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HCI meets Nursing Care

The application of Mixed Reality in basic Nursing Care Education

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Abstract: The traditional education of basic activities in nursing care (e.g. patient mobilization or hygiene) poses different limitations like, e.g. restricted options for self-education or limited realism in the learning context. By blending the real-world with virtual content, Mixed Reality (MR) technology holds great potential to address given shortcomings in interactive learning scenarios. In this work we explore how Human-Computer Interaction (HCI) can inform the development of MR systems for basic nursing care education. We conducted a review of the current employment of MR and Virtual Reality (VR) displays (including desktop-based ones) in basic nursing care education and discuss our results in respect to the conceptual HCI framework Blended Interaction. In contrast to existing reviews, our work differs by placing a clear focus on activities of basic nursing care education and the question how HCI can inspire the design of MR applications which support such activities. We first conducted a search of the Web of Science Core Collection based on predefined search terms. 139 publications were found. We filtered them by inclusion criteria to ensure that only papers which use MR or VR displays to support basic nursing care education remained. The remaining publications were viewed with respect to the four domains of design provided by the Blended Interaction framework, namely (1) individual interaction, (2) social interaction and communication, (3) workflow and (4) physical environment. Our results indicate that MR in basic nursing care education just barely scratches the surface. The majority of systems employs desktop-based VR. Most systems facilitate individual interactions by mouse, keyboard or specific haptic devices, support limited or no social interactions, provide structured workflows or free interactions, and employ 2-dimensional VR displays to simulate work environments. Future MR systems could allow for more realistic interactions, stimulate collaboration through 3-dimensional real-world overlays, enhance learning workflows by rendering or deliberately hiding information within real-world scenarios, and facilitate immersive environments with physically enabled virtual objects. In conclusion, we show that the present use of MR in basic nursing care education is limited and introduce directions for design which can help leveraging the technologies' full potential in the future.

Keywords: Nursing Care Education; Mixed Reality; Human-Computer Interaction; Blended Interaction

I. INTRODUCTION

Throughout a large part of their daily work, nurses and caregivers interact with patients. They conduct activities like providing patients with nutrition, mobilizing them and caring about their body hygiene. Such activities can be seen as fundamentals of care [19]. To avoid negative health implications for nurses and patients, it is important to teach nurses and caregivers how to pursue such basic patient-related activities in proper and ergonomic ways.

Traditionally, patient-related tasks are either taught by presentation of materials from text books or by the demonstration of activities. In the second case, the teacher usually assumes the role of a nurse, one student plays the patient and the remaining students observe the scene [11]. However, traditional education also has numerous limitations [11] [21], such as (i) time and personnel constraints (demonstrating nursing activities requires the attendance of a teacher who has difficulties to adequately supervise multiple students at once), (ii) mobility constraints (demonstrations usually take place in the school setting and it is hardly possible to learn at different places), (iii) limited visual perspective on the demonstrated activity (students have to watch a teacher performing an activity in a crowd limiting the freedom to view this activity from multiple perspectives in order to satisfy individual needs), as well as (iv) limited possibility to simulate different aspects and scenarios of care activities realistically (e.g. patients with different diseases, bodily conditions, etc).

Mixed Reality (MR) displays, which merge real and virtual worlds, can provide options for self-education in various places, allow to view learned activities from multiple perspectives and support the training of different scenarios in varying degrees of immersion.

In this paper, we conduct a review of existing literature to explore how Human-Computer Interaction (HCI) can inform the development of MR systems for basic nursing care education. Milgram & Kishino [25] point out the possibility to situate MR displays along a continuum between fully real environments and completely virtual ones (see Fig. 1). Besides displays between the two extrema of the shown continuum, Virtual Reality (VR) displays (positioned on the right end of the

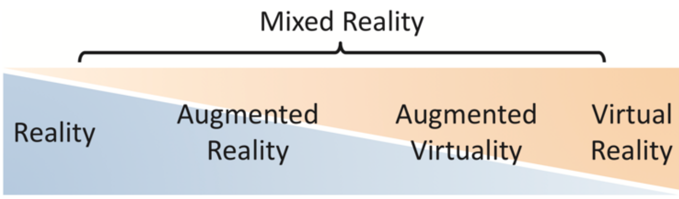

Fig. 1. Milgram & Kishino's Reality-Virtuality continuum (image from [26])

continuum) can also *"help bridge the education gap between knowledge and application for new nurses"* [27]. In our review, we regarded existing systems which provide MR and/or VR displays (including desktop-based ones) for basic nursing care education.

