering, that, as the lag between repetitions increases, the memorial representations approach obtains more independence (Bray, Robbins, & Witcher, 1976). Contextual-variability theory explains the spacing effect as a repeated representation in the different contexts additionally to the representations of the information item itself in the learner's memory. The effectiveness of the spacing effect is realized as the function of the number of contexts, available in the memory trace of spaced repetitions (Verkoeijen, 2005). Deficient processing theory predicts longer time intervals between learning sessions, deactivating of the item in the memory of the learner. Learners pay more attention to spaced repetitions of an item because the content item is not as active in memory (Smolen et al., 2016). In the consolidation theory, creative thinking and reflection on the previous information are essential. Consolidation theory is closely linked to the constructivist epistemological approach in the spaced face-to-face learning as well, as to the spaced e-learning methodology (Verkoeijen, 2005). Most of the theories support the viewpoint that effectiveness of the spaced learning is related to the duration of spaces between repeated content items. Several experiments support this consideration (Schimanke, Ribbers, Mertens, & Vornberger, 2016; Kerfoot et al., 2010; Cepeda et al., 2008). Experiments of Kelley and Whatson (Kelley & Whatson, 2013) showed that short-spaced learning with spaces of 10 to 20 minutes is optimal for forming long-term memory. This approach is the most appropriate for e-learning, so it is used in our study.

3 CONTENT OF REPETITIONS AND SPACES

C. Pappas (Pappas, 2016) emphasizes improvement of knowledge retention, the involvement of real-world applications in the learning process, and reduction of cognitive overload as the most significant advantages of the spaced e-learning pedagogical approach. The author proposes the following five tips for the design of the spaced e-learning courses: (1) the use of reminders or memory aids, (2) building knowledge on the previously learned, encouraging learners to active recall of knowledge, (4) integration of spaces "disconnecting" from the learning content into course design and (5) to find new ways of information delivery. Prasad and Omer (Prasad & Omer, 2019) found that branched scenarios, simulations, and game-based designs make learners willing and active participants in the learning experience. Branched scenarios include contexts in real-life situations, forcing intelligent decisions. Educational games serve for the activation of the competitive spirit of learners, motivating to active application of knowledge. Hanson and Brown (Hanson & Brown, 2020) tested flashcards as an effective application for spaced e-learning. "These strategies can be incorporated in microlearning modules and "pushed" to learners at regular intervals to promote spaced learning" (Prasad & Omer, 2019). Melamed (Malamed, 2019) emphasizes the importance of the diversification of the content delivery forms and design, as well as content generated by users.

Most often the spaced e-learning was implemented in foreign language learning (Seabrook, Brown, & Solity, 2005; Sobel, Cepeda, & Kapler, 2011) and medical studies (Shaw, Long, Chopra, & Kerfoot, 2011)., learning content delivery by e-mail was used for repetitions in most cases. Our research tested the applicability of the method in STEM and e-pedagogy course, where it is necessary to acquire a large amount of theory or instructions. The content of spaces was placed in the e-learning environment. A methodology and information system for spaced learning in the business course also has been designed.

4 THE FIRST PROTOTYPE OF SPACED E-LEARNING

The first prototype of spaced e-learning was implemented in the OpenEdX LMS, designed for the massive online open courses approach (MOOC). There are three essential questions to answer for successful implementation of the method:

1. What form of repetitions' content do students prefer?
2. Do students prefer mandatory or voluntary breaks?
3. What content of spaces do students prefer?

The content was delivered as text, graphics, video, simulations, and exercises with feedback.

