Иновације у настави, XXXVI, 2023/2, стр. 1–16
DOI: 10.5937/inovacije2302001A UDK 004.853.5. 004.92-057.875

Рад примљен: 6. 7. 2022.
Рад прихваћен: 25. 5. 2023.

Оригинални научни рад

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The Impact of Interactive Digital Technology Exposure on Generation Z Students Learning Performance in Computer Graphics and Simulations: A Comparative Study of Greece and Serbia

Abstract: *As the functionality of modern digital societies is largely based on interactive digital technology, educational technology has inevitably gone through a process of digitalization. Studying information technology, computer science, or computer engineering in the post-digital era makes it very hard for students to disjoin personal technology needs, learning necessities, and future career demands, putting them at great risk for developing psychological disorders. The aim of this international comparative study is to examine the effects of interactive digital technology exposure on learning performance in computer graphics and simulations. To conduct a comparison of the 397 generation Z students from Greece and Serbia, a study was conducted evenly representing various geographic, economic, and socio-cultural environments. The research was realized between October 2021 and May 2022. The type of preferred gaming device was the most important digital technology exposure predictor of learning performance factors gain both in Greece and Serbia. Unexpectedly, digital gaming exposure and Internet gaming disorder were not significant predictors of academic success. The resulting model dually provides teachers with the opportunity to adapt their activities more efficiently and students with a self-diagnostic tool helping them to improve learning performance in the field of computer graphics and simulations more effectively.*

Keywords: *educational technology, computer graphics, computer simulations, learning*

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Introduction

Information technology (i.e., IT), computer science (i.e., CS), and computer engineering (i.e., CE) all are part of the key foundation pillars of a modern society whose pores are digitally saturated to the point that life in the social community is no longer possible without their use. One of the common curriculum elements of the previously named study programs of most faculties is computer graphics and simulations, and for a good reason - modern interactive digital technology, whether we are talking about devices or software, relies heavily on interactive graphics. This fact induced our interest in studying the impact and relations between technology exposure and learning about it.

In the context of digital society to which we all belong, educational technology has inevitably gone through a process of digitalization, so functional learning in most situations nowadays represents a mash of formal, informal, and non-formal education almost always supported by the digital technology. The recent COVID-19 pandemic practically cemented this framework and permanently affected educational systems throughout the world. One could argue that this digital shift was a necessity, but in reality, it was an inevitability - the pandemic just speeded things up. Having in mind the complexity of the situation in which IT, CS, and CE students find themselves - on the one hand personally and socially every day surrounded by digital technologies, and on the other in the process of exploring and embracing the proficient use of large part of it in education and future professional practice, the importance of this research is obvious. We have not forgotten the teachers - they are and will be a key factor in ensuring the directed, correct and measured use of digital technologies in the educational process (Bereczki, & Kárpáti, 2021; Çebi et al., 2022; Rubach, & Lazarides, 2021; Starkey, 2019). Even though many teachers in Greek and Serbian primary, secondary and tertiary education have shyly embraced techology-enhanced learning (i.e., TEL) for years, in fact, the situation with the pandemic has for the first time in modern history forced practically all of them to ad hoc adapt their pedagogies and methodical practice at the same time, and find their way in the field of applying digital technologies in education. If not earlier, it is now clear that educational institutions and stakeholders must create a coherent strategy to quickly retrain teachers and empower their digital competencies, so that they can successfully meet new professional demands and student expectations.

This study is an international comparison of the impact of digital technology exposure on the learning performance of undergraduate students who are educated in the fields that are key to digital technology itself. The focus was on the population of older adolescents and young adults in their early 20s often named Generation Z (Seemiller, & Grace, 2017), as they grew surrounded by portable digital devices, common Internet access and a variety of online services that most are in use today.

The rest of the paper is organized as follows. The next section explores previous referent research on digital technology exposure effects on student personalities, learning preferences, and performance. The research methodology is described in the following section. Descriptive and conceptual results are then presented and discussed, followed by concluding remarks.

