https://doi.org/10.36315/2025v1end041
p-ISSN: 2184-044X e-ISSN: 2184-1489 ISBN: 978-989-35728-7-0 © 2025

EMPLOYING KAHOOT GAMING TOOL TO TEACH ELECTROMAGNETIC PROPAGATION AND SIGNAL TRANSMISSION THROUGH OPTICAL FIBERS

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Abstract

Teaching electromagnetic (EM) propagation and signal transmission through optical fibers presents several challenges to educators and students mainly due to the complicated (and time-consuming) mathematics involved as well as the difficulty in associating those mathematics with actual facts regarding propagation and transmission processes. In that respect, the Kahoot gaming tool was employed for the visualization of certain aspects of propagation and transmission with the aim students to develop a practical knowledge on those processes before encountering them in a mathematical manner. More specifically, Kahoot was used to visualize propagating modes (an essential concept of electromagnetic propagation) as well as intramodal (chromatic) dispersion (an essential impairment phenomenon) that both cause difficulties to several students. Employment of Kahoot is facilitated by the fact that Kahoot is a mobile-device application with a usable free version that can be easily embodied in an engineering course. The instruction on the above processes by means of Kahoot took about two one-and-a-half hour lectures that precede the relevant mathematical analysis. Regarding propagating modes, students were given pictures of fibers with specified core and cladding refractive indices and operating at a commonly used wavelength and were asked to include the supported modes as the diameter of the fiber core increases. Regarding intramodal dispersion, the students were given a picture of a single-mode fiber (of a specified core diameter and refractive indices) that is activated by a laser source. Two different laser sources were considered, each with a specified linewidth and the students were asked to observe views of the effect of dispersion on the transmission of a pulse-train (including possible overlapping of the transmitted pulses) and calculate the widening of the transmitted pulses for each laser source as the length of the fiber increases. An important follow-up is for the students to associate the Kahoot pictures with the mathematical analysis presented in the subsequent lecture. The whole process was evaluated by means of a short questionnaire distributed to students which shows that visualization through Kahoot helps them develop a better understanding of electromagnetic propagation and signal transmission through fibers, facilitating, at the same time, the relevant mathematical analysis (particularly regarding dispersion). The presentation took place during five two-teaching-hour lectures in the framework of the 6th-semester "Optical Communications" course at the Department of Electrical & Electronic Engineering Educators of the School of Pedagogical & Technological Education (ASPETE), a tertiary educational institution, located in Athens Greece. Future use of Kahoot could include attenuation phenomena (that are, anyway, easier for students to understand) as well as the phenomenon of polarization-mode dispersion (PMD).

Keywords: *Engineering education, electronic engineering education, fiber optics, gaming tools, Kahoot.*

1. Introduction

Teaching electromagnetic (EM) propagation and signal transmission through optical fibers presents several challenges to educators and students mainly due to the complicated (and time-consuming) mathematics involved as well as the difficulty in associating those mathematics with actual facts regarding the propagation and transmission processes. For example, EM propagation in an optical fiber requires the solution of a boundary-value problem involving the wave equation in combination with specific boundary and far-field conditions (Ming-Kang Liu, 1996). Even if a student is competent enough to follow the solution of such a problem, most probably he/she will find him/herself "lost in mathematics", unable to connect mathematical results with how an optical fiber actually supports

EM waves. A similar situation has been observed regarding signal impairment mechanisms, particularly intramodal and polarization-mode dispersion.

This article describes a teaching approach in which an attempt was made to visualize EM propagation and signal degradation phenomena, prior to their mathematical analysis, with the aim to enhance students' comprehension of the above phenomena. Visualization was achieved by using gamification (Lee & Hammer, 2011) and the Kahoot gaming tool, in particular, owing to the fact that Kahoot is a mobile-device application with a usable free version that can be easily embodied in an engineering course (https://kahoot.com/; Voudoukis, Mantzios & Pagiatakis, 2021).

2. Objective

The objective of using the Kahoot gaming tool was the students to visualize EM propagation and signal transmission through optical fibers. The basic rationale was that if students had first developed a qualitative grasp of the associated processes and mechanisms by means of a visualization tool such as Kahoot, this would help them follow the anyway complicated relevant mathematical analysis and assist them in enhancing their comprehension and practical aptitude regarding EM propagation and signal transmission phenomena.

3. Method

The basic rationale of the applied teaching approach was that if students started with a visual encounter of EM propagation and signal transmission through optical fibers, this would help them follow the complicated and time-consuming associated mathematical analysis (which is, anyway, complicated and time consuming) and develop their aptitude in the practical aspects of the processes involved which is necessary for handling actual engineering problems.

