Using Learning Theories for the Creation of a Distance Digital Course in Mathematics for Higher Education

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Abstract—This article presents the results of research on the effectiveness of distance education in Mathematics for higher education students. A digital course in Differential Calculus was created, which was evaluated by the students who participated in it. The aim of the quantitative research carried out was to identify the conditions needed for the implementation of a digital distance education model. The design includes the integration of activities based on learning theories at targeted points of the distance learning. From the results, it appears that the students achieved the learning outcomes that were identified. Moreover, the integration of the relevant activities had a positive impact on the students, who a) positively evaluated the program they attended and b) stated that their knowledge was enhanced at the issues negotiated on the course.

Index Terms—E-learning, Distance Education, Mathematics, Learning Theories.

I. INTRODUCTION

Nowadays, technology has penetrated education. The spread of the internet as well as the wide integration of digital tools in the educational process enable the transformation of traditional learning into a learning where learners will be activated and will be able to express, communicate and think through technology.

The present research focused on the application of distance education in the course of Infinite Calculus, and specifically in the section “Differential Calculus”. Differential Calculus was chosen as a subject because: a) enables geometric representation (graphs, tangent curve), b) involves concepts of physics (speed, acceleration), c) the student is asked to solve exercises providing computational and theoretical research opportunities in a variety of different approaches and d) provides opportunities to explore whether distance education can support / recall concepts that have already been taught. [1].

II. MATERIAL DEVELOPMENT AND APPLICATION OF LEARNING THEORIES

One important stage of creating online courses, which is also a key factor in the success of such programs, was the development of content and the coherence of the learning objects. For this purpose, video lectures and exercises were developed, learning paths were created and discussions were organized. Each activity was developed and matched with a specific and appropriate learning theory. The learning material was then made available to students through the LMS Free Open e-Class platform, which has been positively evaluated in terms of usability, functionality and efficiency. [2].

A. Creating video lectures

To create video lectures, the method of slides with audio integration was used in order to achieve good quality and embed effects (frames underlines, moving arrows) as well as capture an animation created with the help of GeoGebra (Fig. 1), where the researcher considered it necessary.

![Fig.1. Geometric interpretation of the derivative with motion capture by GeoGebra software.](image)

In this way, it was attempted to increase the students’ attention, emphasizing critical information according to the ARCS theory (Attention, Relevance, Confidence, Satisfaction). ARCS theory is an educational model that focuses on motivation. The theory and model that has been developed is special important for e-learning, since developing motivation in an online course is more difficult than in the physical classroom. The aim of ARCS theory is to enhance and keep active the interest of learners. In addition, it includes the concept of relevance, so that through the learning process, students understand the usefulness of content and bridge the gap between it (content) and the real world. In addition, it includes self-confidence, which must be enhanced so that students can monitor their progress and determine that they can achieve their goal. Finally, it includes satisfaction, which is directly related to motivation, so that students are satisfied with what they have achieved during their learning journey.

For example, one of the video lectures tried to connect the learning content with real situations and personal experiences of the trainees (linking the concept of speed...
with the Sydney Olympics), for a better understanding of the concepts, as social and cultural interaction defines a fundamental role in knowledge development according to Vygotsky [3]. In another example, in a video lecture on the geometric interpretation of the derivative, a moving image created with the help of GeoGebra was recorded as an activity with a different cognitive style, in order to facilitate the transfer of information to long-term memory, according to her theory. double coding [4]. In addition, an attempt was made to connect it to the tangent line, thus asking students to reorganize their previous knowledge, according to Wolfgang Koehler's theory of perceptual learning [5].

Special emphasis was given to the duration of the videos, so that the time of each video does not exceed 5-6 minutes. As a result, some concepts need to be analyzed in more than one video. Fragmentation led to the avoidance of cognitive overload and contributed to the analysis of educational steps, according to the principles of behaviorism [6]. Fragmentation also served to feed students in closed-ended exercises/questions, as will be seen below.

**B. Creating exercises**

For each module, closed-ended self-assessment exercises (multiple choice exercises, "True-False" type questions) were developed, which were used to assess learning and to evaluate the achievement of the expected learning outcomes. In this way, learners had the opportunity to use their metacognitive skills, self-assess [7] and work with learning activities that required the combination of previous and new knowledge through the use of reflective approaches [8].

![Fig. 2. Infinitive Calculus, (Multiple choice with feedback)](image)

The exercises were randomly selected from a database, which allows the instructor to refer the trainees to repeat specific activities to maximize the effectiveness of learning (behaviorism). At the same time, using a behaviorism approach, the random selection of exercises helped the trainees to develop their ability, as they were given the opportunity of frequent repetition.

After each attempt to solve the exercises, the learner received feedback. In case of identification of didactic obstacles, the feedback was links to video lectures related to the object of the exercise, in order for the trainee to watch the video lecture and try to solve the exercise again (Fig. 2). In each case the trainee could see the answer to the exercise in pdf format. In this way, the instructor had a supportive role in the activities of the learners by utilizing a constructive approach, since the assessment included a form of interaction in the learning process. At the same time, this approach allowed the student to gain relative autonomy and be the main organizer of his learning, according to the theory of Self-Learning [9].

