Use of Ubiquitous 360° Learning Environment Enhances Students' Knowledge in Clinical Histotechnology: a Quasi-Experimental Study

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ABSTRACT

Higher education is changing from electronic and mobile learning towards ubiquitous learning and ubiquitous learning environments. A ubiquitous learning environment combines real-life learning situations with corresponding situations in virtual environments by using spherical 360° panorama images, mobile devices, wireless networks, functional objects and sensing technologies. In this study a ubiquitous 360° learning environment was used for clinical histotechnology studies in three universities of applied science. The aim was to compare the differences in students' histotechnological knowledge between and within experimental utilizing a ubiquitous 360° learning environment (ULE) and control group utilizing a web-based learning environment (WLE) before and after the studies. In total 112 students of biomedical laboratory science degree participated voluntarily in this study. The participants were divided into experimental (n=60) and control groups (n=52). The students' knowledge of histotechnology was tested at the beginning and the end of the course by using an evaluation instrument developed in this study. The participants in the experimental group possessed stronger knowledge when compared to students in the control group. Significant differences were defined when interactions between time, group and test scores were analyzed. The students in experimental group achieved significantly better than students in control group. The level of knowledge increased significantly in both groups. Based on the results can be concluded that use of ubiquitous 360° learning environment enhances learning and can be used as effective method in histotechnology studies.

Keywords

Higher education; Histotechnology; Knowledge test; Ubiquitous learning environment; U-learning; 360° technology

What is already known about this topic

- Higher education educators are interested of new technologically supported methods to enhance students´ learning
- Use of ubiquitous learning environments in higher education is not widely used or reported.
- 360° technology supports learning environment development.

What this paper adds

- Practical implication of 360° technology use in higher education context.
- Description how the use of ubiquitous 360° environment enhances students´ learning in histotechnology.
- Instrument developed to evaluate students´ level of histotechnological knowledge.

Implications for practice and/or policy

- The ubiquitous 360° learning environment can be used in any context of health education to enhance students learning.

Introduction

Histotechnology is a part of biomedical laboratory science and one of the core competences required by biomedical laboratory technologists. In Finland, the education of biomedical laboratory technologists is carried out by six universities of applied sciences where approximately 230- 250 students start their studies every year. The education takes 3.5 years (210 ECTS) and leads to a standard qualification for registered biomedical laboratory technologists (B.Sc.).

New methods are rapidly invading the field of higher education and the use of blended learning, distance learning and e-learning options have been widely seen [4, 29, 36, 37]. Multiple new technology enhanced learning environments and methods are under development. New methods with technological components support more personalized studying in virtual or ubiquitous environments where a physical presence is not always needed. New learning environments support studying and learning at the students' own pace and at a convenient time and place. Furthermore, they can be based on the learners' personal needs, schedules and learning outcomes. Teaching, learning, and learning environments typically used in histotechnology are mainly traditional, where lecture-based theoretical studies are combined with practical training in laboratories.

Ubiquitous learning (u-learning) is based on pervasive, interactive and seamless ubiquitous computing [9, 10, 25, 34]. Ubiquitous technology fuses the learner seamlessly into the learning process and allows studying regardless of time and place [3, 11, 19]. One of the main characteristics of u-learning is a fusion between authentic and virtual environments, resources and materials. The definitions, components and contents of ubiquitous learning environments have varied a lot in the previous literature. The most commonly used components have been web-based learning management systems, multimedia learning materials, the use of embedded functional objects with barcodes, tags or badges, sensing technologies and mobile devices. Most of the u-learning environments are a mix of these [9, 16, 20, 37]. The use of ubiquitous learning environments has not been evaluated in the context of biomedical laboratory science, histotechnology, histology or pathology before. In this study, the ubiquitous learning environment used was based on a 360° technique, developed and optimized in our previous study [33]. In our previous study authentic and virtual learning environments were fused together, multimedia learning material was provided, and embedded functional objects with quick response barcodes and mobile devices were used.

In the literature, general competencies for different contributions have been defined. The term competence can refer quality, overall capacity or an ability to do something correctly [30]. In educational use, competence can be widely seen as an outcome of education, and as the capacity to integrate knowledge, skills, attitudes and values in a specific context [21]. The International Federation of Biomedical Laboratory Science (IFBLS) has provided a general statement on the establishment and assessment of staff competence and has described a set of core competences [13, 14]. In their policy competency has been defined as the knowledge, skill or ability to contribute to the successful completion of a work task and the ability to perform activity to the standard expected in employment.