Background and Research Goal

In the following, we first provide a brief overview over existing reviews and inquiries with regard to the support of MR and VR in nursing care education, arguing that HCI research can potentially inform further design and development in this research area. Then, we present the HCI framework *Blended Interaction* and discuss how its four domains of design (individual interaction, social interaction and communication, workflow, and physical environment) can be applied to MR/VR systems in basic nursing care education. Finally, we formulate the research goal of our work.

A. Related Work – MR/VR in Nursing Care Education

Bacca et al. [2] conducted a review of existing studies about Augmented Reality (AR) in education. They found that AR has been rarely applied in the field of "Health & welfare". Another review on the use of AR in educational settings from Chen et al. [5] complements this finding, by stating that only 7.27% of 55 reviewed papers addressed the research field "Health". This strengthens the need for future investigations related to the use of AR in health research.

With a focus on health, Cook et al. [8] pursued a systematic review and meta analysis of technology enhanced simulation – including Virtual Reality - in relation to health professions education. They found that most of the reviewed literature showed an association beween technology-enhanced simulation and improved learning results (e.g. knowledge, skills, and behavior). Zhu et al. [33] conducted a review which explored the application of AR in healthcare education, including its strengths and weaknesses. Green, Wyllie & Jackson [14] discuss literature about virtual worlds and education – with focus on nursing education – and explored different aspects like learning theories, benefits of virtual worlds and challenges when using them for the teaching of nurses. Creating a basis for future User Centered Design (UCD) approaches, Kopetz, Wessel & Jochems [21] analyzed the context of nursing education with regard to the prospective use of AR-based learning media. They found that the current use of interactive media like mobile apps and smart glasses is low and identified a *"demand for additional support in form of information and feedback"* [21], particularly concerning the practical parts of nursing education.

Existing reviews and inquiries facilitate a general understanding of how MR and VR are currently used in health education. However, only few put a clear focus on activities of basic nursing care education. Further, to our knowledge, present work does not provide a structured investigation of the potential provided by HCI to inspire the design of MR systems which support such activities. We believe that insights from an HCI perspective can provide possibilities to expand existing concepts and systems to enhance learning experience and performance. *Blended Interaction* [17], a conceptual framework that describes the nature of human-computer interaction, was used to provide a concrete and structured scope for the conducted review. The framework is briefly introduced in the following section.

B. Blended Interaction

Blended Interaction was proposed by Jetter et al. [17]. It combines the virtues of familiar physical and social environments with the benefits of the digital realm in a way that desired properties of both worlds are preserved while providing a 'natural' human-computer interaction. To illustrate their concept of *Blended Interaction,* Jetter et al. [17] apply it to four domains of design: Individual Interaction, Social Interaction and Communication, Workflow, and Physical Environment. These four domains can basically serve as lenses or points of view to identify HCI aspects of the application of MR/VR displays in basic nursing care education.

- *Individual Interaction* describes the way each individual interacts with a system, the usage of different input and output modalities, but also the interface itself. In nursing care education, MR/VR technology can allow learners to watch and practice patient-related interactions in their own time and pace. The interaction with the system should be intuitive and - if possible - draw as little attention from the learner as possible, to allow him/her to focus on the activity to be learned.

- *Social Interaction and Communication* describes the social aspects, standards or norms that influence the way humans collaborate via a system. As most patient-related activities are taught in group settings, this domain is also highly relevant to the design of technology supporting nursing care education.

- *Workflow* describes the overall workflow in which multiple tasks are embedded. In this domain, the focus is on the dynamics of an activity. Patient-related activities to be learned in nursing care education often involve multiple steps, which have to be adapted to the current situation according to patients' abilities or the specifics of an illness. Thus, accounting for the workflow and possible diversions is an important aspect for successfully teaching and learning patient-related interactions in nursing care education.