Visualization, was achieved by using the Kahoot free version since it is easily available and can be easily embodied in an engineering course. The basic aim was the students to get familiar on one hand with mode patterns and essential aspects of the waveguiding process (such as the dispersion diagram) in a rather practical manner and on the other hand with signal impairment phenomena, particularly dispersion which students usually find it difficult to comprehend. Active participation of students was sought and mainly achieved through the answering of relevant multiple-choice questions in an interactive manner.

4. Design

The content to be presented was divided into two parts, the first dealing with EM propagation (with emphasis to the notion of propagating modes) and the second dealing with signal degradation mechanisms, particularly attenuation and intramodal dispersion. Typically, the first part requires the solution of the wave equation (accompanied by the appropriate boundary and far-field conditions) in cylindrical coordinates and it is the topic that causes most difficulties and misunderstandings among students. The second part is the consideration of the fiber as a transmission medium and the analysis of processes such as the signal's attenuation and dispersion.

The presentation took place during five two-teaching-hour lectures in the framework of the 6th semester "Optical Communications" course (spring 2024) at the Department of Electrical & Electronic Engineering Educators of the School of Pedagogical & Technological Education (ASPETE), a tertiary educational institution, located in Athens Greece. A unique feature of ASPETE is that its graduates, apart from working as engineers in their respective field, can also be employed as teachers in technological secondary schools, that is why students in parallel with their engineering courses they also attend courses on pedagogy and didactics. The potential employment of ASPETE's graduates as educators is an essential reason why particular emphasis should be given to the students developing a conceptual, and not just procedural, understanding of the concepts and processes of their field.

Lectures 1 and 2 were about EM propagation through an optical fiber while lectures 3 and 4 regarded the consideration of optical fibers as transmission media and the analysis of signal degradation mechanisms that is attenuation and dispersion (table 1). To enhance students' comprehension of the associated processes, visualization was an essential element of those lectures and was achieved with the aid of Kahoot, which, all in all, took about half of the above lectures (indicative screenshots are shown in figure 2 and indicative additional questions are given in table 2). This was the second time that Kahoot was used in the context of optical telecommunications. The last lecture was dedicated to a discussion on the content of the preceding lectures.

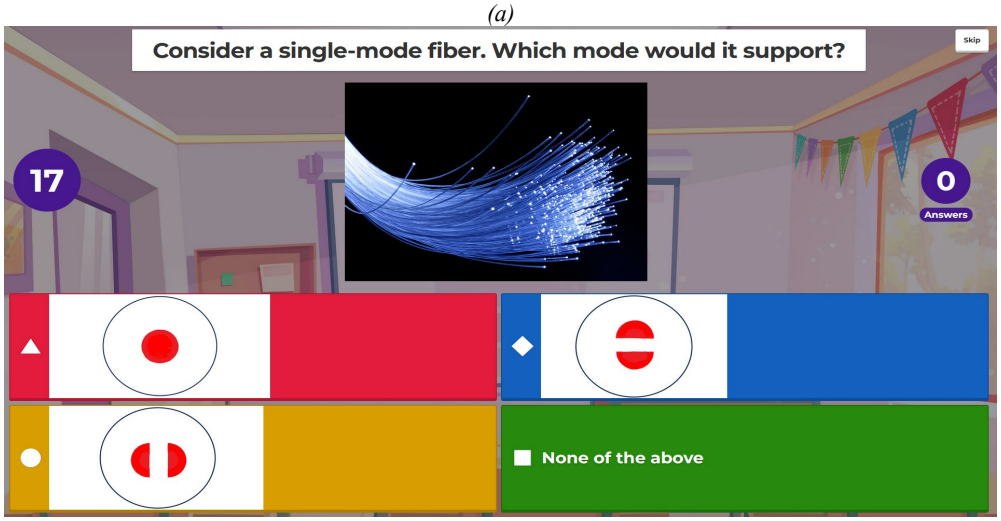
To evaluate the effect of the use of the Kahoot gaming tool on students' comprehension, a short questionnaire was distributed to students, following the lectures, that should be answered by means of a 5-grade Likert scale ("1" strongly disagree, "2" disagree, "3" neither disagree nor agree, "4" agree, "5" strongly agree).

Table 1. Lectures on the EM propagation of signal transmission through optical fibers.