Related research

The term Generation Z represents the first generation born in the Internet era (Bassiouni, & Hackley, 2014). This population of students lives in an environment that has been impregnated with easily accessible information, rapid social networking, and a fast-paced lifestyle from birth (Liu, & Chen, 2019), which led developing advanced cognitive abilities and imagination and more individualized and self-centered personalities (Zhu et al., 2022). The introduction of online learning management systems (i.e., LMS), social media (i.e., SM), and virtual learning environments (i.e., VLE) additionally increased student digital technology exposure, which was already substantial. Generation Z students are pragmatic and most of the time interested in pursuing only the competencies necessary for their future careers (Isaacs et al., 2020). Generally, this population prefers to learn independently/autonomously (Anthonysamy, & Singh, 2023; Livingstone, 2017; Oates, 2019), which should be compensated by introducing more communication and collaboration teaching methods (e.g., flipped classroom, problem-based learning, etc.). The extensive digital technology exposure most often leads to underdeveloped interpersonal communication and social skills as students lack common face-to-face communication, which can be a limiting factor for a successful career in many professions, including IT, CS, and CE. Researchers agree that digital technology is overused by students in everyday activities to the level of spending more than three hours a day using digital devices (Cao et al., 2018; Collisson et al., 2021; Maulina et al., 2020), thus placing them at higher risk for developing mental health issues. Javaeed et al. (2019) confirmed that internet addiction deteriorates student academic performance. The constant exposure to fast interactive digital graphics, video, and audio content often combined with kinesthetic stimuli can easily lead students to expect instant gratification and develop attention deficits (Ding et al., 2017). Due to the specifics of their future careers, some of the before-mentioned findings are favorable for IT, CS, or CE engineers.

As societies enter the post-digital era, labor markets are constantly increasing demands for the new workforce empowered with novel digital competencies and skill sets that often did not previously exist. This fact combined with the inflation of education financial cost puts additional pressure on school stakeholders and educational systems in general, whether funded by the state or private. Digital technology integration into tertiary education reflected the trajectory of technological advancement (Hernández-Lara et al., 2019). Hu et al. (2018) reported positive effects of using digital technology on academic performance. The use of digital technology surely leads to informal learning (Knowles et al., 2015), whether aware of it or not. Even though numerous digital technology manifestations have been introduced into the process of education with the idea of being used as learning tools, there is limited empirical proof that they help or improve learning. This is because the technology is rarely created with the educational context in mind. For example, multitasking is one of the common characteristics of digitalization, but it interferes with cognitively demanding processes because it boosts the number of memory errors and processing time (Rubinstein et al., 2001). On other hand, self-efficacy negatively influences multitasking (Zhang, 2015). As for learning preferences, researchers emphasized that students were less interested in creative assignments, and are keen on working independently at their own pace (Knowles et al., 2015; Smith, & Cawthon, 2017).

Methodology

The research problem is how interactive digital technology exposure impact students learning performance in the field of computer graphics and simulations. The research aims to explore the relations between the ways students use digital devices and technologies, learning performance, and ultimately their academic success. As digital competencies presume the adequate use of technology, we argue that students often overestimate self-perceptive levels, thus they can easily fall into the negative spiral of behavioral and personality disorders. The results may inform whether and which interactive digital technologies should be perceived as valid tools in education that positively affect the academic performance of IT, CS, and CE Generation Z students, or could lead developing personality disorders.

Two research questions guiding us through the study were defined:

1. In what way does interactive digital technology preferences and habits affect IT, CS, and CE students learning performance and Internet gaming disorder?
2. Are there differences between Greek and Serbian students in terms of the effects of interactive digital exposure and academic success?

The research was realized between March and May 2022 at the School of Informatics, Aristotle University of Thessaloniki (Greece), and between October 2021 and January 2022 at the Faculty of Technical Sciences in Čačak, University of Kragu-jevac (Serbia). Both universities educate students in the fields of IT, CS, and CE. The selection of students and universities from these two states was made to evenly represent various geographic, economic, and socio-cultural environments. Students first completed the questionnaire anonymously at the school facilities in about 60 minutes and then performed a specific set of practical activities in accordance with their group affiliation lasting an additional 120 minutes. Two identical survey questionnaires were used to collect demographic and socioeconomic data - Greek and Serbian translated versions. Students provided their responses to three sets of questions. The first set was used to gather basic socio-demographic data, the second set of 21 questions was used to assess students' online technology exposure based on their Internet preferences and habits including the Internet Disorder Scale (IDS-15) (Pontes, & Griffiths, 2017), and the third set of 29 questions was used to assess digital gaming exposure preferences and habits including the Internet Gaming Disorder Test (IGD-20) (Mestre-Bach et al., 2022; Pontes et al., 2014). Key skills and competencies identified as significant for future professional engagement of IT, CS and CE students in the field of computer graphics and simulations were assessed by a series of short practical activities. Since students studied one of the three majors, key skills and competencies were tailored to each of their three future professional directions. In total, a series of 16 practical tasks, assignments, and tests in various areas of interest were performed (e.g., programming, creative thinking, 3D modeling, digital design, project management, focus, precision, and persistence while doing repetitive tasks on computers, etc.). Tertiary education grade point average (i.e., GPA) was administratively obtained.