- *Physical Environment* describes the physical environment in which interaction takes place. One critical aspect of nursing care education is to transfer the learned activities from the school context to the hospital context. Integrating contextual information like the physical environment into the learning scenarios can ease this transfer and significantly increase the learning experience. Thus, we believe that it can serve as a sound foundation for the development of MR/VR systems in basic nursing care education, addressing both technological as well as domain-specific requirements.

The framework of *Blended Interaction* and especially the named four domains encompass not only technical aspects but also physical surroundings and social contexts of an interface.

C. Research Goal

The goal of our work is to apply insights of HCI research concerning the design and implementation of MR/VR systems onto existing work in the domain of basic nursing care education to identify directions for further research and design, leveraging the technologies' full potential. To reach our goal, we followed three steps:

- *Step 1:* Provide an overview of existing work concerning MR/VR systems designed for basic nursing care education.
- *Step 2:* Analyze to what extent the identified systems cover the named four dimensions of design.
- *Step 3:* Based on the results of step 1 and step 2, discuss current limitations and potentials of enhancing the application of MR/VR technology to support basic nursing care education.

In the following method section, we report the procedure and results of a review of the current employment of MR and VR displays (including desktop-based ones) in basic nursing care education (step 1). In our result section, publications are categorized according to the four domains of design of *Blended Interaction* (step 2). Finally, we discuss our findings and provide directions for future research and design in our discussion section (step 3).

II. Method

As the focus of our review is to identify and position existing applications of MR/VR technology in nursing care education, we chose the Web of Science Core Collection [32] as the source for our review. We searched the Science Citation Index Expanded (SCI-EXPANDED), as well as the Social Science Citation Index (SSCI) without limiting the timespan. In order to make sure that only relevant publications were included, we searched for *topics* that covered all of the three aspects: (i) MR/VR, (ii) nursing care and (iii) education. The construction of the search query and the amount of considered terms with a similar or related meaning is depicted in Fig. 2 (different forms of the used terms as well as different ways of writing were considered). In addition, we specified to include only articles and proceedings in our search results. The query was conducted on the 15th February, 2018 and resulted in 139 identified publications to be reviewed manually. In our manual review, we applied the following two criteria to the publications' to further filter relevant work. Only publications that incorporated both components were included in our final list of relevant papers.

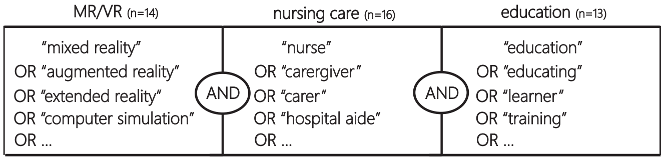

Fig. 2. Structure of the used search query, including samples of search terms

- *Presentation and description of a MR/VR system.* Included publications had to present a MR/VR system. If it was implemented by the authors, the MR/VR system had to be described within the publication. If an existing system was reused, it either had to be described within the publication, or a reference to an external source had to be given.
- *Support of basic Nursing Care Education.* The MR/VR System had to support the teaching of activities or knowledge which nurses have to possess in order to provide patients with basic care. Besides the fundamental activities identified by Kitson et al. [19] (hygiene, safety, nutrition, elimination, rest and sleep, mobility, respiration, respecting choice, temperature control, expressing sexuality, and communication), we also considered activities like the administration of medication, the assessment of wounds, and the management of stress as relevant to the basic everyday tasks of nurses. Publications which addressed more specialized activities like surgery or the treatment of specific diseases were not considered.

We went through all 139 papers abstracts manually in order to apply the above mentioned filters. This process resulted in a total of 44 publications. In a second filter step, we examined the full-text of these publications. After doing so, a total of 18 papers remained. Two of these 18 publications were not accessible for computer scientists and had to be neglected for our review. Finally, 16 publications were taken for the final mapping on the four domains of design of *Blended Interaction*. To this end, we analyzed the full-text of each publication and reviewed *how* each of the four domains of design was addressed by the presented MR/VR system.