Knowledge is one aspect of competence and can be defined as the success to adopt information, skills and activities in practice [5]. Cheetham and Chivers [2] have postulated that competence includes four aspects: 1) knowledge/skills, 2) functional competence, 3) personal skills and 4) ethical competence. Because competence is a broad and multidimensional issue this study will focus on students' histotechnological knowledge. Published descriptions of clinical histotechnology knowledge have focused on the evaluation of specific knowledge or skills. Multiple quizzes concerning tissue staining, tissue morphology, specific tumors, medical topics or immunohistochemistry, for example, have been published but not any related to knowledge concerning the whole histotechnological process [7, 8, 18] which was the basis of this study. Additionally these quizzes seem to be targeted for pathologists instead of technical personnel, such as biomedical laboratory technologists.

In this study histotechnological knowledge was summarized from internal and international curricula of multiple universities in Finland (three), in United States (two) and in New Zealand (one), which were easily and transparently obtained via the Internet [12, 22, 26, 28, 31, 32]. Based on these curricula descriptions, histotechnology studies should possess strong knowledge on routine and complex processes related to human tissue sampling including receiving, accessing and preparing tissue specimens for microscopic evaluations, tissue processing, embedding, sectioning, staining, freezing sections and immunohistochemistry. After their studies students should be able to carry out multiple laboratory processes, identify tissue structures and staining characteristics microscopically relating to quality assessment. They should be capable of making decisions to institute proper quality and accuracy. They should further be able to verify quality control procedures, apply principles of safety, management, supervision, and be able to use information systems [22].

Effective teaching and learning is a combination of multiple elements dependent on instructional design, various components, contents and interaction. All aspects have their own impact on student achievement. The evaluation of achievement can be assessed from the student and teacher perspectives and assessment can be carried out in different stages and by using different methods. Furthermore, assessment should be seen as an integral part of the overall education as a comparison between desired and resulting behavior. Quantitative assessment methods are mainly focused on scores, grades or overall numbers, while qualitative assessment is focused on practice or the transfer of know-how [3, 24]. The means of evaluation has been traditionally been based on processes including: oral, written and practical testing [6]. Modern forms of evaluation include multifunctional characteristics and aspects [1, 5, 23]. In this study, a knowledge test was used with self-evaluation to confirm multifunctionality.

Aim

The aim was to compare the differences in students' histotechnological knowledge between and within experimental and control groups. The study answered the following questions: (1) what were the students' levels of histotechnological knowledge before and after the studies in the experimental and control groups? (2) Were there differences in the histotechnological knowledge between the experimental and control groups? (3) Were there any significant interaction effects between the pretest and posttest scores concerning the groups, the time (pretest vs. posttest), and students'histotechnological knowledge?

Method

Study design and setting

A comparative quasi-experimental study design with experimental and control groups was used. A ubiquitous 360º learning environment (ULE) was used with the experimental group and a web-based learning environment (WBE) with the control group. 133 students enrolled in the clinical histotechnology course, 112 were assigned in the study. The students (n=112) assigned were divided into an experimental group (n=60) and a control group (n=52). The eligibility criteria for the participants were that their studies were progressing as planned in the curriculum. The students were informed of the learning outcomes, contents, evaluation and data collection. Participation was voluntary and confirmed by assignment. Studies were performed in three universities of applied sciences by the researcher (MV) to enhance the reliability. The background of participants and the histotechnology curriculum were equal (Table 1). Significant difference between groups were revealed in semester when studies had started. Most student´s in WLE group had started their studies in fall and most students in ULE group in spring.

Table 1. Participants´ background.

Group	Gender Female/Male	Age Mean	Previous degree, %	Status Full-time, %	Semester No.,Mean	1. semester Spring/Fall
ULE (n=60)	52/8	28.0	68	97	4	34/26
WLE (n=52)	42/10	28.2	52	92	4	13/39

The development process for this environment was reported in our previous study [33]. An ULE combines authentic and virtual learning environments by using 360º technology and offering real-life learning experiences in the digital environment. The ULE included an authentic and virtual laboratory based on 360º spherical panorama image, a virtual microscope, online webinars, video lectures, recorded laboratory demonstrations and tutorials, an electronic library, and electronic learning tasks and exams. Social media tools were used to support interactivity and collaboration. Quick response barcodes were used as functional objects, scanned and used by mobile devices. Ubiquitous environment offers flexible and instant access on all required learning resources managed in the same system. Used 360º technology was based on spherical panorama image where all learning resources can be reviewed, rotated, zoomed and paused by user by using any mobile device connected on the internet. The ULE significantly differs from all other static web-based learning environments by offering real life learning experiences in digital environment, and in any learning context. An overview of the ULE is shown in Figure 1.