Following the theoretical-empirical nature of the research, the participants were examined by the descriptive-analytical non-experimental method using surveys and quantitative observation, based on which the distribution of properties was established and the relationships among variables were analyzed. The data analysis was performed using IBM SPSS Statistics v22. The following methods were used: descriptive statistics (frequency, percentage, arithmetic mean, standard deviation, minimum, maximum, skewness, kurtosis), correlation analysis, χ^2 test, Independent samples t-test, Cronbach's alpha internal consistency coefficient, Kaiser-Meyer-Olkin (KMO) measure of sample adequacy, Bartlett's test, exploratory factor analysis, confirmatory factor analysis, analysis of variance (ANOVA), multivariate analysis of variance (MANOVA), Tukey HSD test, Mann-Whitney test, and regression analysis.

Results and Discussion

A total of 397 students participated in the research. The valid sample of N= 368 students consisted of N_M = 264 (71.7 %) males and N_F = 104 (28.3 %) females. The students were within the age range of 19-35 with an average age of M = 21.0 (SD = 1.77) years. In total, N_{URB} = 218 (59.2 %) of students were living in urban areas and N_{RUR} = 150 (40.8 %) were living in rural areas.

The focus of researchers exploring the relationships between Internet use and learning performance is generally on the time spent online and use frequency (Cao et al., 2018; Feng et al., 2019; Sahithi, 2020). Estimated weekly average hours were not self-evaluated by students but calculated by com-bining daily time with the information on which days of the week and what part of the day students usually used digital technology (Aleksić & Ivanović, 2017). This method is far more reliable and precise as it activates autobiographical memory (Hippler et al., 2012). The responses concerning interactive digital technology exposure time, Internet disorder factors (i.e., ID), and gaming disorder factors (i.e., GD) are presented in Table 1.

We observed the differences between Greek and Serbian students' interactive digital technology exposure related to their use of online services and gaming habits. A one-way multivariate analysis of variance (MANOVA) identified a statistically significant differences in average interactive digital technology exposure time, [F (4, 363) = 3.54, p = .008, Wilk's Λ = .962, partial η^2 = .038]. Students from Greece spent significantly more daily average minutes online, [F (1, 366) = 7.47, p = .007, partial η^2 = .020)], weekly average hours online, [F (1, 366) = 8.12, p = .005, partial η^2 = .022)], and weekly average hours gaming, [F (1, 366) = 7.28, p = .007, partial η^2 = .020)].

Students from Greece and Serbia reported different preferences and habits regarding interactive digital technology use, as presented in Table 2.

A chi-square test of independence showed that there was significant association between students' country and preferred devices used to go online, playing games, and Internet use habits, χ^2 (4, 368) = 12.2, p = .010, χ^2 (5, 368) = 19.8, p = .001, χ^2 (5, 368) = 38.4, p< .001, respectively. The type of preferred devices students used to go online and the weekly average hours spent gaming had the greatest effect on developing Internet gaming disorder. We detected a significant difference between Greek and Serbian students in Gaming disorder factors, [F (6, 361) = 4.60, p < .001, Wilk's Λ = .929, partial η^2 = .071]. All other digital technology exposure factors also significantly predicted the disorder. These findings are consistent with Gentile et al. (2017) research.

The impact of excessive Internet use on academic performance is extensively researched (Chowdhury et al., 2020; Javaeed

Table 1.Interactive digital technology exposure time, ID factor, and GD factor

Time	Greece		Serbia		Mean difference
	M	SD	M	SD	
Daily average minutes online	273.0	46.7	216.7	18.4	20.3**
Weekly average hours online	20.2	3.9	18.4	5.3	1.8**
ID: Escapism and dysfunctional emotional coping	39.8	19.6	32.4	20.4	7.4**
ID: Withdrawal symptoms	40.4	21.4	35.3	19.9	5.1*
ID: Impairments and dysfunctional self-regulation	32.7	20.7	28.7	21.5	4.0
ID: Dysfunctional Internet-related self-control	29.7	23.7	24.3	21.5	5.4
Daily average minutes of gaming	101.6	92.2	81.0	87.4	20.6
Weekly average hours of gaming	6.9	8.3	4.4	6.7	2.4**
GD: Salience	22.8	29.1	15.1	20.7	7.7**
GD: Mood modification	36.0	27.7	23.6	28.8	12.4**
GD: Tolerance	22.8	27.0	10.9	18.3	11.9***
GD: Withdrawal symptoms	10.7	21.2	5.4	12.8	5.3**
GD: Conflict	21.4	24.2	13.2	18.9	8.2**
GD: Relapse	18.4	24.3	9.9	17.0	8.5***