III. Results

Concerning the venue of publication, almost half of the 16 papers which were analyzed in detail was published in the journal *Clinical Simulation in Nursing* (n=7). The remainder of the reviewed literature is widely spread across different journals. Only one work was published as early as 2003 and one in 2008, whereas the other 14 papers were published in the years 2012 (n=3), 2013 (n=1), 2014 (n=2), 2015 (n=2), 2016 (n=3) and 2017 (n=3). Tab. I provides an aggregated overview of the review results. As can be seen, most of the reviewed systems use 2D monitors to simulate 3D content including virtual work environments and patient body parts. Further, the majority of systems offers "windows, icons, menus, pointer" (WIMP) interactions or specific haptic devices for the provision of input, provides only limited or no support for social interactions and facilitates either structured workflows or allows learners to freely interact during learning without a strict framing.

IV. Discussion

As shown in the results section, the reviewed publications were mainly published within the last six years, indicating a re-

TABLE I. OVERVIEW OF REVIEW RESULTS

	Domains of Design			
	Individual Interaction	***Social Interaction and Communication***	***Workflow***	***Physical Environment***
Dubovi, Levy & Dagan [10]	*Input:* WIMP *Output:* 2D monitor	/	structured workflow	virtual clinic environment
McWilliams et al. [24]	*Input:* WIMP & haptic device *Output:* 2D monitor	study: cooperative learning	/	realistic device; artificial context
Gu, Zou & Chen [15]	*Input:* WIMP *Output:* 2D monitor	/	/	virtual clinic environment
Darragh et al. [9]	*Input:* WIMP *Output:* 2D monitor	/	free interaction	virtual patient home
Tiffany & Hoglund [29]	*Input:* WIMP *Output:* 2D monitor	communicate with other persons through avatars	free interaction	virtual clinic/other environment
Carlson & Gagnon [3]	*Input:* touch & direct *Output:* tablet & manikin	simulated dialogs (video) & simulated communication with manikins (Wizard of Oz)	structured workflow (low-level tasks) & free interaction (upper-level tasks)	physical clinic environment (bed & patient manikin)
Choi et al. [6]	*Input:* haptic device *Output:* 2D monitor	/	structured workflow & free interaction (training mode)	3D models of patient body parts; artificial context
Smith & Hamilton [28]	*Input:* WIMP *Output:* 2D monitor	/	structured workflow	/
Gaggioli et al. [13]	*Input:* gamepad *Output:* VR, glasses	therapist guides learning	free interaction & guidance by therapist	virtual clinic/other environment
Vottero [31]	*Input:* touch, move & hand-held trigger-device *Output:* VR, cave	simulated social contact through interruptions	free interaction & workflow interruptions	virtual clinic environment
Johannesson et al. [18]	*Input:* haptic device *Output:* 2D monitor	study: pairwise learning	free interaction	learner wear nursing gowns; artificial context
Jenson & Forsyth [16]	*Input:* haptic device *Output:* 2D monitor	/	structured workflow	/
Choi, Chan & Pang [7]	*Input:* haptic device *Output:* 2D monitor	/	/	artificial context
Jung et al. [19]	*Input:* haptic device *Output:* 2D monitor or optical see-through	/	/	realistic device; artificial context
Tsai et al. [30]	*Input:* WIMP & haptic device *Output:* 2D monitor & physical change	/	structured workflow	/
Engum, Jeffries & Fisher [12]	*Input:* WIMP & haptic device *Output:* 2D monitor	/	/	artificial context

/ = no clear information about support of the respective domain of design provided by the reviewed work; WIMP = "windows, icons, menus, pointer"

cent increasing interest in using MR/VR systems to support basic nursing care activities. Further, the results show how the four domains of design of *Blended Interaction* are addressed by existing systems. In the following, we briefly discuss these results and suggest three future directions for design, related to the four domains of design:

(1) Stimulating collaboration through 3-dimensional real world overlays: Considering the review results, an active support for social interaction and communication seems either limited or completely missing in existing MR/VR systems for basic nursing care education. Although some systems were used to study cooperative learning (e.g. [24]), most of the reviewed systems were not designed with a focus to support collaboration between multiple students and/or teachers. In an attempt to increase realism, Vottero [31] integrated workflow interruptions, like a ringing telephone, social inquiries *("Can Mrs. Adams in room 32 have water? She was NPO earlier?"* [31]) and others. Tiffany & Hoglund [29] allowed the communication of learners with their colleagues while meeting with virtual characters in a virtual world. Finally, Carlson & Gagnon [3] facilitated the scanning of markers in a physical hospital room scenario to view videos with simulated dialogs and allowed the communication of learners with manikins by use of a human speaker who provided the manikin's voice. We argue that the reviewed systems only leverage part of the existing technological potential. Modern MR displays could be used to learn together over remote distances aided by overlays of the real world with virtual instructions (e.g. [4]) or enhance support for collocated collaborative interactive discussions by allowing the highlighting of important aspects or comparative views of conducted experiences (see Fig. 3a). Further, especially when training collaborative real world tasks like the mobilization of patients, real world overlays mapped to the trainees' bodys could be advantageous to provide important information in a non-intrusive way without requiring long training interruptions.

(2) Enhanced Learning workflows by rendering or deliberately hiding information: The review results indicate that existing MR/VR systems for the education of basic nursing care either provide clearly structured workflows or let learners

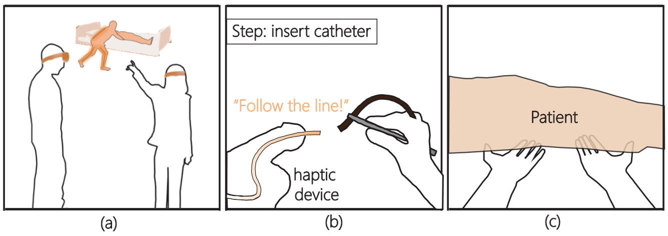

Fig. 3. Suggestions for the support of basic nursing care education through MR. (a) Collaborative view of conducted experiences, including visual highlights of important aspects. (b) Augmentation of a workflow with a haptic device through virtual information. (c) Increasing realism of tasks like patient mobilization by physically enabling a virtual patient representation which can be moved through realistic, direct interactions from an egocentric perspective.

interact freely without clear workflow restrictions. However, most current systems do not strongly differentiate the support between different workflow steps. Only some systems make distinctions in supporting the workflow different for e.g. low and higher-level tasks [3] or initial learning and the training or evaluation of learned activities [6]. Further, in the reviewed systems, workflow related information is often displayed dislocated from the parts of the real world which it addresses. Multiple systems provide physical haptic devices, but display workflow related information on 2-dimensional monitors and require learners to interact with these representations through a mouse and/or keyboard. For learning activities which can be split into different steps, it might be beneficial to provide different support for the individual steps and directly relate this support to the parts of the real world which they address (e.g. display information overlayed on a physical haptic device (see Fig. 3b)). Dependent on the learned task and a learners knowledge about its conduct, real world information could be deliberately occluded (e.g. to reduce distraction by hiding information irrelevant for the present step and facilitate focused learning) or extended with virtual content (e.g. to provide relevant information overlayed on the real world or to train workflows in realistic environments) in order to improve the effectiveness of existing learning workflows and help to guarantee that given standards and norms are adhered to.

