

## Usage of Virtual Reality and Gamification to Enhance Pre-Clinical Endodontic Teaching Process: First Experience among Ukrainian Dental Students

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### Abstract

Objective of the research was to verify impact of using virtual reality and gamification principles during dental education dedicated to the teaching of pre-clinical endodontics on the students' motivation, academic success and readiness for clinical-based courses.

Research was organized in the form of cross-section study to assess and monitor differences of such parameters, as students' motivation, academic success and readiness for clinical-based courses, among students undergoing pre-clinical endodontic education with and without application of virtual reality and gamification principles through the study process. Study cohort was formulated out of 60 students, representing six academic groups of 3rd year of education, which were distributed randomly to study and control groups. Virtual reality for educational objectives was formed in the manner of non-immersive VR type environment with the interaction being kept by the use of smartphone.

Obtained results demonstrated that usage of virtual reality and gamification principles significantly impact intrinsic motivation of student, while also their motivation for future clinical-based endodontic courses, considering that mean values for those parameters were statistically different between study and control groups ( $p < 0.05$ ). Differences in mean values of self-determination, self-efficacy and grade motivation components between study and control groups were not significant ( $p > 0.05$ ). Fact of implementing virtual reality and gamification principles into the educational process and level of classes' interactivity shown the highest level of correlation with educational motivation within study group ( $r = 0.79$ ,  $p < 0.05$  and  $r = 0.77$ ,  $p < 0.05$  respectively). Educational approach with the involvement of virtual reality increases familiarity of dental students with modern digital technologies, while gamification principles support interactivity pattern based on usage of smartphones and adapted software irrespectively of location (in cases if education is held in online mode) and time (full-time access, if classes were interrupted because of different reasons).

Virtual reality and gamification should be considered as additive educational components to keep up the track of continuous education within the conditions when casual educational workflow may be interrupted due to the number of reasons, including war, mass disasters and pandemics.

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### Introduction

Present changes of dental education patterns associated with the significant tendency towards the use of digitalization approaches within the teaching practices.<sup>1, 2, 3</sup> Considerable progress within digital technologies in general and such associated with dental field particularly supported the spread of digital instruments in workflow of dental education, while transition to

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the online or hybrid modes of education during COVID-19 pandemic period strengthened the impact of digitalization and predicted its usefulness in future of education patterns.<sup>3, 4, 5</sup>

Digitalized educational practices also demonstrated possibilities for keeping integrity of educational process and improving students' motivation under the conditions when the classes could not be held in conventional in-room manner due to the various reasons, or when such were held solely in distant online mode for the prolonged period of time (usually observed among students in emigration).<sup>6, 7</sup> Moreover, possibility of interaction with digital dental technologies during the classes demonstrated effect of stress coping and academic interest growth among students undergoing dental education on the background of war taking place in their country.<sup>6</sup> Such effects highlight the potential impact of digital dental education technologies that are still expanding parallel to the new frontiers of all-surrounded digitalization trend.

Ones of the most prominent approaches within relevant dental education strategies are virtual reality technology in various forms of its representation and gamification as an instrument for reasoned students' motivation.<sup>8</sup> Principles of virtual reality technology based on the usage of digital environment that mimics real clinical conditions in which operator can expand his or her knowledge and evaluate its' practicability before starting the real-life clinical trainings.<sup>8, 9, 10, 11, 12, 13</sup> Gamification within dental education includes different modifications of conventional learning patterns, which helps to improve behavior and attitudes towards learning, making educational process more interactive and engaging.<sup>14, 15, 16</sup>

However, recent systematic review has highlighted that even though different forms of dental virtual simulators have been developed through last decade, such still could not replace traditional dental training approaches.<sup>17</sup> Even during the pre-clinical courses virtual simulators should be considered as additives to the convention phantom training mimicking clinical conditions, while no simulations can replace clinical experience which students are gaining through hands-on courses or during their clinical practice within university.<sup>17, 18</sup>

Growing body of evidence regarding the use of different virtual simulators combined with

bid data, cloud services, artificial intelligence technologies and neural networks still do not provide enough support for unambiguous reasoning of using virtual reality during dental education process.<sup>18,19</sup>