The content of spaces is voluntary and designed as engaging material in different forms:

1. "Space" without offered content.
2. "Space" with a YouTube music video
3. "Space" with a YouTube video about attractive adventures and events
4. "Space" with a YouTube beautiful nature video
5. "Space" with an easy-to-understand additional course material video
6. "Space" with an easy-to-understand additional course material with interactivities
7. "Space" with an interactive educational game or interactive model
8. "Space" with a talking head on an easy-to-understand attractive topic
9. "Space" with an optional additional material on the subject of the course
10. "Space" with videos on topics identified in the student survey

The prototype was implemented in two blended learning master-level courses for Digital Humanities program students during the first and second semesters 2018/2019 and 2019.2020. The bachelor level background for most students was foreign language studies, STEM or social sciences. Spaced e-learning was realized in the MOOC type e-learning environment OpenEdX design of Natural Science modelling (14 and 20 students) and E-pedagogy (13 and 17 students) courses. The blended learning process included face-to-face classes for introduction to the topic and discussions, and acquirement of theory in LMS OpenEdX. During the second year of the research learning was heavily affected by the COVID-19 crisis and face-to-face classes replaced by the ZOOM webinars.

5 STUDENTS' OPINIONS

After the first study year, students were asked to evaluate spaced e-learning solution. Most of students - 73 % preferred voluntary spaces.

The diagram in Figure 2 shows that only 73% of the students take the choose to discontinue learning by the recommended built-in content of the spaces.

Spaces must "disconnect" learners from learning content for short time, but prevent them from distracting from the acquisition of the learning content. 64 % of the surveyed students admitted that

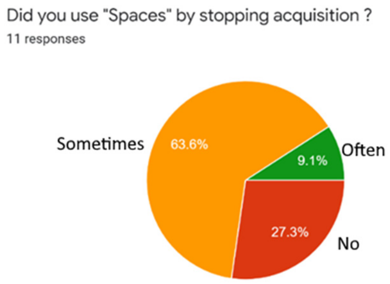

Figure 2: First action research cycle, students' answers about the use of spaces.

sometimes they stopped learning after watching content of space.

All second year students admitted that they would be engaged to watch personalized material, suitable to their interests.

The lecturer's experience showed the high importance of face-to-face interaction with students for the explanation of the advantages of the spaced learning method and encouraging them to use it. Metacognitive skills of students allow to increase effectiveness of the method. After successful finishing of the course, students expressed controversial opinions on the method – ranging from "It's good to have a space!" to a desire to learn the material without breaks. However, the vast majority rated the learning method positively.

The small number of students does not allow to consider the results of the survey as statistically significant, however, it helps to draw conclusions about the principles of using the method in a particular group. Individual discussions with students supports conclusions as well.

6 CONCEPTUAL DESIGN PERSONALIZED SPACED E-LEARNING LMS

6.1 Design of the Information System

The design of the personalized LMS is based on the experience and students'opinions from the first implementation of the prototype.

Figure 3 shows a flowchart of the information system for the implementation of personalized spaced e-Learning. Content of spaces is related to the interests of each learner.

The system includes

- A dataset of user profiles, described by metadata, characterizing personal interests of the learners.
- A dataset of the content of spaces, characterized by metadata.

Assessment of learners' interests is carried out by a poll at the beginning of the course and users' behavior data from the e-learning environment. Personal interest's metadata are added to the profile of each learner and stored in the database.

The content of the spaces is created by the educator and learners and uploaded to the database. Metadata, characterizing the content of every space, is added to the spaces' content database.

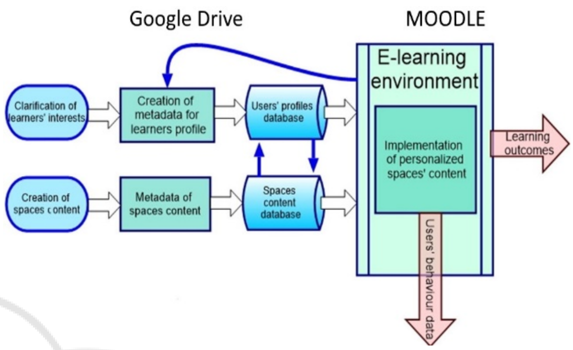

Figure 3: Flowchart of information system for implementation of personalized spaced e-Learning.

The information system provides the most appropriate choice of content of spaces during the learning process in the e-learning environment for each learner personally. The information system analyses user behavior data of every learner while browsing spaces, to improve the choice of the content for the space by personalization or spaced e-learning.