(3) More realistic interactions and immersive environments with physically enabled virtual objects: The outcome of the review suggests that there is a lack of realism in the interaction and the environments offered by current MR/VR education systems for basic nursing care activities. While various interfaces offer more or less realistic haptic devices to provide input, these systems lack realism in terms of visual output. Most of these systems provide 3-dimensional representations on 2-dimensional monitors which are only navigable via classic WIMP interactions. In contrast, the reviewed system, studied by Vottero [31] used stereoscopic glasses to provide a more realistic virtual environment for a simulated medication withdrawal system. However, the system lacked support for realistic interactions when users should grab medications from the dispenser and mainly missed support for the haptic sense. The author herself saw the necessity to create a *"hybrid simulation, combining aspects that can be computer generated and those that require a more realistic approach"* [31]. In order to create more realistic virtual environments, past work [22][1] showed the potential of physically enabling virtual objects and surroundings, by e.g. making parts of the virtual world touchable. In general, combining virtual and real content more effectively, e.g. by simulating haptic aspects of virtual patients (see Fig. 3c), could facilitate more realistic interactions and improved support for individual training in different contexts and situations. Further, when developing new MR interfaces, it might be advantageous to use either low-fidelity interactions or interactions which resemble the real world closely in order to avoid a decrease in user performance. McMahan et al. [23] provided empirical evidence in regard to VR interfaces, which suggests that semi-natural interactions are worse for user performance than low-fidelity and high-fidelity approaches.

V. Conclusion

In this paper we explored possibilities for HCI to inform the design of MR systems for basic nursing care education. We reviewed the current employment of MR and VR displays in basic nursing care education. We found that most reviewed systems support individual interactions by mouse, keyboard or specific haptic devices, lack a design for and support of social interactions, provide structured workflows or allow users to interact freely, and make use of 2-dimensional VR displays for the simulation of virtual models and environments. We discussed our results in relation to the conceptual HCI framework Blended Interaction [17] and suggest directions for design. In conclusion, our results indicate that MR in basic nursing care education just barely scratches the surface. Prospective systems might stimulate collaboration through 3-dimensional overlays, enhance learning workflows by rendering or deliberately hiding information, provide more realistic interactions and allow for more immersive environments through physically enabled virtual objects.

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Literatur

[1] Araujo, Bruno, Ricardo Jota, Varun Perumal, Jia Xian Yao, Karan Singh, and Daniel Wigdor. 2016. "Snake Charmer: Physically Enabling Virtual Objects." In Proceedings of the TEI '16: Tenth International Conference on Tangible, Embedded, and Embodied Interaction, 218–26. TEI '16. New York, NY, USA: ACM. https://doi.org/10.1145/2839462.2839484.

[2] Bacca, Jorge, Silvia Baldiris, Ramón Fabregat, Sabine Graf, and Dr Kinshuk. 2014. "Augmented Reality Trends in Education: A Systematic Review of Research and Applications." *Educational Technology and Society* 17:133–49.

[3] Carlson, Kasey J, and David J Gagnon. 2016. "Augmented Reality Integrated Simulation Education in Health Care." *Clinical Simulation in Nursing* 12 (4): 123–27. https://doi.org/https://doi.org/10.1016/j.ecns.2015.12.005.

[4] Chen, Henry, Austin S. Lee, Mark Swift, and John C. Tang. 2015. "3D Collaboration Method over HoloLensTM and SkypeTM End Points." Proceedings of the 3rd International Workshop on Immersive Media Experiences - ImmersiveME '15, 27–30. https://doi.org/10.1145/2814347.2814350.

[5] Chen, Peng, Xiaolin Liu, Wei Cheng, and Ronghuai Huang. 2017. "A Review of Using Augmented Reality in Education from 2011 to 2016." In *Innovations in Smart Learning*, edited by Elvira Popescu, Kinshuk, Mohamed Koutheair Khribi, Ronghuai Huang, Mohamed Jemni, Nian-Shing Chen, and Demetrios G Sampson, 13–18. Singapore: Springer Singapore.

[6] Choi, Kup-Sze, Xuejian He, Vico Chung-Lim Chiang, and Zhaohong Deng. 2015. "A Virtual Reality Based Simulator for Learning Nasogastric Tube Placement." *Computers in Biology and Medicine* 57: 103–15. https://doi.org/https://doi.org/10.1016/j.compbiomed.2014.12.006.

[7] Choi, Kup-Sze, Sze-Ho Chan, and Wai-Man Pang. 2012. "Virtual Suturing Simulation Based on Commodity Physics Engine for Medical Learning." *Journal of Medical Systems* 36 (3): 1781–93. https://doi.org/10.1007/s10916-010-9638-1.