The same situation have been disclosed also regarding application of gamification during the education of health professionals: even though recent systematic review have demonstrated that gamification tends to improve learning outcomes, however there is still deficiency in research regarding which mechanisms are responsible for such effect, and overall too little evidences are available to prove positive effect of gamification on the dental education in unequivocal manner.<sup>20</sup> It is worth to mention that available gamification examples developed for dental education are rather simple and characterized with linear course of events, while so-called serious games remain under development requiring resources and time for development.<sup>20, 21, 22</sup>

Increase of interactivity level both for the virtual reality applications and games during dental education may enhance their acceptance by students and approximate them to the real clinical conditions, however such improvements should be argumentatively cost effective and simply to spread to reach the sufficient impact on education process. Interactivity on the other hand may be improved not only by increasing level of immersion, but also by enhancing dynamic and recall of interaction, while also supporting possibility to use it without any additional devices, except already available, like smartphones.

Null hypothesis for present study was formulated in the way that application of virtual reality and gamification principles during pre-clinical endodontic education does not impact student's motivation, educational engagement, and academic success, and does not provide any additional effect on students' readiness for future clinical-based trainings.

### Objective

To verify impact of using virtual reality and gamification principles during dental education dedicated to the teaching of pre-clinical endodontics on the students' motivation, academic success and readiness for clinical-based courses.

## Materials and methods

### Study design

Research was organized in the form of cross-section study to assess and monitor differences of such parameters, as students' motivation, academic success, and readiness for clinical-based courses, among students undergoing pre-clinical endodontic education with and without application of virtual reality and gamification principles through the study process. Study cohort was formulated out of 60 students, representing six academic groups of 3<sup>rd</sup> year of education, which were distributed randomly to study and control groups.

Study group was formed of 32 students representing three academic groups of 3<sup>rd</sup> year of education, who were undergoing course of pre-clinical endodontic education including both conventional education pattern, but also with additive use of virtual reality and gamification principles during the education curriculum. After specific topics students were given link to the virtual reality, which they could open through their smartphones, and which was filled with 3D visualization of tooth anatomy, endodontic instruments etc., while also with presentations of study materials.

Control group was formed of 28 students representing also three academic groups of 3<sup>rd</sup> year of education, who were undergoing course of pre-clinical endodontic education in conventional manner without use of any additional digital or immersive technology.

Study was conducted at the Department of Restorative Dentistry (Faculty of Dentistry, Uzhhorod National university).

Outcomes of study were gathered by the online questionnaire-based survey held among students at the beginning of pre-clinical endodontic course and at the end of such to clarify the effect of virtual reality and gamification principles during the endodontic pre-clinical education curriculum on the students' educational motivation, academic success and readiness for clinical-based courses. The overall length of pre-clinical endodontic course corresponds to the 30 targeted topics and 120 academic hours as per approved work program of the academic discipline at the Department of Restorative Dentistry (Faculty of Dentistry, Uzhhorod National university) for 2023-2024 academic year.

Survey was held through complex questionnaire designed within the Google Forms service. Link to the questionnaire was sent to the emails of all 60 students with the official invitation to participate in the study. Invitations were addressed only to the emails of students, which were officially registered at the domain of the university, and the access to the online questionnaire was permitted only to students with verified university domain-linked emails ([uzhnu.edu.ua](mailto:uzhnu.edu.ua)).<sup>6, 24</sup> Overall 60 students received invitation to participate in the online survey.

### Endodontic-oriented educational virtual reality and gaming space

Virtual reality for educational objectives was formed in the manner of non-immersive VR type environment with the interaction being sustained by the use of smartphone. Manipulations within virtual reality were organized through the controls on the screen of the smartphone, or by any other controllers suitable for the model of smartphone available at student.

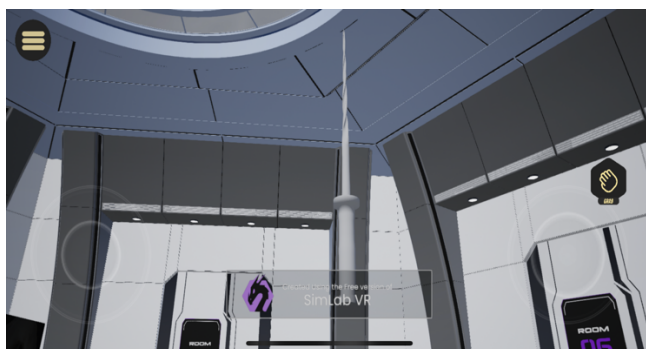
Educational virtual reality was created through the SimLab VR Studio 12.2.18 (Simulation Lab Software L.L.C., Amman, Jordan). Students were interacting with the created virtual environment through the SimLabVRViewer software (Simulation Lab Software L.L.C., Amman, Jordan) (Figure 1).



