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Evaluation of Learning Outcomes Among Practical Nursing Students After Using Three-Dimensional Technology in Their Studies

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There is a lack of evidence-based information on the use of technology in first-aid education. For this reason, this study aimed to describe the learning outcomes of three-dimensional technology among practical nursing students in first-aid courses. In this quasi-experimental study, first-year practical nursing students (n = 59) were divided into intervention group (n = 32) and control group (n = 27). For the intervention group, the first-aid course (a total of 16 hours per group) included three-dimensional images, three-dimensional environments, and three-dimensional printing. For the control group, the teaching was implemented using traditional methods. The data of knowledge (pre, post, and follow-up) and skills (post) were collected. The intervention group obtained statistically significantly higher scores in knowledge in follow-up test than the control group ($P = .048$). They also performed better on the entire resuscitation protocol ($P = .0193$) and in the following parts of resuscitation: *student call for help*, *student opens the airway correctly*, *student checks the breathing correctly,* and *student has a correct depth in the chest compressions*. As a conclusion, three-dimensional technology can enhance students' first-aid knowledge and improve cardiopulmonary resuscitation skills in practical nursing education.

KEY WORDS: Learning outcomes, Practical nursing education, Three-dimensional technology, Vocational education

First-aid knowledge and skills are basic elements of nurses' and practical nurses' professional competence.[1] In Europe, for example, this relates to a huge number of workers, with 6.2 million people employed in healthcare.[2] Therefore, it is essential for students to develop these skills to prepare them for life-threatening situations such as cardiac arrest.[3,4] This also puts pressure on first-aid learning outcomes.[5]

One effective element in first-aid education is regular physical training,[6] which is highlighted in cardiopulmonary resuscitation (CPR), where using a quick and adequate protocol is essential.[7] Besides physical training, the nursing education sector also needs to ensure that technological solutions play a meaningful role in education.[8] This concerns both the educational framework and individualized teaching methods.[5,9] Overall, studies show that, in general, the first-aid education sector is lacking when it comes to using technology.[10]

One promising technological entity in first-aid education is three-dimensional (3D) technology, which has been used in the form of augmented reality (AR)[11] and virtual reality (VR).[12] These can be defined as 3D environments.[13,14] When nursing teachers are coming up with lesson plans, 3D technology could be a useful tool.[15] 3D technology has been researched from the point of view of a number of technological tools,[16] but there is a lack of research that defines the concept to include multiple tools (3D images, 3D environment, 3D hologram, and 3D printing), which can be used.[13] The aim of this study is to examine learning outcomes among practical nursing students in first-aid education when 3D technology is used.

CONCEPTUAL FRAMEWORK

3D Technology

3D technology can be defined from two perspectives: visualization and technical.[14,16] The visual perspective refers to when the person can feel the image or environment from

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three dimensions and have some kind of interaction.[14] The interaction can be implemented, for example, with haptic devices.[17] Examples from the visual perspective are 3D images,[18] 3D environments (eg, VR),[15,19] and 3D holograms.[17] The basic elements of these 3D technologies are the following:

1. A 3D image is an image that can be moved and observed from three different dimensions, which the user can only utilize.[18] Nearly the same idea is covered in 3D hologram, but the hologram has been created with a laser.[17]
2. A 3D environment can refer to VR, where the user is partly or fully surrounded with a virtual environment and interacts with the content of the environment. Moreover, the 3D environment can mean AR, where the real world and virtual elements are mixed, and the user can interact with virtual elements in the real world. When the user can utilize VR and AR at the same time, it becomes a mixed reality. There is also a concept of extended reality, which is basically an umbrella term for all different realities.[15] A 3D environment also includes an environment that is created with 360-degree images or videos.[19]

The technological perspective basically refers to 3D printing, where the 3D modeled image will be printed as a concrete object.[16]

Practical Nursing Education

In Finland, practical nursing education is organized at level 4 of vocational education.[20] The vocational education system is guided by the Vocational Education and Training Act[21] and the National Board of Education,[22] which sets guidelines for vocational qualification in social care and healthcare. Eligibility to apply for a practical nursing degree course is conferred by at least a lower secondary school certificate. Practical nursing studies usually last from 2 to 3 years. The full practical nursing degree is valued at 180 competence points (European Credit System for Vocational Education and Training), where one competence point is equal to a minimum of 12 hours of actual study hours. The curriculum for practical nursing students includes basic study units (eg, "promotion of wellbeing and functional capacity"), study units of specialization (eg, mental health), and general subjects (eg, mathematics).[22]