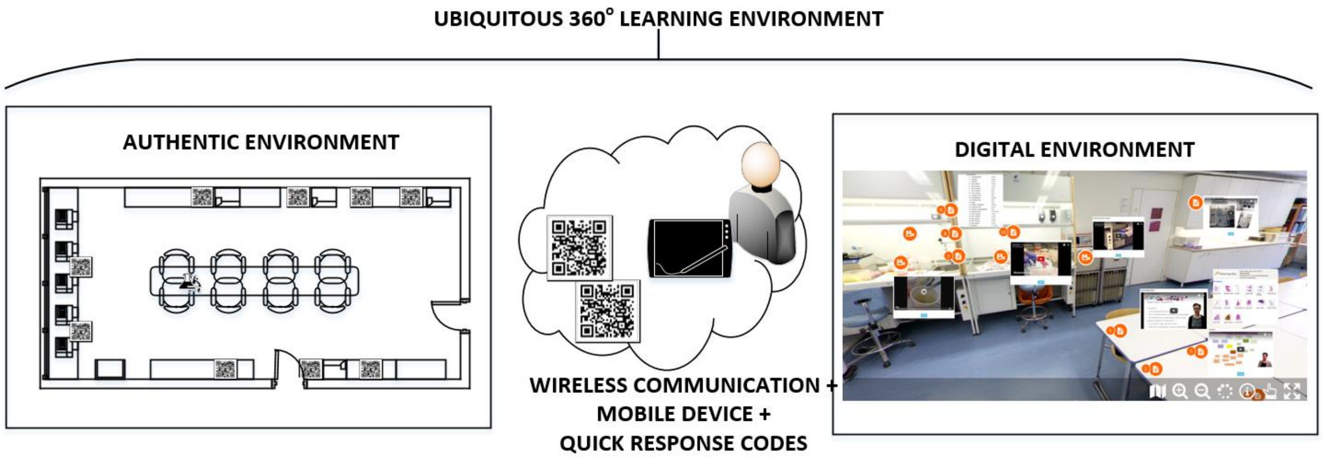

Figure 1. Overview of the ubiquitous 360º learning environment.

The control group studied via a web-based learning environment (WLE). All learning material for the WLE group was distributed via a learning management system (Moodle 2.7). The WLE group were not able to use the virtual laboratory, virtual microscope, social media tools, quick response barcodes or mobile devices. Recorded video lectures, laboratory demonstrations, on-line webinars, electronic exams, and e-books were in free use, however. The learning outcomes for a five-week study period were to identify the importance of histotechnological processes as a part of diagnosis and patient treatment, and to possess theoretical knowledge on the pathological basis of diseases and histotechnological processes. After the studies, the students should be able to perform basic and complex histotechnological tissue sample processes independently.

Evaluation instrument

Evaluation instruments for knowledge, skills or competence evaluation in histotechnology, histology or pathology were researched in the previous literature. Multiple international databases were used (Science Direct, PubMed, EbscoHost, ProQuest, Google Scholar) for searches. Multiple quizzes concerning specific items in histology or histotechnology were found [7, 8, 18], but not any related the overall histotechnological process.