**Figure 1.** Schematic representation of virtual reality environment containing 3D models within the specialized software.

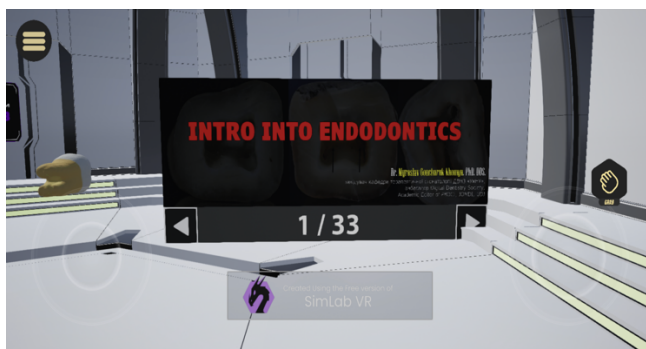
Filling of created virtual environment with 3D models was provided with those available from the Internet with free share license, while the most models were created at the Department of Restorative Dentistry (Uzhhorod National University) by scanning different targeted objects with the intraoral or laboratorial scanner. 3D models of teeth were obtained from the CBT

scans with further conversion, segmentation, and processing into \*.stl. files (Figure 2).



**Figure 2.** Representation of endodontic file's 3D model available from the internet with free share license incorporated within created endodontic-oriented virtual reality.

Educational materials in the form of presentations were also incorporated into the virtual environment. Within the provided environment student could move from one virtual room to another by opening doors and discovering new materials and 3D models related to the study topic; such approach represented gamification principles at the formulated virtual reality (Figure 3).



**Figure 3.** Schematic representation of virtual reality environment containing lecture's materials within the specialized software.

### Questionnaire design

Assessment of students' motivation toward pre-clinical endodontic learning was provided based on adapted version of Science Motivation Questionnaire II (SMQ-II), in which word «science» was changed to the word «endodontics». <sup>23</sup> SMQ-II helps to assess several parameters of educational motivations, such including intrinsic motivation, self-determination, self-efficacy, career motivation, and grade

motivation. <sup>23</sup> Component of career motivation was changed into component of motivation for future clinical-based endodontic courses. Response options on the SMQ-II questionnaire were presented in the form of 5-point rating scale with further interpretations of answers: 0 – never, 1 – rarely, 2 – sometimes, 3 – often, 4 – always. <sup>23</sup>

Assessment of connections between students' educational motivation, academic success and readiness for clinical-based courses and specifics of providing educational workflow with or without the use of virtual reality and gamification principles was provided based on the adapted questionnaire, which included 5 questions. <sup>6</sup> These questions were following:

1. Q1: Rate the connection between the fact (for study group)/or perspective (for control group) of implementing virtual reality and gamification principles into the educational process and your personal educational motivation.
2. Q2: Rate the connection between the quality of educational material provided and your personal educational motivation.
3. Q3: Rate the connection between the accessibility to the education material and your personal educational motivation.
4. Q4: Rate the connection between the level of visualization used during the classes and your personal educational motivation.
5. Q5: Rate the connection between the level of classes' interactivity and your personal educational motivation.
6. Q6: Rate the connection between your engagement into education during pre-clinical endodontic education and your readiness for further clinical-based courses.
7. Q7: Rate the connection between your personal educational motivation and your personal academic success during pre-clinical endodontic courses.

Answers to the above-mentioned questions could be provided corresponding to conventional Likert scale with the following interpretation: 1 – no connection, 2 – weak connection, 3 – moderate connection, 4 – good connection, 5 – strong connection.

Online questionnaire was organized in the format of multiple-choice, closed-end type, so students could choose only one answer to each question. <sup>6</sup> Questionnaire considered completed only if answers on all questions were obtained.



Only fully completed questionnaires were considered for further data analysis with subsequent statistical processing.