AIM

The aim of this study is to examine learning outcomes among practical nursing students in first-aid courses when using 3D technology. It uses a quasi-experimental design with two research questions:

1. What kinds of differences, if any, are there in practical nursing students' knowledge development in the context of first-aid courses comparing students who received 3D technology or traditional teaching?
2. What kinds of differences, if any, are there in practical nursing students' CPR skills in the context of first-aid courses comparing students who received 3D technology or traditional teaching?

METHODS

Setting and Participants

The study was implemented among practical nursing students from a vocational institute in Finland. The vocational institute was chosen for this study because it is large and serves a significant geographical area within Finland.

The population of first-year practical nursing students (n = 59) that it was possible to include in the study was divided into the following groups: intervention group (n = 32) and control group (n = 27). There was no randomization in this division. Rather, the division was guided by the curriculum of the students.

Every student was given a personal code to guarantee anonymity. Inclusion criteria for the students were as follows: (1) first-year practical nursing student and (2) attendance requirement of the first-aid course. The exclusion criteria were as follows: (1) some other phase of studies than first year and (2) the student had already completed the first-aid course somewhere else.

The study followed ethical guidelines.[23] Before implementation, ethical permission was granted by the Ethics Committee for Human Sciences at the University of Turku, decision 34/2021. Every participant signed the informed consent form. They were also informed that they could withdraw from the study at any point without having to give a reason.

Data Collection

All data were collected during the period from January 2022 to May 2022. Data concerning first-aid knowledge and CPR skills were collected separately. Two different instruments were implemented to collect the data: (1) knowledge test and (2) CPR skills observation tool.

Data concerning first-aid knowledge were collected in the classroom in three phases: (1) before the start of the course (pretest), (2) at the end of the course (posttest), and (3) 1 month after the end of the course (follow-up test). Data concerning CPR skills were collected at the end of the first-aid course. Each practical nursing student performed 2 minutes of CPR with observation by the researcher. Students in each group had the same amount of time to practice CPR during the course before the observation. The manikin used was Laerdal's manikin (Laerdal Medical, Finland) with the Bluetooth facility to evaluate the CPR with a mobile device. The manikin was calibrated before the study, and each student used the same manikin. Each performance was evaluated using the same instrument.

The framework for the knowledge test was the international first aid, resuscitation and education guidelines,[4] and the national vocational competence requirements.[22] Moreover, the researcher discussed the content and the structure of the knowledge test with five teachers, who have taught first aid in vocational education. These teachers were from a different vocational institute than that from which the data were collected. Teachers provided feedback, which was used while creating the knowledge test. The knowledge test was a multiple-choice test (a total of 30 questions, six possible options to select with one correct answer) and concerned general questions about first aid. The values of correct and incorrect answers were 1 and 0 (maximum 30 points and minimum 0 points with no competence levels).

Before the study, the questionnaire was pretested with 15 practical nursing students. The purpose of the pretesting was to improve the comprehensibility of the questionnaire. After answering the test questionnaire, the students gave oral feedback about the questionnaire. Regarding the feedback, some rewording was done to make the questions more understandable. The rewording considered the structures of the sentences and some individual words. After rewording, the questionnaire was presented again to the same students (n = 15) to make sure that the changes were appropriate. Finally, before the actual data collection, the questionnaire was also evaluated by a separate teacher from the vocational institute that did not teach the first-aid course. This review was performed to ensure that the content was in alignment with the information provided to students.

The CPR skills observation tool was developed for this study according to international guidelines for resuscitation.[3] The tool included 10 different steps that practical nursing students had to follow. The value of correct performance was 1 and of incorrect performance 0 (maximum 10 points and minimum 0 points). Complete performance by one student lasted 2 minutes. The duration of 2 minutes was selected according to other studies.[24] Rescue breathing was excluded due to COVID-19 restrictions.