6.2 Linking Users' Interests with the Content of Spaces

It is essential that the spaced learning information system can be used in various LMS. Because of this, an application for the personalization of the content of spaces was designed using Google Drive tools. The following stages of personalization were implemented:

1. Assessment of the students' interests and uploading this data in the user profiles database,
2. Creation of engaging content of spaces such as YouTube video, Prezi presentation or other,
3. Adding metadata to the content of spaces and uploading this data to the of Spaces' content database,
4. Identification of the most relevant spaces' content to the interests of each student.
5. Creation of a database for implementation of personalized spaces' content in the LMS.

Google form is used for assessment of students' interests. Interests are clustered as follows:

1. Educational interests – information technologies, humanities, history, geography, social sciences, ecology, arts, research activities, engineering.
2. Professional interests: technologies, marketing, service, organization of events.
3. Entertainment: fiction, science fiction, traveling, participation in mass events, social networking, driving, and tuning, hunting, fish-catching, sports, computer gaming.

Each student rates the level of every interest on the levels one to five points (1- not interested, 5- very interested). The students are identified in accordance with ID number. At the beginning of the course, students are asked to create a five to ten minutes long engaging material – video, Prezi presentation, Google slides or other – corresponding to their individual interests. An attractive form of the design of the content is strongly recommended. In some cases, this material can be related to the topic of the course. Each students shares created material with others. Then each student fills out Google form, providing a link to it, describing the content and adding metadata. Metadata consists of the same keywords and rating levels as the characterization of the student's interests. The student's ID, evaluation of interests, links to engaging material, and keywords are uploaded to the Google spreadsheet for further processing and creation of the content personalization database.

The relevance of a particular material (identified by i) to the interests of each student is characterized by coefficient C_s

$$C_{si}=I_{s1}*K_{mi1}+I_{s2}*K_{mi2}+\ldots+I_{sn}*K_{min}$$

Where I_{s1} is a self-evaluation level of the first interest (1 to 5) by the student, K_{mi1} is the first keywords "rating" level (rated from 1 to 5) of the engaging material, identified with i. If each student created an engaging material, the maximal value of i corresponds to the number of students. If the method is used in other courses, groups, or the next year – the number of engaging materials increases, making the choice richer.

An example of the calculated coefficients C_{si} for materials created by 13 students for the student Jānis Bērziņš (virtual personality) is shown in Table 1. The coefficients are listed in descending order. The engaging YouTube video or Prezi presentations will be placed in the course as content of spaces for the student, starting from the second row.

For example, the course "Business Fundamentals" includes 8 spaces, and the student Jānis Bērziņš will watch the materials listed on rows 2 to 9.

Implementation of the spaces' content in the course is provided by the personalization function of LMS. In our research, it is designed in the Moodle e-learning environment.

Table 1: Example of the calculated coefficients C_{si} for materials created by 13 students for the student Jānis Bērziņš (virtual personality) in the Google spreadsheet.

	A	B	C	D	E
1	Student	StudentID	Title of material	Link	Csi
2	Jānis Bērziņš	ID00016	10 Scientifically Impossib	https://www.youtube.c	199
3	Jānis Bērziņš	ID00016	Interpretation of folklore	https://prezi.com/view/	199
4	Jānis Bērziņš	ID00016	Archives of Latvian folklo	https://prezi.com/view/	176
5	Jānis Bērziņš	ID00016	The Brave New World of	https://www.youtube.c	168
6	Jānis Bērziņš	ID00016	Hillforts in Latvia	https://www.youtube.c	167
7	Jānis Bērziņš	ID00016	Portugal	https://prezi.com/view/	163
8	Jānis Bērziņš	ID00016	Art and artists in Latvia	https://docs.google.co	150
9	Jānis Bērziņš	ID00016	Otters (ūdri)	https://prezi.com/view/	138
10	Jānis Bērziņš	ID00016	What Makes a Good Lec	https://www.youtube.c	132
11	Jānis Bērziņš	ID00016	Simpsons Constructivism	https://www.youtube.c	118
12	Jānis Bērziņš	ID00016	Behaviorist teaching acti	https://www.youtube.c	109
13	Jānis Bērziņš	ID00016	Teaching and Learning A	https://www.youtube.c	106
14	Jānis Bērziņš	ID00016	RAIDING THE BORDER	https://www.youtube.c	102

