VR as innovation in dental education
Validation of a virtual reality environment: collecting evidence ‘on-the-fly’ during development and implementation
de Boer, I.R.

Citation for published version (APA):

General rights
It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

Disclaimer/Complaints regulations
If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: https://uba.uva.nl/en/contact, or a letter to: Library of the University of Amsterdam, Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.
General discussion
REFLECTION

This thesis describes the evaluation and validation of assumptions made prior to the development of a virtual reality learning environment (VRE) for use in dental education: the Moog Simodont dental trainer. This technological development was conducted using the ‘on-the-fly’ approach for simultaneous development, implementation, and evidence collection. This approach permitted the developed VRE to be immediately employed in the dental curriculum, enabling feedback acquisition for further development, without a participant selection bias. An iterative process was maintained throughout, with user-feedback continuously used to improve and expand the possibilities of the VRE.

Virtual teeth, with and without pathology, were created with a specially designed computer programme, called ColorMapEditor (CME), that allowed the creator to build a virtual patient with virtual teeth with realistic dental characteristics, to simulate a clinical situation as much as possible. Aside from learning from the theoretical aspects of the case (e.g. patient history, x-rays), the VRE with virtual teeth enables users to perform treatments in the virtual world. CME is a feasible programme, but requires continuous updating with further possibilities, to strive for a vast library of virtual teeth resembling realistic dental problems for students to learn from.

The first batch of virtual teeth was evaluated among key VRE users: dentists, teachers, and students. Their opinions on the appearance of several aspects of the virtual teeth, compared to plastic teeth (contemporary preclinical teaching method) and human extracted teeth (gold standard), were evaluated. Results revealed that, compared to plastic teeth, virtual teeth were better in terms of appearance and learning possibilities; however, natural teeth remained the gold standard. Nevertheless, as natural teeth are becoming increasingly rare, alternatives are needed and virtual teeth seem promising as a replacement. Further research on the quality of virtual teeth in the treatment of virtual patients is necessary to improve learning possibilities and increase the potential of the VRE as an alternative to certain clinical procedures.

Very specific choices were made early in the development of the VRE, which affected the technical properties of the dental trainer.

Firstly, a major decision was whether to work with two-dimensional (2D) or three-dimensional (3D) vision. Both options have their advantages (e.g. 3D vision could be more clinically realistic for acquiring manual dexterity, 2D is less expensive) and disadvantages (e.g. 3D vision is complex to produce, and with 2D users can experience problems with depth in their vision). Evaluation of the performance and user preferences revealed that 3D vision has significant positive effects on performance and was identified as highly preferable among students compared to 2D vision. Thus, with the development of this VRE, the use of 3D vision was confirmed.
and if cost reductions are of importance, there should not be saved on the visualisation in the dental trainer.

Secondly, it was decided to build a Simodont dental trainer with haptic or force feedback (FFB) during virtual treatments or exercises. This decision had major implications, as it increases both the building and implementation complexity. User feedback revealed that users have strong, albeit diverse, opinions on the level of FFB that they experience while working with the dental trainer. Discussions, as to the amount of FFB required, are still ongoing, and will probably continue until a high level of realism is achieved, making the dental trainer a simulator. To nuance the discussion it was investigated whether FFB is required in the VRE, as well as the effect of different levels of FFB on the performance and experience of students. The first study revealed that FFB is a requirement for performance in the VRE; it was almost impossible to complete an exercise without tactile feedback. The second study on FFB revealed that, after a certain amount of practice, the level of FFB seemed less relevant, as students could perform satisfactorily independently of the FFB received. This provides information as to whether a certain level of FFB is required to train students within the VRE to enable them to perform the same treatment in the clinic, even though the level of FFB is not (yet) an exact simulation of reality. In contrast, FFB in reality varies considerably between different materials and between and within different individuals’ teeth.

All research presented in this thesis was based on the steps of the ‘on-the-fly’ approach, concerning simultaneous stepwise development, stepwise implementation, and stepwise collection of evidence with the goal of improving technological development and dental education, as well as expanding the VRE applications. Innovation in dental education necessitates many choices to enable continuous development prior to scientific evidence to confirm choices and demonstrate effectiveness. Creating evidence as soon as possible is fundamental to support the acceptance of the innovation within the academic environment. Collecting user-feedback to improve the innovation and conducting scientific research to confirm decisions are helpful for implementation within the curriculum. All factors are inter-connected.

Pioneering in a specialty field usually encounters resistance from many directions; a feeling of ‘why change what has worked for many years?’ is very likely to result. Innovation could feel ‘unsafe’ and evoke hesitation. Of interest, the well accepted traditional learning environment is based on very limited evidence. However, the development of the Simodont dental trainer arose from the necessity to innovate, improve the quality of dental education, and thus ensure that the dental curriculum is future-proof.

All research described in this thesis has the advantage of evidence collection with a complete cohort of students and therewith the exclusion of a selection bias in the group. The disadvantage was that performing research in a running curriculum implied that all tests had to adhere
to the educational rules and regulations as set by the Board of Exams and had to be performed within the timeframe that all students were available. This resulted in limitations concerning the distribution of students in groups, as each student had to receive the same amount of training time and education.

The research performed so far has confirmed the developmental choices of the Simodont dental trainer. Further research on validation should be performed concerning the use of sound in the dental trainer and the necessity of co-location; meaning that the 3D image in the Simodont should be projected where the hand of the operator is located.

**The importance of innovation in dental education**

There are several reasons why innovation in dental education is not a luxury or an ‘option’.\(^2\) Contemporary society is rapidly changing. In the past, the primary focus in dentistry was on repairing tissue damage and creating durable restorations. A paradigm shift has now turned the focus to prevention of (dental) problems and sharing knowledge with the patient by coaching and providing guidance toward a healthier lifestyle. Society standards, values, and priorities change over time. Thus, innovation for continued progression to meet future needs is of high importance.