Context of the Study

Each first-aid course was implemented via face-to-face teaching over 2 consecutive days and lasted a total of 16 hours. The same teacher taught all groups and used the same methods and tools: 3D technology with the intervention group and traditional teaching (eg, lecturing) with the control group. The framework for the content of the first-aid courses was the vocational competence requirements.[22] The amount of physical training (eg, CPR skills) was the same for each student.

Description of the Intervention

In this study, the intervention was defined as 3D technology,[13] which included the following technologies: 3D images, 3D environment, and 3D printing. All of the 3D technologies were selected from the resources (content with 3D images, 360° camera and programs for the camera's material, haptic devices, and 3D printer) of the vocational institute. The 3D images covered anatomical content about the lungs, heart, cardiovascular system, brains, and neuromotor system. The 3D images were from the material of the vocational institute, and the students used 3D images with an interactive device, where they could move and observe (eg, zoom in and out) the organs in three dimensions. The 3D environments covered a 360° environment of a detached house and the surroundings of that house, as well as the AR of the anatomical 3D image of the heart and a heart attack. The 360° environment was created for this study with a 360° camera from the real living environment. The environment included different cases about first aid, and students utilized the 3D environment with mobile devices and haptic devices. In the 3D environment, students could move around and face different cases, for example, moving to the living room and facing the need for wound care. Moreover, the students used AR with glasses, where they saw a heart attack in a real environment (classroom) and observed what happens in the heart during the heart attack. Finally, the students studied fractures and strains with the 3D-printed objects. The students handled the object and discussed and observed a 3D printer, which was actively printing the same objects the students were handling. In this way, the students also saw, for example, the different layers of the objects. A more specific description of the intervention can be found in Table 1.[25]

Data Analysis

All data were analyzed using the statistical software SAS Enterprise Guide 7.1 (SAS institute inc., Cary, North Carolina). The knowledge test data and data collected from observations were analyzed separately. The analysis was carried out by significance level at *P* value of .05 with the data from the intervention group (n = 32) and the control group (n = 27).

Statistical Analysis of the Knowledge Test

The knowledge test was analyzed as the sum of 30 questions. There was no grouping of questions or analysis of single questions. The repeated mixed model was used (pretest, posttest, and follow-up) to find statistically significant differences by the following variables: group, the three time points, and interaction between group and time.

First, it was found out that there were outliers (n = 6) in the control group, which were analyzed more specifically with a residual normality check (Shapiro-Wilk test) and influence diagnostic statistics (Press and Cook's D statistics) from the repeated-measures mixed model. It was then identified that these outliers impact the model too much to make it valid, and they were excluded, making the final data from 21 students (n = 21) in the control group.

Two students (n = 2) from the intervention group and three students (n = 3) from the control group were absent from the posttest and follow-up test, but all the students who participated

Table 1. Description of the Intervention According to the TIDieR checklist[25]

Question	Content
Name	Using 3D technology to teach first aid in practical nursing education.
Why?	To increase first-aid learning outcomes.
What?	Practical nursing students used 3D images, 3D environments, and 3D printing while learning first aid.
Who (participants)?	Practical nursing students on the course.
How?	3D technology was implemented as a teaching method to all content of the first-aid course.
Where?	Practical nursing students used their own institution's 3D technologies.
When and how much?	The course lasted a total of 16 h divided into 2 consecutive days. During these 16 h, each subject was taught with a short theoretical part by a teacher following the use of the 3D tool. Each technology was used for the following time: (1) 3D images: 3 h (2) 3D environment (360° environment with mobile devices): 3 h (which included 2 h of concrete first-aid practice) (3) 3D environment (360° environment with glasses and hand controls): 5 h (which included 3 h of concrete first-aid practice) (3) 3D environment (AR): 2 h (4) 3D printing: 3 h
Tailoring?	Each technology was tailored following: (1) 3D images: Different sudden attacks, eg, cerebrovascular accidents. Students used a television with interacted 3D images of different organs and discussed the sudden attacks with guiding questions on the paper in front of them and made by the teacher. (2) 3D environment (360° environment) with only mobile devices: Traffic accident, wound care. Students used different 360° environments with tablets or mobile phones and discussed each content with questions on the paper in front of them and made by the teacher. (3) 3D environment (360° environment) with glasses and hand controls: Resuscitation, shock and unconsciousness. Students moved through the 3D environment and faced different cases. After using the 3D environment, they immediately discussed in groups what they had experienced. Next, all students practiced resuscitation and first aid in case of unconsciousness with guidance from the teacher. (4) 3D environment (AR) with glasses: heart attack. Students used glasses to experience heart structure and what happens in a heart attack. (5) 3D printing: bone fractures and strains. Students had different kinds of 3D-printed objects (eg, 3D-printed patella with fracture). They needed to work out the location and quality of the fracture and discuss how to give first aid for the different fractures. The teacher guided students throughout. There was also a 3D printer actively printing objects during the intervention, so the students saw how the objects were made.
Modifications?	During the intervention, there were no modifications.
How well?	Knowledge of the first-aid course was tested (pre, post, and follow-up) and CPR skills were tested by means of a skill test (post).