In this study an evaluation instrument was developed in iterative phases with experts and was based on the literature and curricula of different universities (three in Finland, two in United States and one in New Zealand) [12, 22, 26, 28, 31, 32]. The instrument was divided into a knowledge test and self-evaluation sections to form a total level of knowledge. The knowledge evaluated using the evaluation instrument was defined as expertise in histotechnological laboratory processes, as well as decent basics concerning the pathological basis of diseases, in addition to basics in tissue morphology, quality assessment and laboratory safety. Items for the knowledge test (n=81) were formed by the researcher. The content validity was critically evaluated and confirmed by experts and pilot tests (Figure 2). Items for the knowledge test were critically evaluated by one senior lecturer (n=1), one pathologist (n=1), biomedical laboratory technologists (n=13), two specialists (n=2) and five students (n=5). Evaluations were done against the current curriculum, learning outcomes and biomedical laboratory competence in practice. Experts ranked all items by using a Likert scale from 1-3, where 1 was not important at all and 3 was critically important. It was also possible to flag an item as unclear or totally irrelevant (0). Evidence of content validity was computed by using a content validity index (CVI) based on experts' ratings of item relevance [27]. Items lower than .78 (n=36) were deleted from the instrument. After the expert evaluation the knowledge test included 45 items in the following sub-areas: histotechnological processes as a part of diagnosis and patient treatment (n=8), normal cell and tissue morphology (n=13), tissue sampling techniques (n=10) and laboratory processes for histological samples (n=14). The item types used were true/false (n=20), multiple choice (n=16) and images (n=9). The total score from the knowledge test was set at 60 points (in histotechnological processes maximum score 12 points, in normal cell and tissue morphology 13 points, tissue sampling techniques 10 points and in laboratory processes for histological samples 25 points). The item types used were true/false (n=20), multiple choice (n=16) and images (n=9). Pearson correlations were calculated and positive linear correlations were revealed in all items.

Items for self-evaluation (n=153) were formed by the researcher. These items were evaluated by biomedical laboratory technologists (n=9) and one specialist (n=1). Content validity was critically evaluated against learning outcomes and ranked by using a Likert scale of 1-3. A content validity index (CVI) was computed to consider good content validity (>.78) for 68 items. After evaluation, the self-evaluation section included 68 items (Likert 1-5): the pathological basis of diseases (n=18), histotechnological processes as a part of diagnosis and tissue sampling (n=8), normal cell and tissue morphology (n=23) and laboratory processes for histological sampling (n=19). The total score in the self-evaluation was based on a Likert scale of 1-5, and was set at 340 points. The final items were tested in a comparative, quasi-experimental pilot study in 2014 and 2015 (n=57). Internal consistency of the instrument was assessed by using Cronbach alphas in both the experimental and control groups' data. All values indicated very good internal consistency. The values are shown in Table 2.

Table 2. Internal consistency of the self-evaluation instrument.

	Cronbachs' alpha	
Sub-area	**ULE**	**WLE**
Pathological basis of diseases (n=18)	.963	.954
Histotechnological processes as a part of diagnosis, incl. tissue sampling (n=8)	.963	.970
Normal cell and tissue morphology (n=23)	.992	.991
Laboratory processes for histological sampling (n=19)	.988	.984
Total	.994	.992

The final instrument included a knowledge test and self-evaluation. Final scores from both sections were calculated together to indicate the students' levels of knowledge. The evaluation process of the instrument is shown in Figure 2.