### Statistical analysis

Considering that questionnaire was organized via Google Forms service it was possible to convert all the obtained answers into the \*.xls-spreadsheet files suitable for further processing within Microsoft Excel 2019 software (Microsoft Office 2019, Microsoft Corp., USA). Such software with the pre-installed XLSTAT add-in (Addinsoft Inc., Long Island, NY, USA) was used for inferential statistical analysis.<sup>6, 24</sup> All the obtained responses were tabulated to verify their distribution specifics, and mean values with standard deviations were calculated for each analyzed category. Pearson's correlation coefficient was used to objectify the inter-relations between studied parameters, while significance of observed correlations were approved only if p-value corresponded to  $< 0.05$ . Correlation level was classified due to the standard established scale ( $0 < r \leq 0.19$  – very low correlation,  $0.2 \leq r \leq 0.39$  – low correlation,  $0.4 \leq r \leq 0.59$  – moderate correlation,  $0.6 \leq r \leq 0.79$  – high correlation,  $0.8 \leq r \leq 1.0$  – very high correlation).<sup>25</sup> Differences between study and control group were assessed considering Mann–Whitney U test analysis, taking into account observed data distribution pattern.

### Ethical aspects

Design of present study was approved by Institutional Review Board of Faculty of Dentistry at Uzhhorod National University (Ukraine) as such corresponding with generally accepted ethical standards. Provided research is a part of complex scientific research work of the Department of Restorative Dentistry at Uzhhorod National University (Ukraine). Even though access to the survey was possible to obtain only from university-linked e-mails of the students, it was held in this manner just to verify students' affiliation either with study or control group. No personal information was disclosed after the survey, obtained answers were anonymized and only quantitative parameters were the matter of research objective.

### Results

28 out of 32 students from the study group completed the survey demonstrating response rate of 87.5%, while all students from

the control group finished the survey providing 100% response rate.

Obtained results demonstrated that usage of virtual reality and gamification principles significantly impact intrinsic motivation of student, while also their motivation for future clinical-based endodontic courses, considering that mean values for those parameters were statistically different between study and control groups ( $p < 0.05$ ). Differences in mean values of self-determination, self-efficacy and grade motivation components between study and control groups were not significant ( $p > 0.05$ ) (Table 1).

Educational motivation components	Study group		Control group		Significance of difference p-value
	Mean value	SD (standard deviation)	Mean value	SD (standard deviation)	
Intrinsic motivation	15.45	2.73	11.14	2.56	$p < 0.05$
Motivation for future clinical-based endodontic courses	17.41	2.34	14.02	3.14	$p < 0.05$
Self-determination	14.45	3.09	12.72	3.65	$p > 0.05$
Self-efficacy	13.72	3.26	12.85	3.98	$p > 0.05$
Grade motivation	13.56	3.52	13.73	2.96	$p > 0.05$

**Table 1.** Mean values of educational motivation components registered among students after the completion of pre-clinical endodontic course.

Considering distribution of responses obtained from students it was found that all of the studied parameters demonstrated statistically approved correlation with educational motivation, which may be quantified as high-level correlation ( $0.6 \leq r \leq 0.79$ ). Fact of implementing virtual reality and gamification principles into the educational process and level of classes' interactivity shown the highest level of correlation with educational motivation within study group ( $r = 0.79$ ,  $p < 0.05$ , and  $r = 0.77$ ,  $p < 0.05$  respectively). Control group disclosed such factors as level of classes' interactivity and accessibility to the educational material as such being the most correlated with the educational motivation ( $r = 0.79$ ,  $p < 0.05$  and  $r = 0.74$ ,  $p < 0.05$  respectively). The most significant differences regarding correlation levels established between studied factors and educational motivation within study and control groups were observed for fact or perspective of implementing virtual reality and gamification principles into the educational process ( $r = 0.79$ ,  $p < 0.05$  for study group vs.  $r = 0.65$ ,  $p < 0.05$  for control group), and for level of visualization used during the classes ( $r = 0.77$ ,  $p < 0.05$  for study group vs.  $r = 0.65$ ,  $p < 0.05$  for control group).

Both study and control groups demonstrated prominent levels of correlation between engagement into education during pre-clinical endodontic education and readiness for further clinical-based courses ( $r = 0.72$ ,  $p < 0.05$  and  $r=0.70$ ,  $p < 0.05$  respectively). In regard to personal academic success both study and control groups demonstrated the lowest level of correlation between such parameter and educational motivation ( $r = 0.69$ ,  $p < 0.05$  and  $r=0.56$ ,  $p < 0.05$  respectively) compared to all other observed correlation levels. Nevertheless, study group was characterized with high level of correlation between personal educational motivation and personal academic success, while control group demonstrated moderate correlation between such parameters (Table 2).