[8] Cook, David A., Rose Hatala, Ryan Brydges, Benjamin Zendejas, Jason H. Szostek, Amy T. Wang, Patricia J. Erwin, and Stanley J. Hamstra. 2011. "Technology-Enhanced Simulation for Health Professions Education: A Systematic Review and Meta-Analysis." *JAMA* 306 (9):978–88. http://dx.doi.org/10.1001/jama.2011.1234.

[9] Darragh, Amy R, Steve Lavender, Barbara Polivka, Carolyn M Sommerich, Celia E Wills, Bradley A Hittle, Renee Chen, and Donald L Stredney. 2016. "Gaming Simulation as Health and Safety Training for Home Health Care Workers." *Clinical Simulation In Nursing* 12 (8). Elsevier: 328–35. https://doi.org/10.1016/j.ecns.2016.03.006.

[10] Dubovi, Ilana, Sharona T Levy, and Efrat Dagan. 2017. "Now I Know How! The Learning Process of Medication Administration among Nursing Students with Non-Immersive Desktop Virtual Reality Simulation." *Computers & Education* 113: 16–27. https://doi.org/https://doi.org/10.1016/j.compedu.2017.05.009.

[11] Dürr, Maximilian, Ulrike Pfeil, and Harald Reiterer. 2017 (in press). "Einsatzmöglichkeiten von Mixed Reality Zur Unterstützung von Motorischem Lernen." In *Proceedings of DeLFI 2017*.

[12] Engum, Scott A., Pamela Jeffries, and Lisa Fisher. 2003. "Intravenous Catheter Training System: Computer-Based Education versus Traditional Learning Methods." *American Journal of Surgery* 186 (1): 67–74. https://doi.org/10.1016/S0002-9610(03)00109-0.

[13] Gaggioli, Andrea, Federica Pallavicini, Luca Morganti, Silvia Serino, Chiara Scaratti, Marilena Briguglio, Giulia Crifaci, et al. 2014. "Experiential Virtual Scenarios with Real-Time Monitoring (Interreality) for the Management of Psychological Stress: A Block Randomized Controlled Trial." *Journal of Medical Internet Research* 16 (7): e167. https://doi.org/10.2196/jmir.3235.

[14] Green, Janet, Aileen Wyllie, and Debra Jackson. 2014. "Virtual Worlds: A New Frontier for Nurse Education?" *Collegian* 21 (2):135–41. https://doi.org/https://doi.org/10.1016/j.colegn.2013.11.004.

[15] Gu, Yaohua, Zhijie Zou, and Xiaoli Chen. 2017. "The Effects of VSIM for Nursing (TM) as a Teaching Strategy on Fundamentals of Nursing Education in Undergraduates." *Clinical Simulation In Nursing* 13 (4). Elsevier: 194–97. https://doi.org/10.1016/j.ecns.2017.01.005.

[16] Jenson, Carole E, and Diane McNally Forsyth. 2012. "Virtual Reality Simulation: Using Three-Dimensional Technology to Teach Nursing Students." *CIN - Computers Informatics Nursing*. https://doi.org/10.1097/NXN.0b013e31824af6ae.

[17] Jetter, Hans-Christian, Harald Reiterer, and Florian Geyer. 2014. "Blended Interaction: Understanding Natural Human--Computer Interaction in Post-WIMP Interactive Spaces." *Personal Ubiquitous Comput.* 18 (5). London, UK, UK: Springer-Verlag:1139–58. https://doi.org/10.1007/s00779-013-0725-4.

[18] Johannesson, Eva, Charlotte Silén, Joanna Kvist, and Håkan Hult. 2013. "Students' Experiences of Learning Manual Clinical Skills through Simulation." *Advances in Health Sciences Education* 18 (1): 99–114. https://doi.org/10.1007/s10459-012-9358-z.

[19] Jung, Eun-Young, Dong Kyun Park, Young Ho Lee, Hyun Sook Jo, Yong Su Lim, and Rae Woong Park. 2012. "Evaluation of Practical Exercises Using an Intravenous Simulator Incorporating Virtual Reality and Haptics Device Technologies." *Nurse Education Today* 32 (4): 458–63. https://doi.org/https://doi.org/10.1016/j.nedt.2011.05.012.