$^{*}p$< .05, $^{**}p$< .01, $^{***}p$< .001

Table 2. Online and gameplay preferences and habits

Interactive digital devices exposure	Greece		Serbia		Total	
	N	%	*N*	%	*N*	%
Online device						
Faculty/university computer	0	0.0	2	0.7	2	0.5
Home computer (desktop)	29	36.3	53	18.4	82	22.3
Laptop	9	11.3	58	20.1	67	18.2
Tablet	0	0.0	1	0.3	1	0.2
Smartphone	42	52.5	174	60.4	216	58.7
Internet use						
Search/browsing	18	22.5	49	17.0	67	18.2
Music	18	22.5	56	19.4	74	20.1
Video	21	26.3	41	14.2	62	16.8
Social networks	8	10.0	85	29.5	93	25.3
Messaging, chat, forums, etc.	15	18.8	45	15.6	60	16.3
Download	0	0.0	12	4.2	12	3.3
Gaming device						
At friend's or at the Internet café	0	0.0	3	1.0	3	0.8
Home computer (desktop)	41	51.3	104	36.1	145	39.4
Laptop	14	17.5	89	30.9	103	28.0
Gaming console	12	15.0	10	3.5	22	6.0
Smartphone or tablet	8	10.0	10	3.5	18	4.9
Don't play games	5	6.3	72	25.0	77	20.9

et al., 2019; Sengupta et al., 2017). In our case, 17 students from Greece (21.3 % of the sample group) and 31 students from Serbia (10.7 % of the sample group) were identified with the Internet gaming disorder. Multinomial logistic regression was performed to ascertain the effects of interactive digital technology exposure on the likelihood that students develop Internet gaming disorder. The logistic regression model was statistically significant, χ^2 (7) = 47.54, $p< .001$. The model explained 22.4 % (Nagelkerke R^2) of the variance in Internet gaming disorder and correctly classified 88.0 % of cases. However, a Mann-Whitney test indicated that the difference in tertiary education GPA between students regarding having Internet gaming disorder was not statistically significant, U (N_{NO} = 320, N_{YES} = 48) = 7159.5, z = -.799, p = .425. These findings are not consistent with (Hawi et al., 2018; Javaeed et al., 2019; Rehbein et al., 2016).

The learning performance construct factor analysis validity was initially tested by the Kaiser-Meyer-Olkin (KMO) measure of sample adequacy and Bartlett's test. As the value of the KMO measure of sampling adequacy .869 was satisfactory and Bartlett's test result was statistically significant χ^2 (120) = 492.9, $p< .001$, it was confirmed that the factor analysis can be performed and that the sample is adequate. The exploratory factor analysis was performed using the maximum likelihood method on the initial 16 variables using Promax rotation, which was further reduced to 7 following the analysis results. The Promax rotation with Kaiser Normalization converged in 5 iterations. One-factor solution explained 51.6 % of the variance. The established solution was checked by confirmatory factor analysis (i.e., CFA) with the maximum likelihood method. Indicator values χ^2/df = 5.66, $p< .001$, RMSEA = .013, SRMR = .078, CFI = .940, GFI = .902 were satisfactory. The learning performance construct was found to be of excellent overall reliability (16 items, $\alpha = .903$). The inter-item correlation matrix for each of the 16 factors show the existence of significant correlations that confirmed the validity of the construct. The average inter-item correlation mean was .347 confirming the internal consistency. The differences in learning performance construct factors are presented in Table 3.

A one-way multivariate analysis of variance (MANOVA) identified a significant difference between students from Greece and Serbia in learning performance [$F(16, 351) = 53.3$, $p < .001$, Wilk's $\Lambda = .292$, partial $\eta^2 = .708$]. Students from Serbia achieved better results than students from Greece in all activities except the Test of focus, precision, and persistence while doing repetitive tasks on a computer.

A Pearson correlation coefficient was computed to assess the relationship between digital technology exposure time and learning performance construct factors. There were weak negative correlations between daily average minutes spent online, weekly average hours spent online, and technical literacy score, $r(307) = -.147$, $p = .010$, $r(307) = -.157$, $p = .006$, respectively. Increases in time spent online correlated with decreases in the level of technical literacy skills. There also were weak negative correlations between daily average minutes spent online, weekly average hours spent online, and 2D Computer drawing score, $r(307) = -.179$, $p = .002$, $r(307) = -.186$, $p = .001$, respectively. Increases in time spent online correlated with decreases in the level of 2D Computer drawing skills. Negative correlations were also detected between daily average minutes spent online, weekly average hours spent online, and the level of teamwork/communication competence, $r(307) = -.137$, $p = .016$, $r(307) = -.149$, $p = .009$, respectively. Increases in time spent online correlated with decreases in teamwork/communication competence. These before-mentioned findings are consistent with (Feng et al., 2019). Cao et al. (2018) also pointed that increased cognitive preoccupation led to adverse psychological problems and indicated the presence of addiction disorder. Their research revealed that negative con-