6.3 Spaces' Content Personalization in the Moodle LMS

In base use case Moodle LMS generates static content from data stored in Moodle database. Content is generated and presented to Moodle user upon content page request. This content generation approach provides limited options for content personalization. The following personalization are approaches currently available on Moodle LMS:

1) Moodle plugin FilterCodes (Moodle, 2020a) provides customization and personalisation options for Moodle LMS site and course content using predefined text tags. This allows Moodle content creator insert specific values from user profile data such as student ID, firstname, lastname, country, etc. This provides learning content personalization limited to personalized welcome messages.
2) Second approach provides more extended personalization options. This is achieved through "Restrict Access" feature. This feature enables content creator to restrict access to Moodle activities, content according to conditions specified. The conditions can be date, student group id, grade, etc. (Moodle, 2020b). This feature allows creation of multiple content/activities assigned to specific student

groups and/or based on student's level of knowledge.

The methods mentioned above provide limited personalization options for spaced learning approach. "Restrict Access" feature could provide required functionality but requires extra manual work and scalability options are limited for large number of students.

Moodle LMS FilterCodes plugin provides limited personalization options but we will use it for spaced learning content personalization tool.

Moodle LMS personalized spaced learning content injection tool has three main components:

1) EMBED TAG in Moodle LMS content,
2) HTML Content generation script,
3) External data repository.

The first component of spaced learning content injection tool is HTML EMBED TAG (W3schools, 2020). The EMBED TAG is included in Moodle content page as placeholder for personalized content and it contains all the information required for the content generation. The current setup (spaced learning content) requires two variables: student ID and section ID. Any other student specific variables can be included such as student ID, firstname, lastname, group ID, etc. EMBED TAG calls a PHP script located on Moodle server. This generates content using parameters included and embeds it in the content area enclosed by the TAG. Technically embedded content is created externally in injected into Moodle content.

A preinstalled Moodle plugin FilterCodes (Moodle, 2020a) is required for the EMBED TAG functionality. As described before FilterCodes plugin is the first step in content personalization enabling insertion of plain text tags in Moodle content site. The inserted plain text tags are translated into requested values such as students firstname, lastname, Id, and other data from student's profile. EMBED TAG is inserted in Moodle learning content (by switching Wysiwyg editor into HTML mode) in format displayed below:

```
<embed frameborder="0" src="https://artss.mii.lv/local/customcontent.php?firstname={firstname}&lastname={lastname}&userid={userid}&spaceid=3" width="900 " height="500">
```

All the values included in the TAG are sent to the content generation script (firstname, lastname, user id, space id). Width and height variables provide extra formatting options. Personalized content generation will be based on these values only. The content generation script will not be able to access any other information from Moodle site.

This is the script written in PHP7 (PHP, 2020) generates personalized content in HTML based on parameters included in the EMBED TAG. Any other programming language or online service can be used for this task. The only requirement is the script/service has to be able accept variables from the EMBED TAG and return content in HTML format. The content generation script performs the following tasks:

1) Content generation script receives variables from the EMBED TAG and validates them.
2) It requests personalized data from Google Sheets using PHP library Google PHP API Client Services ("Github," 2020). Data request includes an authorization request and a data query after.
3) It generates HTML content using data from Google Sheets and returns it to EMBED TAG located in learning content.

All personalized data is stored and managed by an external data repository. We use Google Sheets as it provides flexible environment for testing different algorithms using formulas and data analysis tools. Google Sheets lists all the locations of spaced learning personalized content and assigns it to a specific student ID using a set of Google Sheets functions. System can be adapted to use a database instead of Google Sheets for complete integration in Moodle LMS.