Factors	Educational motivation			
	Study group		Control group	
	r	p-value	r	p-value
Fact or perspective of implementing virtual reality and gamification principles into the educational process	0.79	$p < 0.05$	0.65	$p < 0.05$
Quality of provided education materials	0.76	$p < 0.05$	0.72	$p < 0.05$
Accessibility to the education material	0.70	$p < 0.05$	0.74	$p < 0.05$
Level of visualization used during the classes	0.76	$p < 0.05$	0.65	$p < 0.05$
Level of classes' interactivity	0.77	$p < 0.05$	0.78	$p < 0.05$
	Readiness for further clinical-based courses			
Engagement into education during pre-clinical endodontic education	0.72	$p < 0.05$	0.70	$p < 0.05$
	Personal academic success			
Level of personal educational motivation obtained during the classes	0.69	$p < 0.05$	0.56	$p < 0.05$

**Table 2.** Correlations between studied parameters and students' educational motivation, academic success, and readiness for clinical-based courses considering students' subjective assessment.

## Discussion

Due to the available literature analyzed by authors of present publication this research is the first one which reports results of using virtual reality and gamification principles to enhance endodontic teaching process specifically among Ukrainian students.

Considering obtained results null hypothesis may be rejected partially, because application of virtual reality and gamification principles during pre-clinical endodontic education impact only some components of students' educational motivation (intrinsic motivation and motivation for future clinical-based endodontic courses), supported students' enthusiasm for further clinical-based courses, but

did not significantly influenced students' academic success and grade motivation.

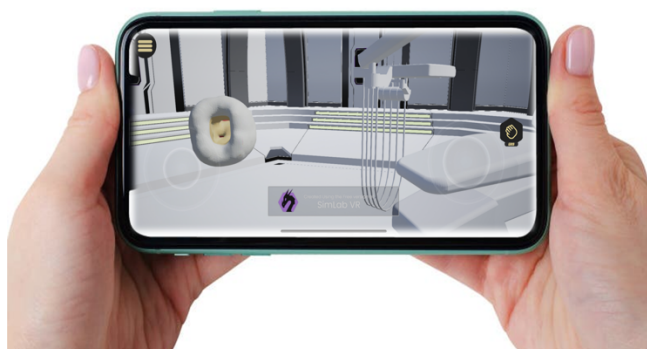
Previously provided systematic review demonstrated that implementation of virtual reality and interactive simulators significantly improve educational outcomes and have been positively accepted by the respondents.<sup>9</sup> Within systematic review studies dedicated to the experience of using VR for endodontic teaching reasons demonstrated that such may even improve participants' procedural performance in clinical conditions after realizing such within VR haptic simulators.<sup>9</sup> Moreover, students demonstrated higher adherence for studying root canal anatomy based on the materials provided through VR-environment compared to the conventional education approach based on periapical radiographs.<sup>9</sup> Present research also demonstrated well established tendency of increasing both students' motivation and readiness for future clinical-based endodontic courses considering experience of using virtual reality and gamification principles during pre-clinical endodontic education.

Several previous studies have described methodologies of creating virtual reality simulations which may be further used specifically for endodontic teaching reasons.<sup>10, 11, 12, 26, 27</sup>

Carpegna G. et al described experience of using VR simulations for endodontic microsurgery with possibilities to save all the provided progress and review it after some time.<sup>11</sup> Such simulator was created using Virteasy Editor, which enables transformation of stereolithography format into the volumetric haptic solid objects, while also specific interface of software was created for such purpose.<sup>11</sup> In present study SimLab VR Studio software was used to create endodontically centered virtual reality filled with 3D models of endodontic instruments, teeth, dental equipment, and study materials. It should be highlighted that such software is easy and intuitive to use, it provides possibility to fill virtual environment with all the needed content, while proposing some basic templates of virtual environment surroundings. In present study most of the 3D objects were created by the first author of manuscript using intraoral and laboratorial scanning technologies and graphical manipulation with CBCT results, which further were converted into the suitable format and transferred into virtual environment.