Table 3. Learning performance differences

Skills and competencies	$F(1, 366)$	p	partial η^2
Procedural programming	27.1	.001	.069
Object-oriented programming	3.28	.071	.009
Computer architecture	.418	.518	.001
Digital signal processing	9.96	.002	.026
Technical literacy	90.8	.001	.199
2D Computer drawing	196.1	.001	.349
3D Computer modeling	175.9	.001	.352
Computer animation	142.4	.001	.280
Digital video editing	174.4	.001	.323
Teamwork/Communication	663.7	.001	.645
Creative thinking	8.50	.004	.023
Digital literacy	34.8	.001	.087
Digital design	42.8	.001	.105
Project management	20.7	.001	.054
Software development	78.7	.001	.177
Focus, precision, and persistence	3.19	.075	.009

sequences (e.g., life invasion, techno-exhaustion, privacy invasion) exerted a negative influence on students' academic performance. This negative relationship could also be interpreted as the consequence of cognitive and/or emotional technological preoccupation, as regular craving for interaction with digital devices surely lead developing obsession, social overload and exhaustion, ultimately causing downward spiral of academic success.

A one-way multivariate analysis of variance (MANOVA) was conducted to examine whether there was a significant difference between online device students preferred and learning performance construct factors. There was a statistically significant difference between preferred online devices in learning performance [F (16, 351) = 53.3, $p < .001$, Wilk's $\Lambda = .292$, partial $\eta^2 = .708$]. Post hoc comparisons using the Tukey HSD test indicated that the level of 3D Computer modeling skills was significantly higher for students who preferred using laptops compared to students who preferred using a desktop computer ($p = .019$). There also was a significant effect of online habits on object-oriented programming skills, $F(5, 362) = 2.17$, $p = .049$, $\eta^2 = .029$. Tukey HSD test indicated that the level of object-oriented programming skills was significantly higher for students that mostly used the Internet for search/browsing compared to students who mostly used the Internet for watching videos ($p = .033$).

Researchers exploring the influence of time spent playing digital games on learning performance are generally split into three camps by their observed positive, negative, or non-existent detected relation (Adžić et al., 2021; Blanco-Herrera et al., 2019; Buiza-Aguado et al., 2018; Dindar, 2018). A one-way between subjects ANOVA was conducted to compare the effect of preferred gaming device on learning performance construct. There was a significant effect of type of gaming device on computer architecture competence, $F(5, 362) = 2.43$, $p = .035$, $\eta^2 = .032$, technical literacy, $F(5, 362) = 3.11$, $p = .009$, $\eta^2 = .041$, 2D Computer drawing, $F(5, 362) = 3.82$, $p = .002$, $\eta2 = .049$, 3D Computer modeling, $F(5, 362) = 2.49$, $p = .031$, $\eta^2 = .033$, computer animation, $F(5, 362) = 2.31$, $p = .044$, $\eta^2 = .031$, digital video editing, $F(5, 362) = 3.14$, $p = .009$, $\eta^2 = .041$, and team-work/communication competence, $F(5, 362) = 3.74$, $p = .003$, $\eta^2 = .049$. Tukey HSD test indicated that the level of computer architecture competence was significantly higher at students that preferred playing on desktop computers, laptops or didn't play games compared to students that preferred gaming consoles, $p = .025$, $p= .029$, $p = .014$, respectively. The level of technical literacy skills was significantly higher at students that preferred playing on laptop, or didn't play games compared to students that preferred gaming consoles, $p = .047$, $p = .038$, respectively. The level of 2D Computer drawing skills was significantly higher at students that preferred playing on laptop, or didn't play games compared to students that preferred gaming consoles, $p = .009$, $p = .030$, respectively. Similarly, the levels of 3D Computer modeling and computer animation skills were significantly higher at students that preferred playing on laptop compared to students that preferred gaming consoles, $p = .009$, $p= .022$, respectively. The level of digital video editing skills was significantly higher at students that preferred playing on desktop computers, laptops or didn't play games compared to students that preferred gaming consoles, $p = .028$, $p= .005$, $p = .003$, respectively. The teamwork/communication competence was significantly lower at students that preferred playing on gaming consoles compared to students that preferred laptops ($p = .014$) or didn't play games ($p= .003$).