Abbreviation: TIDieR, Template for Intervention Description and Replication.

in the poststudy also attended the follow-up study. The deviation of the overall score was greater for the control group than for the intervention group at every measured time point. The normality of the overall score variable for each group at each time point was inferred from a plot review and from significant key statistical figures, including the P value of a Shapiro-Wilk test for normality.

Due to the normality of the overall score by group at every time point, a repeated-measure analysis was produced to capture whether the change in the mean overall score at different time points differs significantly between groups. The data included some missing data that were assumed to be missing at random, which is allowed when using the repeated-measures mixed-model procedure (proc mixed in SAS). By comparing the Akaike information criteria for different covariance structure options for the model, the smallest Akaike information criteria value was found with unstructured covariance structure, which was therefore used in the repeated-measures mixed model.

Statistical Analysis of Cardiopulmonary Resuscitation Skills

Observation of CPR was conducted for 53 practical nursing students because some were unwilling to participate ($n = 6$). To have consistency in results across the entire analysis, the same outliers ($n = 6$) that were deleted from the knowledge test analysis were deleted from the CPR analysis. The final sample was 47 students divided into the intervention group ($n = 29$) and the control group ($n = 18$).

The CPR analysis consisted of two phases. The first phase sought to identify whether there were significant differences between the two groups in achieving the CPR score. Normality could not be justified by plot review or by the Shapiro-Wilk P value. Also, no general transformation of the data made it normally distributed. These were the reasons for using the nonparametric Mann-Whitney U test to compare the groups' rank sum. In addition, due to the small

Table 2. Overall Results of the First-Aid Knowledge Test

Time Point	Group							
	Intervention Group				Control Group			
	n	Mean (SD)	Min-Max	P^a	n	Mean (SD)	Min-Max	P^a
Prestudy	32	16.5 (3.14)	11–22	.1551	21	17.3 (4.94)	6–24	.1241
Poststudy	30	24.1 (2.84)	18–30	.7089	18	23.0 (2.97)	16–27	.3855
Follow-up	30	23.9 (2.60)	18–29	.8282	18	22.4 (2.94)	18–28	.3172

[a]Shapiro-Wilk test for normality.

size of the sample, the central limit theorem could not be applied to continue with an independent-sample *t* test. Second, logistic regression was calculated comparing the groups to get the odds that a student in the study group would perform in comparison to the student in the control group. Ten logistic regressions were performed to compare every 10th performance between the intervention group and the control group.

This study utilized TREND (Transparent Reporting of Evaluation with Non-randomized Design) as a framework[26]

RESULTS

Differences in First-Aid Knowledge Between Intervention and Control Groups

The overall score was studied as the response with explanatory variables of groups, time, and their interaction at three different time points. From descriptive statistics, some differences were found in the means of the data. Even though the pretest mean was lower in the intervention group than in the control group, the increase in the mean seems to be greater in the intervention group, because from the posttest onward, the overall score is higher for that group than for the control group (Table 2).

The repeated-measures mixed model itself showed that there were statistically significant differences between the group's population averages when trying to explain the change in the overall score with group, time, and their interaction. Group as a main effect was not a statistically significant exploratory variable. However, the time variable ($P < .0001$) and the interaction between time and group ($P = .0380$) turned out to have a statistically significant effect on the overall score, indicating that the total score of the knowledge test for the groups differed statistically significantly between time points (Table 3).