On the other hand, in case of success, the trainee received an e-reward message in order to feel satisfied, which is a critical parameter for the learner's learning motivation (ARCS theory). Finally, he could see the answer to the exercise in pdf format, as there was a case where the learner had answered correctly but had not followed the same thought path. The above design gives priority to reducing learners' mistakes (behavioral theory) or eliminating teaching barriers (cognitive theories) as well as increasing the sense of confidence and self-esteem when the tasks assigned to them are successful (ARCS theory).

**C. Creating learning paths**

Learning paths were created for each cognitive module that included the stages: recording goals and learning outcomes, watching video lectures, exercises to be solved for each video lecture, "True-False" type questions to evaluate the proposed structure. The learning paths, the representation of material, the repetition of concepts were defined by the instructor according to the behavioral theory, in order to help the learner to work in a specific logical process.

Of course, the learning paths could be bypassed by the learner, giving him/her control of his/her learning process according to his/her personal needs [10].

**D. Organization of the Forum**

The forum was another tool that was activated in this course. Learners could create threads with questions or comments, while the researcher / trainer created threads on critical issues. Thus, the trainees had the opportunity to work both with the instructor and with each other.

Through dialogue processes and taking the time to respond to the learning content [8], the trainees had the opportunity to activate their existing knowledge and present their personal interpretations and perspectives. In this way, an attempt was made to turn learning into a social and collaborative activity, according to Vygotsky [3].

**E. Material creation of theory-methodology**

For each learning unit, material was created that included the existing theory in the form of questions-answers and proofs of the theorems with accompanying observations. The learners had the opportunity to choose the type of learning material (video lectures or documents) according to their preferences and needs. With this approach, the same material was offered in different ways and multiple representations according to cognitive learning theories.
Learners could work with multiple representations, having the opportunity to develop more learning pathways and transfer information to long-term memory, according to Paivio's dual coding theory [4].

III. METHODS

A. Objectives and research questions

The aim of the work was: a) to identify the conditions needed for the implementation of a digital model/ e-course, b) to explore the limits of this application and c) to draw conclusions from the implementation of the proposed teaching, which attempts to integrate targeting learning theories in the learning objects of the digital model. The research questions asked are:

1) What is the degree of learners' satisfaction with the program?
2) How do the learners evaluate the program?
3) What is the effect of demographic profile and knowledge of computer use on program evaluation and satisfaction?
4) Is satisfaction related to program evaluation?

B. Sampling

For the research, the positivist paradigm was adopted and the quantitative method of data collection was selected using a questionnaire. The questionnaire included 10 closed-ended questions of the Likert scale with grades of "Not at all", "Little", "Moderate", "Very" and "Very much", as well as 33 open-ended questions.

A convenience sample was used for data collection, which included students from the researcher's environment as well as students from the Department of Informatics of the Ionian University. A necessary condition was that the students have in their curriculum the course of Differential Calculus. 101 students participated in the research. To access all the tools of Open e-Class, students registered on the platform as a guest user, to facilitate their access.

Finally, through the Google Forms platform, the students answered the questionnaire. Factor analysis was applied to study the validity of the conceptual construction.

IV. SELECTED RESULTS

The students who participated in the research were almost equally distributed in terms of gender. The vast majority came from the General Lyceum (77.2%) with a written grade in the national exams in Mathematics between 10 and 16 (67.3%). The majority of participants were familiar with the use of computer (95.1%) and internet (94.1%).

From the analysis of the data of the answers to the first research question (Table I) it emerged that the students expressed high satisfaction with the possibility of repeating the exercises (\(A = 4.27\)), as well as with the contribution of the material, in the better understanding of the concepts (\(A = 4.21\)). This seems to agree with the results from a research at the University of Bologna, where in multiple choice questions in Mathematics (in the form of assessment tests and automatic random selection through the Moodle platform) the learners expressed high satisfaction and at the same time the improvement of their grades was highlighted [11].

Also, the learners stated that they were satisfied with the "Organization, Structure, Environment" (\(A=4.09\)) of the course. Among other things, their statement shows that they were satisfied with the fragmentation of the course into small independent sections to avoid cognitive overload. Similar results were recorded in the Kinnari-Korpela study where step-by-step solutions, including the learner's explanations, were considered particularly valuable by the learners [12].

In addition, they were satisfied with the way the video lectures were structured, the dynamic use of GeoGebra in them and the connection of the learning content with different and real situations. The results are in line with the results of Glass & Sue's research, which states that lectures with enriched material (presentations, electronic writing) are highly acceptable [13].