In order to predict the impact of interactive digital technology exposure on learning performance construct more accurately, we developed an Artificial Neural Network (i.e., ANN) model using seven predictor variables: daily average minutes online, weekly average hours online, online device, Internet use, daily average minutes gaming, weekly average minutes gaming, and gaming device. A multiplayer perception (i.e., MLP) class of ANN was used to build the model and test its accuracy. The data were randomly assigned to training (70%) and testing (30%) subsets. All covariates were normalized before the training. The scaled conjugate gradient method was used for the batch training of the ANN.MLP class of ANN identified N = 366 valid cases for processing, out of which N = 268 (73.2 %) was used for training, and N= 98 (26.8 %) was used for testing. The neural network identified 2 nodes in the hidden layer. The output layer used the SoftMax function. Cross entropy error for the training sample was 77.9 with 11.3 % of incorrect predictions. Cross entropy error for the testing sample was 24.5 with 8.7 % of incorrect predictions. The small value of error indicates the power of the predictive model. The MLP network correctly classified 235 students in the training sample, and 94 students in the testing sample. Overall, 88.7 % of the training cases were correctly classified. The identified predictors sorted by importance were: type of preferred gaming device (B = .26), type of preferred online device (B = .15), average weekly hours online (B = .14), average weekly hours gaming (B = .13), average daily minutes online (B = .12), Internet use habit (B = .11), and average daily minutes gaming (B = .10).

Researchers generally agree that academic success positively corelates with student learning performance (Putwain et al., 2012; York et al., 2015; Zhang, & Aasheim, 2011), and that the prolonged use of digital technology negatively reflects on academic success (Aaron, & Lipton, 2017; Flanigan, & Babchuk, 2022; Will et al., 2020). Our research show that the average tertiary education GPA of IT, CS, and CE students was M = 7.68 (SD = .905). An independent samples t-test was conducted to examine whether there was a significant difference between Greek and Serbian students concerning their GPA, and revealed a significant difference between groups $t(366) = -4.10$, $p< .001$. Students from Serbia achieved significantly higher tertiary education GPA M= 7.78 (SD= .880) than students from Greece M = 7.32 (SD = .907). A one-way between-subjects ANOVA showed that there was a significant effect of the type of online device on students' academic success, $F(4, 363) = 2.51$, $p = .042$, $\eta^2 = .027$. Tukey HSD test indicated that the GPA was significantly higher for students that preferred laptops compared to students that preferred smartphones, $p = .034$. A Pearson correlation coefficient was computed to assess the relationship between academic success and interactive digital technology exposure time. There were weak positive correlations between tertiary education GPA, average daily minutes online, r (362) = .107, p = .040, and average weekly hours online, r (362) = .110, p = .035. The increase in time spent online correlated with the GPA increase. When we compared the samples from Greece and Serbia, we detected weak positive correlations between GPA, average weekly, and daily online time only in the population of students from Serbia, r (282) = .136, p = .021; r (282) = .131, p = .027. Also, a significant effect of type of online device on GPA was detected only on Serbian population, $F(4, 283) = 2.89$, $p = .022$, $\eta^2 = .039$. The GPA was significantly higher at students from Serbia that preferred laptops compared to smartphones, p = .019.

A Pearson correlation coefficient was computed to assess the relationship between learning performance construct factors and academic success, as presented in Table 4. The findings are consistent with York et al. (2015).

When we compared the results from Greece and Serbia, we detected weak and strong positive correlations in the sample from Greece between tertiary education GPA, object-oriented programming, r (62) = .356, p = .001, and focus, precision and persistence while doing repetitive tasks on computer, r (62) = .789, $p< .001$. Weak positive correlations were also detected in the sample from Serbia, where GPA correlated with procedural programing skills, r (47) = .311, p = .012, computer architecture competence, r (47) = .255, p = .041, technical literacy, r (209) = .241, $p< .001$, 2D Computer drawing skills, r (209) = .149, p = .025, 3D Computer modeling, r (209) = .265, $p< .001$, computer animation, r (209) = .281, $p< .001$, digital video editing, r (209) = .304, $p< .001$, teamwork/

Table 4. Correlations between learning performance factors and academic success

	PP	OOP	CA	DSP	TL	2D	3D	ANI	DVE	T/C	CT	DL	DD	PM	SD	FPP
PP	-															
OOP	.35**	-														
CA	.15	.13	-													
DSP	.34**	.18*	.47**	-												
TL	.22*	.13	.42**	.23*	-											
2D	.19	.09	.44**	.47**	.42**	-										
3D	.18	.04	.60**	.55**	.44**	.59**	-									
ANI	.15	.07	.52**	.58**	.36**	.52**	.63**	-								
DVE	.20	.14	.33**	.40**	.51**	.48**	.49**	.64**	-							
T/C	.20	.00	.46**	.49**	.52**	.71**	.72**	.74**	.69**	-						
CT	.22*	.21	.31**	.34**	.31**	.39**	.29**	.43**	.37**	.32**	-					
DL	.15	.17	.40**	.19	.59**	.39**	.42**	.36**	.44**	.45**	.55**	-				
DD	.32**	.08	.49**	.57**	.37**	.58**	.55**	.62**	.58**	.65**	.47**	.51**	-			
PM	.16	.06	.41**	.34**	.47**	.42**	.43**	.44**	.53**	.53**	.33**	.50**	.61**	-		
SD	.30**	.21	.53**	.44**	.52**	.55**	.66**	.71**	.64**	.75**	.41**	.47**	.55**	.45**	-	
FPP	.29**	.08	.02	.10	.16**	.04	.01	.00	.01	-.04	.08	-.07	-.19*	-.03	-.10	-
GPA	**.32****	**.24****	**.07**	**.09**	**.28****	**.17****	**.25****	**.24****	**.26****	**.23****	**.24****	**.24****	**.20***	**.22***	**.37****	**.27****