Significant advantage of proposed study

model with the use of virtual reality and gamification principles represented by the student's possibility to reach out to the created virtual environment at any time using just a smartphone as the only needed device. Manipulations by the touchscreen were the main controlling principle ensuring dynamics, interaction, and gamification of the approach, since environment consisted of several virtual rooms filled with different 3D models and study materials (Figure 4).



**Figure 4.** Schematic representation of interaction with endodontic-oriented virtual reality through the smartphone which could be provided through the finger-tapping principle (example of interacting with 3D models)

Development of the virtual reality analogical to proposed one is relatively fast, cost effective and requires only limited amount of time and financial resources, which are reasonable considering impact of proposed approach on students' motivation and readiness for future clinical courses.



**Figure 5.** Schematic representation of interaction with endodontic-oriented virtual reality through the smartphone which could be provided through the finger-tapping principle (example of interacting with lecture's materials).

Proposed educational approach with the involvement of virtual reality and gamification principles also characterized with the possibilities to improve dental educational outcomes when integrity and continuity of conventional teaching workflow may be compromised due to the number of reasons, like war-linked, mass disaster or pandemic conditions.<sup>6</sup> In the circumstances of constant classes interruption and dismissal because of missile threat it is important to try keep the focus and motivation of students and such pedagogical attempts should be targeted not only on reaching some specific educational aims, but also directed on overcoming and lowering stresses and anxiety levels among students in general. Well-structured and appropriately organized educational process with the correct manner of realization may be used as somewhat of coping technique to overcome the impact of surrounding stress factors to some extent.<sup>6</sup>

During present research it has been shown that implementation of digital dental technologies into the study process helps to increase students' motivation regarding knowledge expansion and readiness for further clinical-based courses, but still, such did not impact their motivation for the better grade. Analogical results were also observed in previous study, but it is worth to mention that study group of students which experienced pre-clinical endodontic education with application of virtual reality and gamification principles through the study process demonstrated higher level of correlation between educational motivation and personal academic success.<sup>6, 7</sup>

Limitations of present study related with its pilot design, so on the factual stage of research the first effect of implementing virtual reality and gamification into the educational process has been investigated, while it is important to understand the remote outcomes of such approach and its interaction with components of conventional teaching practices. Another limitation of study is linked to the fact that virtual reality and gamification principles were used as additives but not substitutes to the conventional education approach, so it is impossible to justify their solitary impact on the studied outcomes. Results registered within present study also should be interpreted prudently, considered that students' responses were recorded in singular manner at specific time



period, which corresponded to the cross-sectional study design, and it is unclear what was the retention of effect obtained after implementing virtual reality and gamification into the educational process, and how such effect may change based on the impact of personal, social or environmental factors, and within the matter of time.

Also, it should be mentioned that incorporation of virtual reality and gamification changed educational process not only for students, but also for teachers, but such effect was not studied in present research, meanwhile it may be hypothesized that teachers' effort itself within new educational conditions may support better educational outcomes among students with the same level of significance as virtual reality and gamification instruments themselves. There is still a problem for establishing some unified approach of implementing both virtual reality and gamification into the dental educational process, and logically that such may vary based on the discipline content, structure, and possibility of transferring components into the virtual environment.<sup>9, 10, 11, 12, 19, 21, 22</sup>

In present study virtual reality was studied as an educational instrument to expand students' knowledge within pre-clinical educational phase, and thus increase students' preparedness to the future clinical courses, while in future it would be relevant to verify how virtual environment and gamification may impact endodontic clinically-oriented education especially in cases of mastering practical manipulations.

## Conclusions

Considering limitations of present study and its pilot design it may be resumed that usage of virtual reality and gamification help to improve process of dental education dedicated to the teaching of pre-clinical endodontics in means of increasing students' motivation, their personal involvement and readiness for the future clinical courses. No impact of using virtual reality and gamification principles during pre-clinical endodontic education was observed regarding students' self-determination, self-efficacy and grade motivation.

Educational approach with the involvement of virtual reality increases familiarity of dental students with modern digital technologies, while gamification principles

support interactivity pattern based on usage of smartphones and adapted software irrespectively of location (in cases if education is held in online mode) and time (full-time access, if classes were interrupted because of different reasons).

Virtual reality and gamification should be considered as additive educational components to keep up the track of continuous education within the conditions when casual educational workflow may be interrupted due to the number of reasons, including war, mass disasters and pandemics.

## Declaration of interest

The authors report no conflict of interest, and article was not funded or supported by any research grant.

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