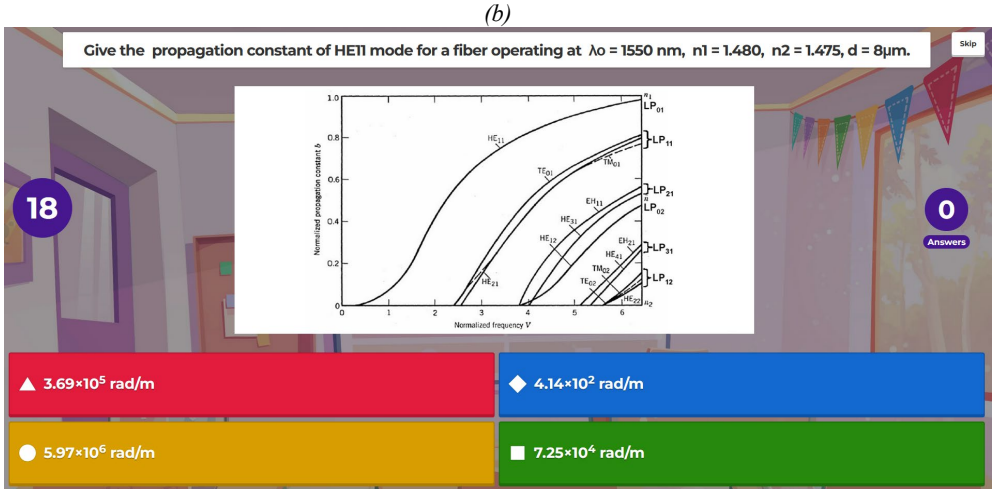
Lecture	Topic	Objective	Topics to be presented and discussed (indicative list)
1 & 2	EM propagation through an optical fiber	The students to comprehend the basic mechanisms and processes regarding EM propagation through an optical fiber.	• Visualization of the concept of propagating modes. • Visualization of the dispersion diagram. • Practical issues. • Association with the solution of the relevant boundary-value problem (wave equation combined with boundary conditions).
3 & 4	The optical fiber as a transmission medium	The students to comprehend the transmission properties of optical fibers and the phenomena and parameters regarding signal attenuation and dispersion.	• The attenuation process. • The dispersion process (with emphasis to chromatic dispersion visualized by means of Kahoot).
5	Discussion		

Figure 1. Indicative Kahoot screenshots regarding EM propagation and signal transmission through fibers.

(a)



(b)



(c)

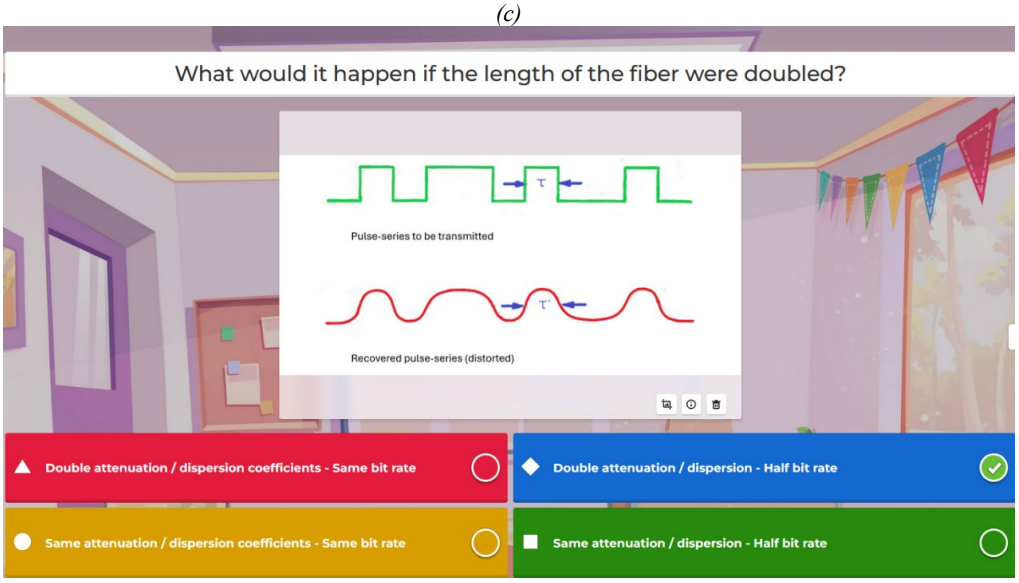


Table 2. Indicative possible additional questions.

	Question	Relevant figure
1.	What would be the profile of the LP11 mode?	1a
2.	Suppose that the picture depicts mode's profile the distribution of the optical power at a cross-section of a single-mode fiber at an instant considered as the starting one (t_o = 0). What comments can you make on the mode's profile at distances L such as $\beta L = \pi/4, \pi/2$ and π (where β is the mode's propagation constant)?	1a
3.	What would be the mathematical expression of the electric field in a fiber with indices n1 = 1.480 and n2 = 1.475 and diameter d = 12 μm operating at a wavelength λ_o = 1550 nm?	1a
4.	Could there be an optical fiber with no propagating mode?	1b
5.	Suppose we have an optical source operating at a wavelength λo = 1550 nm and optical fibers with refractive indices n1 = 1.480 and n2 = 1.475 and diameters (d) equal to 8 μm, 12 μm, 16 μm and 20 μm. Define the propagating modes supported by each fiber.	1b
6.	In what way, e.g. modes HE21, TE01 and TM01 can be considered as the LP11 mode?	1b
7.	Suppose that the figure depicts a signal with bit-rate R = 2.5 Gb/s. What will it happen if the bit-rate considerably increases (e.g. to R' = 10 Gb/s)?	1c

5. Discussion

The answers to question 1 (m = 3.632) show that regarding the usability of Kahoot by the students, there is certainly room for improvement. A possible solution would be the students to be given some time to practice with Kahoot as preparatory homework (prior to its use in the class).