Students should be trained and educated to operate in the contemporary knowledge-driven society; patients have the availability of information of varied quality (high and low), to which a dentist must respond. Moreover, the use of patients for learning is now less acceptable; if a student provides care to a patient, the student should have demonstrated competence prior to the treatment. Thus, the question remains, how should we educate students to meet this principle while also ensuring that they are sufficiently competent prior to entering the clinic? A phantom head offers opportunities for developing manual dexterity with precise handling of the instruments on plastic teeth, by copying the environment and tools but without clinical problem solving, a situation far from reality or comparable to the clinical setting. With contemporary possibilities in the 21st century, developments within information computer technology seem an obvious path for the development of dental education. Embedding technological innovations within education increase the guarantees of a future-proof curriculum.

**A future-proof curriculum for dental education**

The creation and development of a future-proof dental curriculum involves both updating the contemporary curriculum and ensuring that (technological) developments, such as the VRE applications, continuously advance to become less and less dependent upon the availability of patients in the clinic.\(^2\) In this way, a curriculum will always be subject to change. Educating dental students should be possible without dependence on the availability of patients with certain dental pathologies. Being less dependent on patients’ availability also creates the opportunity to easily adapt to higher or lower intakes of students. In the near and distant future, the dental
profession is subject to change, influenced by both society and commercial technological innovations. Current dental students have developed competences which may or may not be needed one or two decades from now. What are the future societal and patient requirements? To prepare for this, a training environment should be flexible and easily adaptable to changing learning needs, to serve both undergraduate and postgraduate training, as well as lifelong learning. High quality education should prepare to meet the expectations of society.

The contribution of a virtual learning environment to a future-proof curriculum

With the use of technology in education, changes occur not only in teaching, but also in the methods of learning. A VRE can meet the high demands and standards of students in terms of flexibility and communication with teachers and fellow students, and thus developments such as the Simodont dental trainer would be instrumental in the creation of a future-proof curriculum. A VRE offers virtual patients, endless treatment opportunities and helps ensure student competency before treating a real patient. Other technological innovations can be aligned to create enhanced resemblance to reality, such as uploading patient data of an intra-oral scanner into the virtual learning environment. New dental treatments can be practised in the VRE before application in a real patient. Additionally, this offers the opportunity for continuous education or reintegration courses. Over time, the VRE should evolve from a ‘trainer’ into a ‘simulator’, thereby further closing the gap between learning and training in preparation for the clinic and actual clinical treatment of patients.

Dreams, wishes, and expectations for the future

Based on the current development and application of technology for dental education, what can we expect for the future? Is it possible that a VRE in dental training will no longer be an adjunct, but will completely replace contemporary educational means? Will it be possible to switch between a VRE and reality without noticing? How far can technology take us in optimizing education and striving for a future-proof dental curriculum, future-proof dentists, and lifelong learners? The technology requirements for educational use will become increasingly more complex, aiming for a smooth transition between simulation and reality. When will the use and replacement of reality by a VRE in dental training be accepted in education and considered 100% ‘safe’? Learning completely new skills on real patients in clinic has become increasingly less acceptable with the introduction and early use of virtual reality in education many years ago. Moreover, this was one of the many reasons why virtual reality was initially developed and introduced.

How far can we go and what is ethically desirable in a profession that is also based on human interaction? Could virtual reality become a social major as well and replace human interaction? Is the social transition to virtual reality desirable?
The constant drive to keep on innovating, moving forward, accomplish aforementioned dreams, and renew possibilities of the virtual world for transition of the VRE into reality is only possible with continuous educated risk-taking and the introduction of new developments without the availability of scientific evidence. The continuous collection and creation of evidence remains important to support and guide future innovation. The ‘on-the-fly’ approach, as presented in this thesis, will remain a constant iterative and necessary process to conquer hesitance to change of the academic world.

*If the aforementioned could become possible, replacement of contemporary educational tools and transition to a complete educational virtual world might just become reality....*

**A well-educated guess**
Approximately fifteen years ago I made my entrance into the (educational) world of dentistry. Considering the application of computer technology in dental education over time, several aspects in the curriculum have changed. Treating patients early on in the curriculum was common; my first invasive procedure occurred in the second year of my training. Learning and acquiring skills on patients was the standard, which is in line with the fact that no alternative methods were available.

Considering the present time, it is less acceptable to use patients for learning new (invasive) skills, surely since the process of offering an alternative and safer learning environment to students is expanding. This requires a transition by letting go the ‘old reality’ and accepting the ‘new reality’, which is specifically applicable to the technical aspects of the training, as interaction with patients remains important for development of social skills.

Moving forward in time; with the wish to create a more sustainable, more efficient, safer and more (cost) effective curriculum for dental training, the use of alternatives such as VR will continue to expand. Assuming that the opportunities with VR continue to expand and improve, a fast take-over of traditional methods can be expected in both preclinical and clinical education. Depending on the speed of further technological development (i.e. advanced computer aided methods, interactive software, artificial intelligence), demands from universities and students and therewith the necessity for this revolution, this may be realized in a timeframe of fifteen to twenty years. This revolution will probably be (at first) most important for the acquisition of technical skills, as it could remain desirable to keep the training of social aspects in the clinic with patients from both a costs point of view as well as the will to remain socially connected through face-to-face meetings. However, in the continuously developing society, human interaction is increasingly more digital and thus even the training in communication may in the future - if costs are no longer a limitation - be designed in VR, enabling students to develop complete clinical competency without clinical exposure.
References