When comparing the difference in answers between the intervention and control groups at different time points, it was observed that the Bonferroni-adjusted *P* value only showed statistical significance between groups at follow-up ($P = .0408$). Therefore, it can be concluded that the intervention group had on average a 1.74 higher overall score in their follow-up test than the control group. Residual diagnostics were carried out with plot review and Shapiro-Wilk normality test, confirming the residuals to be normally distributed and therefore that the model fit the data (Table 3).

Differences in Cardiopulmonary Resuscitation Skills Between the Intervention and Control Groups

The mean and the median were higher in the intervention group than in the control group, indicating that there could be a possible statistical significance found with a statistical test. A statistically significant difference was detected between the rank sums of the intervention group and the control group ($P = .0004$). On average, the students' CPR score in the control group is two points lower than in the intervention group, when comparing the groups' ranks with a 95% confidence interval between −1 and −3 (Table 4).

The second phase of the CPR analysis consisted of investigating the performance of each student differently. This was based on the first phase results, where it was concluded that the overall CPR score was on average higher in the study group than in the control group. It was not possible to calculate the odds of one performance ("awaken the victim") because there were no students in the study group with zero points ("no") in the observation (Table 5).

Table 3. Result According to the Different Time Point From the First-Aid Knowledge Test

Statistical Analysis With Repeated-Measures Mixed Model			
	P	*F*	
Model	<.0001[a]		
Group	.3413	0.92	
Time	<.0001[a]	75.97	
Group vs time	.0380[a]	3.53	
Time point	*P*	*t*	**Diff. in means**
Intervention group vs control group **PRE**	.4396	−0.78	−0.86
Intervention group vs control group **POST**	.1284	1.55	1.35
Intervention group vs control group **FOLLOW-UP**	.0408[a]	2.11	1.74

[a]Statistically significant difference in level of <.05.

Table 4. Result of the Overall Score From the CPR Test

Descriptive Statistics				
Group	**n**	**Median**	**Mean SD**	**Shapiro-Wilk *P***
Intervention	29	8.0	8.0 (1.60)	0.0193[a]
Control	18	6.5	6.0 (1.75)	0.0659
Statistical analysis with Mann-Whitney *U* test				
Group	*Z*	*P*	**Difference in Location (95% Confidence Interval)**	
Control vs intervention	−3.5272	0.0004[a]	−2.0 (−3.0, −1.0)	

[a]Statistically significant difference in level of <0.05.

A statistically significant difference was detected between the intervention group and the control group in four of 10 performances. The performances were the following: "calling for emergency assistance" ($P = .0028$), "opening the airway of the victim correctly" ($P = .0489$), "checking for possible breathing correctly" ($P = .0016$), and "having the correct depth in chest compression" ($P = .0107$) (Table 5).

DISCUSSION

The aim of this study is to examine learning outcomes among practical nursing students when using 3D technology in first-aid courses included in the curriculum. According to the results, 3D technology may be connected to better knowledge and skills in the context of first aid. Broadly speaking, these findings support studies already conducted, which connect 3D images and VR or AR to better knowledge and skills in nursing education.[13] It is worth pointing out that this study defined 3D technology as an assembly of technologies (3D images, 3D environment, and 3D printing), which highlights the message to teachers that there are several possibilities as regards using 3D technologies in teaching and that the use can be creative. It is also significant that all 3D technologies support teaching, rather than creating it. This means that teachers need to plan their teaching carefully when it comes to using 3D technology. With the results of this study, teachers can at least connect a certain 3D technology to certain topics (eg, 3D printing to teach bone fractures) in first aid when following the content of the intervention.