[20] Kitson, Alison, Tiffany Conroy, Yvonne Wengstrom, Joanne Profetto-McGrath, and Suzi Robertson-Malt. 2010. "Defining the Fundamentals of Care." *International Journal of Nursing Practice* 16 (4). Blackwell Publishing Asia:423–34. https://doi.org/10.1111/j.1440-172X.2010.01861.x.

[21] Kopetz, Jan Patrick, Daniel Wessel, and Nicole Jochems. 2018. "Eignung von Datenbrillen Zur Unterstützung von Pflegekräften in Der Ausbildung." *Zeitschrift Für Arbeitswissenschaft* 72 (1):13–22. https://doi.org/10.1007/s41449-017-0072-9.

[22] Lopes, Pedro, Sijing You, Lung-Pan Cheng, Sebastian Marwecki, and Patrick Baudisch. 2017. "Providing Haptics to Walls & Heavy Objects in Virtual Reality by Means of Electrical Muscle Stimulation." In Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems, 1471–82. CHI '17. New York, NY, USA: ACM. https://doi.org/10.1145/3025453.3025600.

[23] McMahan, Ryan P, Chengyuan Lai, and Swaroop K Pal. 2016. "Interaction Fidelity: The Uncanny Valley of Virtual Reality Interactions." In Virtual, Augmented and Mixed Reality, edited by Stephanie Lackey and Randall Shumaker, 59–70. Cham: Springer International Publishing.

[24] McWilliams, Lenora A, Ann Malecha, Rae Langford, and Paula Clutter. 2017. "Comparisons of Cooperative-Based Versus Independent Learning While Using a Haptic Intravenous Simulator." *Clinical Simulation in Nursing* 13 (4): 154–60. https://doi.org/https://doi.org/10.1016/j.ecns.2016.12.008.

[25] Milgram, Paul, and Fumio Kishino. 1994. "A Taxonomy of Mixed Reality Visual Displays." *IEICE Trans. Information Systems* E77–D:1321–29.

[26] Schmalstieg, Dieter, and Tobias Höllerer. 2015. *Augmented Reality: Principles and Practice*. Addison-Wesley Usability and HCI Series. Addison-Wesley.

[27] Simpson, Roy L. 2002. "The Virtual Reality Revolution: Technology Changes Nursing Education." *Nursing Management* 33 (9). Lippincott Williams & Wilkins:14.

[28] Smith, Pamela C, and Bernita K Hamilton. 2015. "The Effects of Virtual Reality Simulation as a Teaching Strategy for Skills Preparation in Nursing Students." *Clinical Simulation in Nursing* 11 (1): 52–58. https://doi.org/https://doi.org/10.1016/j.ecns.2014.10.001.

[29] Tiffany, Jone M, and Barbara A Hoglund. 2016. "Using Virtual Simulation to Teach Inclusivity: A Case Study." *Clinical Simulation in Nursing* 12 (4): 115–22. https://doi.org/https://doi.org/10.1016/j.ecns.2015.11.003.

[30] Tsai, Sing-Ling, Sin-Kuo Chai, Li-Feng Hsieh, Shirling Lin, Fang-Meei Taur, Wen-Hsu Sung, and Ji-Liang Doong. 2008. "The Use of Virtual Reality Computer Simulation in Learning Port-A Cath Injection." *Advances in Health Sciences Education : Theory and Practice* 13 (May): 71–87.

[31] Vottero, Beth A. 2014. "Proof of Concept: Virtual Reality Simulation of a Pyxis Machine for Medication Administration." *Clinical Simulation in Nursing* 10 (6): e325–31. https://doi.org/https://doi.org/10.1016/j.ecns.2014.03.001.

[32] Analytics, Clarivate. "Web of science core collection." Citation database. Web of Science. 2017.

[33] Zhu, Egui, Arash Hadadgar, Italo Masiello, and Nabil Zary. 2014. "Augmented Reality in Healthcare Education: An Integrative Review." *PeerJ* 2 (July):e469. https://doi.org/10.7717/peerj.469.