$^{*}p < .05$, $^{**}p < .01$

Note: PP - Procedural programming; OOP - Object-oriented programming; CA - Computer architecture; DSP - Digital signal processing; TL - Technical literacy; 2D - 2D Computer drawing; 3D - 3D Computer modeling; ANI - Computer animation; DVE - Digital video editing; T/C - Teamwork/Communication; CT - Creative thinking; DL - Digital literacy; DD - Digital design; PM - Project management; SD - Software development; FPP - Focus, precision, and persistence; GPA – Academic success (tertiary education GPA)

communication competence, r (209) = .332, $p< .001$, creative thinking skills, r (30) = .355, $p = .013$, project management, r (30) = .327, $p = .023$, and focus, precision and persistence while doing repetitive tasks on computer, r (270) = .250, $p< .001$. The level of object-oriented programming skills was significantly higher among students that mostly used the Internet for search/browsing compared to students who mostly used it for watching videos, which is consistent with Chowdhury et al. (2020). Comparing the results from Greece and Serbia, neither group detected significant difference in relation to Internet gaming disorder or GPA.

The levels of teamwork/communication competence, computer architecture competence, technical literacy, 2D Computer drawing, 3D Computer modeling, computer animation, and digital video editing skills were significantly lower among students that preferred playing on gaming consoles compared to students that preferred desktop computers or laptops. The type of preferred gaming device was the most important digital gaming exposure predictor of learning performance. To the best of our knowledge, no other studies compared the effects of various gaming devices on student academic performance and success.

No significant correlations were detected between time spent gaming and learning performance construct factors or GPA. These findings are consistent with (Adžić et al., 2021; Dindar, 2018).

Limitations

The research was realized with certain limitations. Even though the sample was adequate in structure and size, and the psychometric instruments were reliable and valid, the conclusions about the identified causal relationship between interactive digital technology exposure, learning performance construct factors, and academic success was impossible to confirm due to the correlation nature of the research, so the focus of these relations should be clarified by longitudinal research which would add the dynamic dimension. Further research is needed in other countries to examine our proposed learning performance conceptual model. We also did not examine demographic differences between students from Greece and Serbia. Despite these limitations, this research supports the importance of fostering digital technology in education, taking into account all its advantages, but risks of also.

Concluding remarks

To investigate relations between interactive digital technology exposure, learning performance in the field of computer graphics and simulations, Internet gaming disorder, and the Generation Z Greek and Serbian IT, CS, and CE students' academic success we developed a conceptual model with three main constructs: digital online exposure, digital gaming exposure, and learning performance. Our theoretical contribution to the literature is the proposal of an integrated theoretical model that includes defined constructs and combined Internet gaming addiction factor as predictors of academic success. The examination was performed on a sample of 397 students from two state universities in Greece and Serbia. The results showed that students from Greece spent significantly more time online and more time gaming compared to students from Serbia. However, no significant difference between these two populations was detected for the occurrence of Internet gaming disorder. Students from Serbia achieved better results in all learning performance activities except the test of focus, precision, and persistence while doing repetitive tasks on a computer. Comparing the results, in neither group a significant correlation was detected concerning Internet gaming disorder and GPA.

The conceptual learning performance construct in the field of computer graphics and simulations was found to be valid and of excellent overall reliability. The types of preferred gaming and online devices were the most important digital exposure predictors of learning performance factors. Contrary to online exposure, digital gaming exposure was not related to academic success. To our surprise, Internet gaming disorder also was not a significant predictor of academic success. Research results contribute to a deeper understanding of the extremely complex relationships between the digital social environment, students' preferences and habits, and learning performance factors that are specific for the field of computer graphics and simulations. It has been proven that students' daily activities have a great impact on their learning performance. Learning performance construct can be utilized in two ways: (1) as a diagnostic tool with which teachers/instructors adjust their activities and effectively improve teaching practice; (2) as an indicator that help students self-diagnose and correct behavior in order to improve learning performance and consequently academic success.