The answers to questions 2 and 3 (m = 4.167 and 4.105 with a small m/s value) show that visualization through Kahoot, prior to the mathematical analysis, did help the students comprehend the facts and issues of EM propagation and signal transmission through optical fibers (table 3 and figure 2).

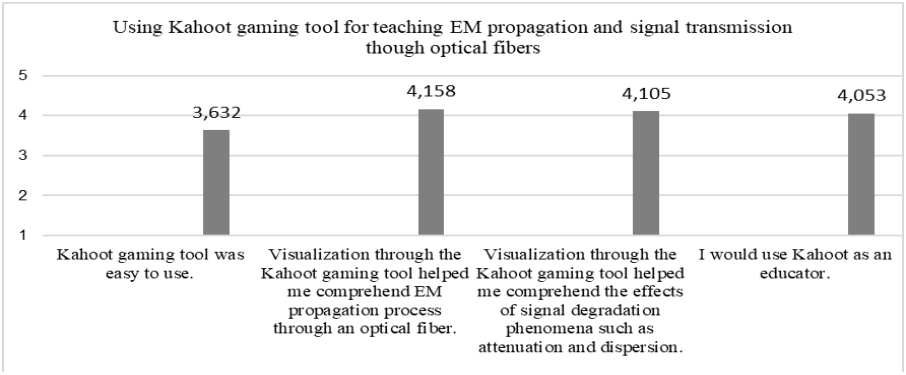
The aim of question 4 was to evaluate the intention of the participating students to use Kahoot as future educators. This question was included given the fact that the department's graduates can be employed as teachers of electrical and/or electronic engineering in technological high schools. It is encouraging that the majority of students agree or strongly agree with using Kahoot as future educators.

In the framework of the described approach, the use of Kahoot regarded the Content Knowledge (CK) and Pedagogical Knowledge (PK) parts of the TPACK framework (Mishra & Kohler 2006). A further aim was the students to develop Pedagogical Content Knowledge (PCK) in view of their possible future employment as school teachers and, by creating their own Kahoot displays to also address the Technological Knowledge (TK) aspect. Regarding Bloom's revised taxonomy (Armstrong, 2010) the presentation mainly covered layers 2 and 3 (understand and apply) and maybe layer 4 (analyze).

Table 3. Questions and answers regarding the presentation of the use of the Kahoot gaming tool for the presentation of EM propagation and signal transmission through optical fibers (participation: 19 students).

Question	Average (m)	Standard deviation (s)	Ratio m/s
1. Kahoot gaming tool was easy to use.	3.632	0.895	0.25
2. Visualization through the Kahoot gaming tool helped me comprehend EM propagation process through an optical fiber.	4.167	0.898	0.22
3. Visualization through the Kahoot gaming tool helped me comprehend signal degradation phenomena such as dispersion.	4.105	0.658	0.16
4. I would use Kahoot as an educator.	4.053	0.621	0.15

Figure 2. Questions and answers regarding presentation the use of the Kahoot gaming tool for the presentation of EM propagation and signal transmission through optical fibers (participation: 19 students).



Kahoot could be also used for the visualization of additional topics of Optical Communications, e.g., the operation of optical amplifiers and receivers or the wavelength division multiplexing technology, to name a few. Active participation of students could be enhanced by encouraging them to create their own Kahoot displays (probably with proper guidance and/or hints) in view of their possible employment as future educators. In the framework of more advanced applications, Kahoot could be used for developing self-teaching educational material, e.g. for incoming international students.

6. Conclusions

The aim of the proposed teaching approach was to facilitate comprehension of EM propagation and signal transmission through the visualization of the relevant notions by means of the Kahoot gaming tool. Students' feedback was encouraging and this could motivate further use of Kahoot to support topics mathematical analysis of which may be complicated, time consuming and with dubious results. Given the dynamic nature of EM waves and waves in general), the use of video presentations in combination with Kahoot (which, however, would require more effort and more sophisticated equipment) could be also considered as an option.

Acknowledgments

The authors acknowledge financial support for the dissemination of this work from the Special Account of Research of ASPETE through the program "Strengthening Research of ASPETE Faculty Members".

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