Research has shown that the use of video and audio helps learners to understand complex concepts and processes that would be difficult to explain in plain text and graphics [14]. In addition, it has been reported that students with low math proficiency using videos are able to repeat their projection and as a result had more time to think and delve into mathematical concepts [12]. At the same time, the students' satisfaction with the clarity of the course instructions, the relevance of the material in the "Learning Paths", the "Organization Structure" of the course, the monitoring and the environment of the program, show to a large extent that characteristics of Attention, Relevance and Satisfaction of ARCS theory were incorporated. The learners' satisfaction with the program environment agrees with researches that has positively evaluated the Open e-Class platform.

Satisfaction with the ability to store files on the computer (\(A=3.57\)) probably suggests that e-learning materials should include a plurality of activities and learning materials to provide adequate and appropriate support for learners with different learning needs.

Presenting information in a variety of ways facilitates its transfer to long-term memory, according to Paivio's dual-encoding theory [5].

In the second research question (TABLE II), the learners evaluated the program positively as it helped them to gain experience with the distance education, while at the same time it helped them to cover the shortcomings they had in Mathematics (\(A=4.15\)). It is an important element that students seem to trust the program in terms of their learning process (ARCS learning theory). Matzakos and Kalogiannakis came to similar conclusions, arguing that distance learning helped the learners to study and understand the material, as a modern and pioneering
The students also stated that the digital course will help them in the exams of the course. In addition, they stated that they had developed the ability to apply theory in practice and at the same time considered that their improvement in Mathematics was being achieved. The students agreed that the limitations and possibilities of the program, its overall picture was effective (A=4.11). They stated that they understood what they have been taught in the program and believe that the program provides them with autonomy and control of their educational course, something that characterizes the theory of self-learning.

| TABLE II: AVERAGES VALUES AND STANDARD DEVIATIONS OF THE FACTORS |
|---------------------------------------------------------------|
| Factors                     | Mean | S.D. |
|----------------------------|------|------|
| Familiarity with Distance Education - Mathematics improvement | 4.15 | 0.54 |
| Benefits - Effectiveness  | 4.11 | 0.55 |
| Suggestions - Improvements | 3.72 | 0.91 |
| Preference for Distance Education          | 3.71 | 0.65 |

Participants also mentioned possible improvements, such as: synchronous communication, interaction between learners and collaborative learning between them. In a similar study the use of simulations that required interaction by the trainees, together with appropriate guidance, contributed to the acquisition of knowledge [15]. However, this result is not verified in DePriter's research, which concluded that interaction with team members is as successful as behavior-based learning [16].

In addition, the research showed that students believe that discussing concepts (through the forum) helps them to better understand the concepts, as they are given the opportunity to activate their existing knowledge. At the same time, their reflection is encouraged, and they are given the opportunity to process information. This seems to be in line with research that has shown that the participation of learners in a discussion forum that includes the composition of messages, has a positive effect on their learning [17, 18]. However, in the digital lesson that was created, no student participated in the forum, although the researcher had created threads to encourage them. This result is partly justified by the nature of this research.

In the third research question, it was found that people who have in their personal space the material and technical infrastructure for Internet access state that they have relative benefits from such actions. This may be due to the students' familiarity with the Internet and, indirectly, the ease of use of this educational platform or any other Learning Management System. Research by Orfanou et al. on the Moodle and Open e-Class platforms has shown that the ease of use of a Learning Management System is related to the knowledge of learners in the use of the Internet [19].

Also, students who have taken part in a discussion forum in order to improve their knowledge in Mathematics, prefer collaborative learning and communication, and state to a greater extent that the forum helps to understand the concepts. What could be further explored is whether the above approach leads to better performance.

The latest research question showed that people who are most satisfied with the “Organization, Structure, Environment” of the program evaluate the program better in all dimensions. This leads to the conclusion that if the learning objects and the way they are constructed in a digital lesson satisfy the learners, then this will lead to a positive attitude towards the lesson. Thus, the instructor can improve his/her teaching by using the self-assessment information of the Open e-Class platform.

Finally, people who are more satisfied with the use and repetition of the self-assessment exercises, evaluate the program higher in terms of "Benefits, Effectiveness", which means they believe that they have developed the ability to apply the theory in practice and that it will help them in their exams course. This is in line with Lowe's research, in which students used self-assessment questions to better prepare for exams [21].

V. CONCLUSIONS

The present research recorded the satisfaction of the students and at the same time showed the positive evaluation of an e-learning course on Mathematics for higher education.

In this context, future efforts could investigate the use of simulation models (Java Applets, GeoGebra applications or other related software) as observation tools or integrated into exercises. The non-participation in the forum, highlights the need to create incentives and therefore it is important to explore the incentives that can be given to students to participate.

An additional point of research is whether or not the inability to write mathematical expressions on the Open e-Class platform and general in Learning Management Systems affects students' participation. It is also necessary to investigate whether the learning materials related to the performance of students, as a means of assessing learning teaching and how it is related to their performance in the final written exams.

The present study tried to explore an issue that due to the pandemic, emerges as the only way of education. The integration of relevant courses and activities can contribute to the creation of the appropriate profile for the integration of digital tools in distance education. An important element is the training of instructors and digital material creators, as the importance of learning theories in the education of learners plays a crucial role in the success of this attempt.

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