Even though students from Greece and Serbia have different preferences and habits using digital technology, the comparative analysis of its relations and effects on learning performance and academic success presented similar results and conclusions confirming our initial expectations.

Future research will include experimental measurement points to better reflect the complex spectrum of digital technology exposure. Based on the presented findings, the conceptual model proposed in this article will be adapted for future research.

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УТИЦАЈ ИЗЛОЖЕНОСТИ ИНТЕРАКТИВНОЈ ДИГИТАЛНОЈ ТЕХНОЛОГИЈИ НА ПЕРФОРМАНСЕ УЧЕЊА РАЧУНАРСКЕ ГРАФИКЕ И СИМУЛАЦИЈЕ СТУДЕНАТА ГЕНЕРАЦИЈЕ З: КОМПАРАТИВНО ИСТРАЖИВАЊЕ ИЗМЕЂУ ГРЧКЕ И СРБИЈЕ

С обзиром на то да је функционалност савремених дигиталних друштава примарно заснована на интерактивној дигиталној технологији, образовна технологија је неизбежно прошла кроз процес дигитализације. Студије информационих технологија, рачунарских наука или рачунарског инжењерства у постдигиталној ери студентима значајно отежавају раздвајање личних потреба за технологијом, потреба за учењем и захтева будуће каријере, доводећи их у велики ризик од развоја психичких поремећаја. Фокус нашег истраживања је на популацији старијих адолесцената и младих у раним двадесетим годинама, често називаних генерација З, јер су одрасли у окружењу преносивих дигиталних уређаја, уобичајено повезаних на интернет, и разноврсних онлајн-сервиса који се већином и данас користе.

Циљ истраживања је испитивање утицаја изложености интерактивној дигиталној технологији на резултате у изучавању рачунарске графике и симулација. Испитане су релације између начина на које студенти користе дигиталне уређаје и технологије, перформанси учења и њиховог академског успеха. Будући да дигиталне компетенције подразумевају адекватно коришћење технологије, тврдимо да студенти често прецењују сопствени ниво компетенција, те да последично лако могу ући у негативну спиралу поремећаја понашања и личности.

Истраживање је спроведено између октобра 2021. и маја 2022. године на Департману за информатику Аристотеловог универзитета у Солуну (Грчка) и на Факултету техничких наука у Чачку Универзитета у Крагујевцу (Србија). Узорак истраживања сачињавало је укупно 397 студената из Грчке и Србије, одабраних тако да равномерно представљају различите географске, економске и социокултурне средине. Студенти су најпре вршили самопроцену дигиталних навика, склоности и вештина путем упитника, а потом и реализовали скуп практичних задатака и активности које су биле оцењиване. У складу са теоријско-емпиријском природом истраживања, учесници су испитивани коришћењем дескриптивно-аналитичке неексперименталне методе реализоване путем анкета и квантитативног посматрања, на основу којих је успостављена дистрибуција својстава и анализирани су односи међу варијаблама.

Студенти из Грчке су проводили просечно значајно више времена у коришћењу онлајн-сервиса и играјући дигиталне игре. Врста дигиталних уређаја које су студенти користили за приступ интернету и просечан недељни број сати проведених у игрању ди-

гиталних игара имали су најзначајнији утицај на поремећаје понашања у виду развоја зависности од играња дигиталних игара на интернету. Студенти из Србије су постигли боље резултате од студената из Грчке у свим практичним активностима осим у тестовима фокуса, прецизности и упорности при обављању репетитивних задатака на рачунару. Повећање времена проведеног онлајн негативно је корелирало са процењеним нивоима вештина техничке писмености, 2Д цртања на рачунару и компетентношћу за тимски рад и комуникацију. Ова негативна веза је интерпретирана као последица когнитивне и/или емоционалне преокупације технологијом, будући да редовна жеља за интеракцијом са дигиталним уређајима може довести до развијања опсесије, преоптерећења друштвеним мрежама и исцрпљеношћу, што студента на крају уводи у спиралу пада академског успеха. Врста омиљених уређаја за играње дигиталних игара била је најважнији предиктор изложености дигиталној технологији у погледу побољшања фактора учења, како у Грчкој, тако и у Србији. Изненађујуће, изложеност дигиталним играма и зависност од играња дигиталних игара на интернету нису били значајни предиктори академског успеха.

Резултати истраживања доприносе дубљем разумевању изузетно сложених веза између дигиталног социјалног окружења, дигиталних преференци и навика студената и фактора учења који су специфични за област изучавања рачунарске графике и симулација. Стога модел процене и предикције представљен у овом раду дуално пружа наставницима могућност да ефикасније прилагоде своје активности, а студентима алат за самодијагностику који им може помоћи да побољшају резултате учења.

Кључне речи: *образовна технологија, рачунарска графика, рачунарске симулације, учење*