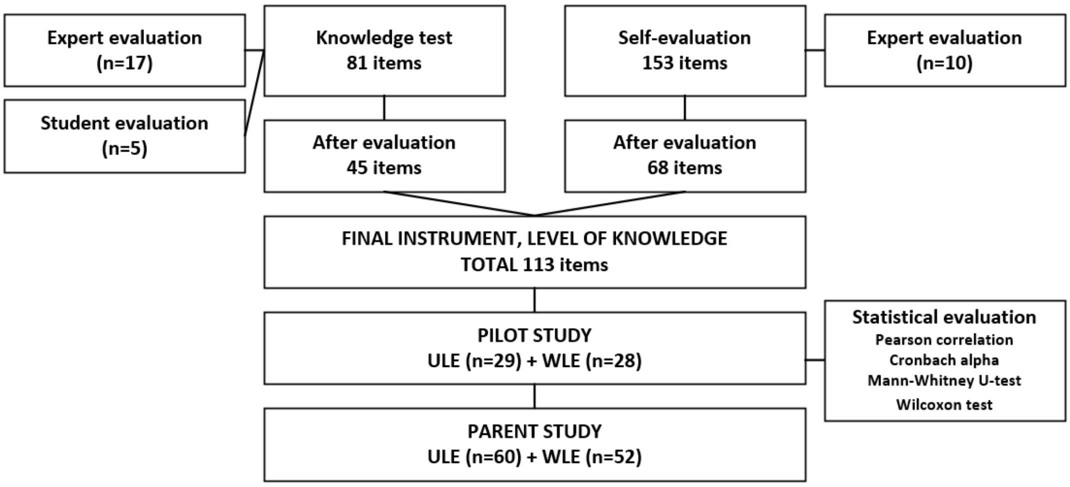

Figure 2. Evaluation process of the instruments

Data collection and analysis

The study was carried out between September 2015 and November 2016 and the data were collected at three universities of applied sciences in Finland. The universities were chosen based on having similar curricula and learning outcomes in histotechnology. The data were collected electronically by using a knowledge instrument as a pre-and post-test by using Eduix software (version 3.1). The data were analyzed using descriptive statistics with the IBM SPSS statistical software version 21 (SPSS, Chicago, IL). Mean values and standard deviations were used to characterize the participants and variables of knowledge. Differences of means between groups were tested by using non-parametrical independent samples Mann-Whitney U-test and the two-way ANOVA to compare mean differences between groups and time (pretest vs. posttest) to understand the interactions between variables. Differences within groups were tested by using Wilcoxon's test. The level of statistically significant difference was set at p- value <0.05.

Results

All students within the experimental and control groups scored significantly higher ($p < 0.001$) after the studies than before them. The total level of histotechnological knowledge (knowledge test and self-evaluation) was 41.1% higher in ULE group and 37.5% higher in WLE group after studies when compared to scores before the studies. Students in the ULE group scored higher in their self-evaluation, as well as in the knowledge test and in the overall level of knowledge than the students in WLE group. At the end of studies, the level of histotechnological knowledge was 3.6% higher in the ULE group than in the WLE group (Table 3).

Significant two-way interaction between the groups and time (pretest vs. posttest) indicated that the students' overall level of knowledge improved more in the experimental group than in the control group ($p = 0.013$) (Table 4). Statistically significant differences were seen, in both groups in their knowledge test scores when comparing pretest and posttest data. Changes in all variables were statistically significant ($p < .001$). The changes were higher in all variables in the ULE group than in the WLE group. There was some interaction between the scores and the group ($p < .001$) but no two-way interaction between the group and time ($p = .089$) (Table 5).

Table 3. Knowledge test scores, self-evaluation scores, and level of knowledge.

	Pre-test (Mean/SD)	Post-test (Mean/SD)	Change (mean)	Change,% (mean)	p
Knowledge test, ULE (60p)	31.7 (5.9)	49.1 (4.7)	17.4	29.1	<.001*
Knowledge test, WLE	36.0 (6.1)	50.8 (6.5)	14.8	24.6	<.001*
p	<.001*	0.028*	.074	.074	
Self-evaluation, ULE (340p)	114.2 (26.0)	261.0 (38.8)	146.8	43.2	<.001*
Self-evaluation, WLE	124.7 (28.7)	259.8 (29.9)	135.1	39.7	<.001*
p	.013*	.748	<.001*	<.001*	
Total level of knowledge,ULE (400p)	145.9 (26.7)	310.1 (38.0)	164.3	41.1	<.001*
Total level of knowledge, WLE	160.7 (29.2)	310.5 (30.3)	149.9 .	37.5	<.001*
p	<.001*	.949	.052*	.052*	

Mann-Whitney U test, Wilcoxon test, *p < 0.05

Table 4. Two-way interactions between group and time.

	Pre-test (mean)	Post-test (mean)	Time (pre-post)	Group (ULE-WLE)	Time + group
Self-evaluation, ULE (340p)	114.2	261.0	<.001*	.276	.164
Self-evaluation, WLE	124.7	259.8			
Knowledge test, ULE (60p)	31.7	49.1	<.001*	<.001*	.089
Knowledge test, WLE	36.0	50.8			
Total level of knowledge,ULE (400p)	145.9	310.1	<.001*	.073	.013*
Total level of knowledge, WLE	160.7	310.5			

Two-way ANOVA, *p < 0.05

Table 5. Interactions between group and time

Knowledge test	Pre-test (Mean/SD)	Post-test (Mean/SD)	Time (Pre-Post)	Group (ULE-WLE)	Time+ Group
Pathological basis of diseases, ULE (12p)	6.8 (1.8)	10.5 (1.3)	<0.001*	.002*	.100
Pathological basis of diseases, WLE	7.8 (1.6)	10.8 (1.5)			
Histotechnological processes, ULE (13p)	7.5 (2.0)	10.4 (1.4)	<0.001*	.103	.663
Histotechnological processes, WLE	7.9 (1.7)	10.7 (1.7)			.249
Normal cell and tissue, ULE (10p)	5.1 (1.4)	7.7 (1.4)	<0.001*	.005*	
Normal cell and tissue, WLE	5.8 (1.4)	8.1 (1.5)			.114
Laboratory processes, ULE (25p)	12.3 (3.2)	20.5 (2.7)	<0.001*	.001*	