First-aid education has been well studied.[4,27] Most research focuses on CPR skills.[27] According to the results of this study, 3D technology can increase the quality of CPR. This result is in line with other studies that have successfully tested 3D environments in CPR education.[11,12] However, it is notable that this study was implemented with the guidance of adult resuscitation, and the other two studies tested children's resuscitation guidance.[11,12] CPR skills are also usually measured according to the quality of chest compressions and ventilations,[28] which, as in this study, should be considered critically, because of the amount of the sensitive variables (eg, the margin of 50-60 mm in correct depth of chest compressions). Moreover, this study also divided the CPR protocol into different parts of performance, and the results show that 3D technology may have promising effects in terms of skills, especially at the beginning of the CPR process. 3D technology was connected to better performance in the recognition of lifelessness, which includes opening the airways and correctly checking for breathing. This may be caused by the immersive element of 3D technology, where students experienced the CPR protocol in different dimensions. This is also a significant result, because previous studies show that adequate skills for handling airways are difficult even for professional healthcare workers.[28,29] From a

Table 5. Results of Each Performance From the Observation Tool

Performance Observed	Estimate	Std. Error	*P*	Odds Ratio (95% Wald Confidence Intervals)
2. Student calls for emergency assistance.	2.61	0.87	.0028[a]	13.50 (2.447, 74.478)
3. Student opens the airway correctly.	1.35	0.68	.0489[a]	3.84 (1.007, 14.649)
4. Student checks for possible breathing.	3.48	1.10	.0016[a]	32.30 (3.735, 279.310)
5. Student starts chest compression immediately after checking for breathing.	1.25	1.26	.3217	3.50 (0.294, 41.700)
6. Student performs chest compression in correct place on the chest.	0.69	0.65	.2860	2.00 (0.560, 7.146)
7. Student has the correct depth (50-60 mm) in chest compressions.	1.66	0.65	.0107[a]	5.25 (1.468, 18.772)
8. Student has the correct rate (100-120 times/min) in chest compressions.	−0.24	0.61	.6892	0.78 (0.237, 2.593)
9. Student releases the chest 100% after each compression.	0.64	0.61	.2945	1.90 (0.572, 6.308)
10. Student performs chest compressions without interruption for 2 full minutes.	0.52	1.05	.6178	1.69 (0.216, 13.177)

[a]Statistically significant difference in level of .05.

pedagogical perspective, the studies highlight the need for different and effective educational tools,[28,29] and according to the results of this study, we can think of 3D technology as one of them.

It has been said that there is a lack of theoretical knowledge of first aid among nursing students.[30] Most studies focus on some specific first-aid knowledge, for example, burn injuries[31] and not so much on the body of first-aid knowledge, as is the aim of this study. The results of this study support the findings of Chen and Liou,[11] who report that 3D technology may be connected to better theoretical knowledge of first aid after the first-aid course. Moreover, the significant element of this study is that theoretical knowledge was significantly higher 1 month after the course had ended. This result may mean that 3D technology is an effective teaching tool for reaching students' long-term memories, which makes learning more effective.[32] In this study, the reason for long-term recall may be that most of the 3D tools used provided a totally new learning experience for the students. However, it has been previously observed that 3D visualization (eg, 3D images and 3D environments) has an effect on the human brain when the stimulus is more widespread and can support long-term memory.[33] From this perspective, this study may support 3D printing as an effective tool for increasing the activity of long-term memory, although the students only observed the active 3D printer, which created the objects they handled. These results also encourage the evaluation of the long-term memory outcomes of 3D technology in teaching subjects other than first aid.

With this study, the researchers also aim to emphasize the significance of vocational education as an important element in the field of healthcare education. Most of the studies that have been conducted with some 3D technology tools focus on nursing education at the higher level.[13]

This study has limitations that need to be considered. First, the number of participants is moderate, and so the option of studying this subject with a larger sample may be advisable. Second, this study was the first to study the concept of 3D technology as a body of different 3D tools in first-aid education. This means that the results cannot be identified in certain technological tools, for example, 3D images. Third, this study did not evaluate or separate the contents of the students' discussions after using 3D technologies, which may have had a significant effect on the learning outcomes.

CONCLUSION

This study indicates that 3D technology can be considered as a promising set of tools when teaching first aid among practical nursing students. 3D technology may support students to remember the content of first-aid teaching better, and with the help of 3D technology, they can learn good resuscitation skills. The different 3D tools can be used together to carry out innovative and creative first-aid teaching. Teachers should think of 3D technology as an alternative tool to use in their teaching. This study encourages future research to evaluate learning outcomes of 3D technology with randomized controlled trials and highlights the need for further research in vocational education.

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