7 EVALUATION OF THE SPACED E-LEARNING OUTCOMES

Two essential sections of the learning outcomes must be evaluated to understand the success of the personalization of the spaced learning method in the e-course:

1. Fitness of the course to the individual needs of a particular student.
2. Fitness of the course design to its objectives.

Most appropriate to for characterizing adequacy of the course to the learners' needs and course objectives is TELECI method, created by the Riga Technical University (Kapenieks et al., 2020). Designed in accordance with spaced e-learning method, a graphical representation named "Telecides" is the appropriate way for evaluation of the course effectiveness in the e-learning environment. The authors split each unit into small subunits, including indicative multiple-choice questions at the beginning of the subunit and similar diagnostic questions at the end of each subunit. The content of the subunit was available only after submitting the appropriate indicative test. The design of the subunit of the course in the e-learning environment is shown in Figure 4.

Analysis of the results enabled recording, tracking, and visualizing the students' activity and their answers to the questions after each subunit.

Analysis is conducted by the calculation of the probability from retrieved user behavior data, as shown in Table 2.

Figure 4: Structure of subunit for implementation of the TELECI method in the LMS.

Table 2: Analysis from the calculation of the probability from retrieved user behavior data.

Experimental value	Answer to indicative question	Answer to final question
N-P	incorrect	correct
P-P	correct	correct
N-N	incorrect	incorrect
P-N	correct	incorrect

The authors of the method provided the following "ideal" experimental average probability values for the characterization of the course, if each multiple-choice question has three answers (Kapenieks et al., 2020):

1. Too complicated: N-P =0.222; P-P=0.111; N-N=0.444; P-N=0.222
2. Too easy: N-P =0; P-P=1; N-N=0; P-N=0
3. Perfectly matching to learners' needs: N-P =0.667; P-P=0.333; N-N=0.444; P-N=0

The method allows the data to be interpreted graphically (Figure 5).

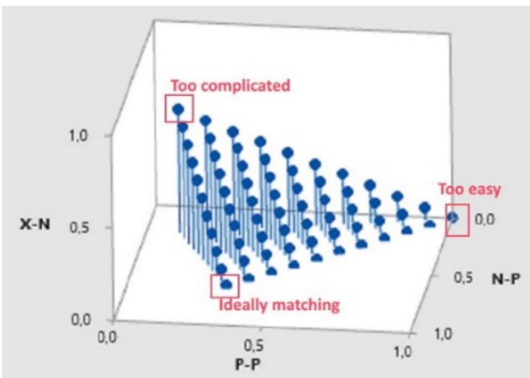

Figure 5: Graphical interpretation of "telecides" for evaluating course content and design (Kapenieks et al., 2020), author's additions.

8 CONCLUSIONS

With the growing importance of online learning, the introduction of pedagogical findings in the e-learning environment is becoming increasingly important. Neuroscience and cognitive sciences findings show spaced e-learning method as an effective approach for improvement of knowledge acquisition. After implementation of the method in the LMS most students rated spacing of the content positively. The effectiveness of the method depends on the duration of spaces. Short spaces – 10 to 20 minutes between repetitions of the learning content is implemented in e-learning to improve the acquisition of the subject matter. Metacognitive skills and face-to-face communication with the lecturer are essential in the spaced e-learning practice. Learning content will be split into short units and repeated two or three times in different forms – text, video, simulations. The way the content is presented should be as attractive as possible.

It is recommended to adapt the content to the individual interests of each student. If students create interesting content themselves, it is engaging for other students with similar interests.

An information system for the implementation of personalized spaced e-learning approach in the LMS can substantially facilitate the use of the method in e-courses. Google applications as a component of such an information system enable using the method in different e-learning environments.

TELECI method, implemented in the LMS, is powerful approach for evaluation of the fitness of e-course content and design to the needs of learner to reach learning objectives. TELECI method is used for testing of effectiveness of spaced learning in the e-courses.

Proposed information system could serve as the tool for creation of the adaptive learning content as well. Such method for designing of adaptive learning courses is the topic for future research.

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