Laboratory processes, WLE	14.4 (3.5)	21.3 (1.5)			.089
Knowledge test total, ULE (60p)	31.7 (5.9)	49.1 (4.7)	<0.001*	<0.001*	
Knowledge test total, WLE	36.0 (6.1)	50.8 (6.5)			

Two-way ANOVA, *$p < 0.05$

Discussion

Results from this study were very encouraging. The use of the ubiquitous 360° learning environment enhanced the learning, students' histotechnological knowledge increased. All students, in both groups, scored significantly higher at the end of study period than at the beginning. This was not surprising. It is rather the basic premise of teaching. It was seen that the use of new technology enhanced the teaching and the methods used supported learning. The new methods were seen to be as effective as traditional ones or even better. Previous studies have reported that the learning environment, as virtual laboratories, can enrich the learning experience [29] by offering multifunctional learning opportunities. Positive effects have seen in orientation towards the laboratory environment before practical sessions or hands-on training [4, 35]. Previous studies have also reported that virtual learning environments can provide meaningful learning experiences when converting theoretical knowledge into practice. Moreover, interactive methods can offer clear and enjoyable learning experiences [15, 29, 35]. These effects were also seen in this study.

The differences between the ubiquitous 360° learning environment and web-based learning groups were statistically significant when the interactions between time, group, and the test scores for the target knowledge areas were analyzed. Students in the ULE group achieved significantly better in all variables. Their performance increased concerning histotechnological processes, normal cell and tissue morphology, tissue sampling techniques, and laboratory processes.

Several limitations narrowed the study. Because no previous studies concerning use of ubiquitous 360° learning environment in histotechnology or a health science educational context have been published, it was hard to make accurate comparisons. Conclusions are tentative because development of ubiquitous learning environments are still in early stage. Combination or fusions of virtual and authentic learning spaces have not previously been used or reported. Additionally, the evaluation instruments of histotechnological knowledge have not been previously published. In the future study design used should be designed more carefully. Assigned participants should take the pre-test in the beginning and randomization into experimental and control groups should be done based on test scores, thus making groups consistent. Larger study population is recommended to demonstrate the more significant findings.

Although the 360° technology is not widely known or used in education, results from this study encouraged on continuous development. In the future the developed ubiquitous 360° learning environment will be used as a template for a multiple learning environments. Practical implementations will be done in radiology, dental health, midwifery and nursing degree programs. The unique ULE, based on the spherical panorama 360° image, can simulate real-life learning situations in relevant way and in any learning contexts. ULE can support theory transformation into practice by offering authentic learning experience digitally regardless space and based on their own needs.

The students were encouraged by the use of the ubiquitous 360° learning environment and the learners' attitudes towards the new methods were positive, and the satisfaction high [33]. Development process was fast and easy, and expenses were lower when compared on virtual world or 3D model development. The ubiquitous 360° learning environment template developed can be easily modified and implemented into any educational context in the any field of higher education.

Conclusions

The ULE tested in this study enhanced learning and increased students' histotechnological knowledge. The students' achievements in knowledge tests and scores in selfevaluations increased significantly when they studied via a ubiquitous learning environment. Significant differences were defined when two-way interactions between the time, group, and test scores of the target knowledge were analyzed. Performance increased in all variables. The results confirmed that students in the ULE group achieved significantly better than students in the WLE group.

We recommend future studies with larger study populations with a more accurate study design. We also recommend that ubiquitous 360° learning environments to be adopted permanently in higher education, to provide supportive, effective, diverse, and innovative learning experiences for students.

Compliance with Ethical Standards

The study was carried out with the permission of directors of health and nursing science departments in all universities. The students participated voluntarily in the study and were informed of the study objectives, contents, and data collection before starting. Participation was confirmed by assignment. The collected data was treated confidentially, coded, and stored password-protected. Identification of the individuals who participated in the study was not possible. The authors stated no conflicts of interest. The study design was done by MV, EH, EL, and MK. Instrument development, data collection, data analysis, and drafting the manuscript were done by MV,MK, and EL, while EH made critical and intellectual revisions.

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