VR as innovation in dental education

Validation of a virtual reality environment: collecting evidence ‘on-the-fly’ during development and implementation

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General introduction and thesis outline
The history of dental education is marked by both change and continuity. The first marked dental education dates to the year 1530, in which the earliest dentistry textbook was published in Leipzig. This thesis enhances “change” in dental education, and reflects on the developmental processes. For the continued development, growth, and broadening of future dental professionals’ knowledge and possibilities, innovation and the continued enhancement of knowledge are paramount. The new possibilities afforded over time, by technical innovations and knowledge should be used to shape the academic and professional development of dentists.

Innovation in dental education encompasses many areas. A current major pillar of innovation in medical and dental education is the introduction of virtual reality (VR) and virtual reality environments (VRE). The use of simulation has been proposed as the next major step in the evolution of health science education. VREs have a very wide operational capability.

Advantages of VR often discussed in (dental) education:

Patient care:
- Patient safety: procedures can be practiced in a VRE and mistakes corrected before the patient receives the actual treatment.

Environmental:
- The possibility to practice without wasting (disposable) materials and water.
- Avoidance of the use and waste of human tissue (e.g. extracted teeth).
- Hygiene: no contact with possible contaminated (human) tissues or fluids.

Educational:
- As procedures are undertaken in a computer environment, each step is traceable. This enables users to go back in time and re-analyse specific difficult aspects of procedures or practices. For teachers, this option presents the opportunity to judge the complete process of a treatment, rather than just the end-product or result.
- Objective assessment by the computer: no subjectivity is introduced by examiners during assessment and the computer calculates the score.
- Overcoming the disconnection between the classroom/pre-clinic and clinic.
- Cost: reducing the waste of practice materials (e.g. disposables, plastic teeth for students, etc.).
Possible *disadvantages* of VR education:

**Patient care:**
- Privacy of digital patient data needs to be guaranteed.
- Lack of human interaction.

**Environmental:**
- The use of extracted human teeth for dental education remains the ‘gold standard’. Virtual teeth are not (yet) available as a complete replacement.

**Education:**
- Cost: the development, maintenance and acquisition of a VRE can be very costly.
- The level of realism achieved in a trainer or simulator: how real should a (dental) trainer or simulator be to enable students to acquire clinical skills? Managing the expectations of users in this matter can be of high importance.
- Implementation in a curriculum can be challenging, as a completely new environment is added to existing teaching methods.

At many dental schools, including the Academic Centre for Dentistry Amsterdam (ACTA), educational challenges were experienced due to the shortage of extracted human teeth with the desired pathologies to train students in simulated clinical problem solving. Additionally, there is a lack of patients with the proper dental diseases for the development of all clinical competencies. The use of extracted teeth and the variety of patients also alter students’ circumstances; student experiences were difficult to compare due to different circumstances during learning and testing. Plastic teeth, used as a substitute for human teeth, differ considerably to human teeth in terms of their colour and hardness. Moreover, they are either sound or contain unrealistic simulated caries.

ACTA was searching for a solution to overcome these challenges in dental training, and secure a ‘future proof’ curriculum that offered a training environment in which students could become competent professionals within the timeframe to graduation, whilst also meeting the increasingly high ethical standards pertaining to learning on patients. Additionally, renewing and improving the quality of dental education is a constant agenda. Therefore, an exploration of the possibilities of VR simulation in dental training was carried out.
THE DAWN OF THE SIMODONT DENTAL TRAINER

The beginning
To sustain dental training, ACTA tested since 2000 almost all new dental training technologies available on the market, varying from augmented reality to virtual reality. Based on the testing outcomes, an important requirement for a new VRE was identified. VREs should enable students to perform entire procedures or exercises in the virtual world, thereby embracing the opportunities provided by VR and avoiding the complexities of combining VR with reality. ACTA was looking for a learning environment to enhance competency based learning and to introduce a better integration of theory with practice. In 2002, ACTA made first contact with Fokker Control Systems (a few years later known as Moog Inc.)\(^4\), a company specializing in precision motor control products and systems.\(^5\) In 2007, ACTA sought to form a partnership with FCS (now Moog Inc.), following proof of concept of the proposed solution to meet the educational needs (i.e. a learning environment in which students’ could work safely and independently to learn at their own pace). Development of an entirely new simulator was planned by cooperation between ACTA and FCS. A subsidy from the Ministry of Education of the Netherlands (the Hague, the Netherlands) was received by ACTA to invest in the development of the educational courseware in the Moog Simodont dental trainer. In 2007, the first contract was signed with Moog to co-develop 50 machines that would be installed in the preclinical lab of ACTA by September 2010.

Designing the Simodont dental trainer
The first sketch of the Simodont dental trainer was created in 2005 (Figure 1).

The operator hands and the field of view (FOV) were positioned in accordance with real-life scenarios of a working dentist. The working area was restricted by the FOV, and thus, the operator was unable to move around the ‘patient’. However, the position of the “patient”

Figure 1. The first draft of the Simodont dental trainer.
could be changed during ‘treatment’, enabling the work to be conducted from realistic positions respective to the patient.

Many prototypes followed until 2009 (Figures 2a & 2b). In 2010, the latest version was installed at ACTA (Figure 3). To achieve future proof education, the Simodont dental trainer was intended to offer the possibility for use in both pre-clinical and clinical settings. The transition between these learning environments should be effortless for users; therefore, the development of haptics in the Simodont dental trainer was a major focal point, meaning that the force feedback (FFB) or ‘feeling’ during drilling needed to be as life-like as possible. Additionally, the final design of the Simodont dental trainer was required to be ‘student proof’, meaning that the machine should facilitate independent student use without the need for constant teacher or technician supervision.

Figure 2a. Prototypes of the Simodont dental trainer.

Figure 2b. Prototypes of the Simodont dental trainer.
Continuous development

The Simodont dental trainer is still currently under development, and its software and hardware specifications are continuously being improved. The Simodont dental trainer can now be used for manual dexterity exercises, treatment of virtual patients including treatment planning, as well as for basic cavity preparation and crown preparations. Future applications for the VRE are aimed at bridge preparation, paedodontics, endodontic access cavity preparation, and periodontal examination of virtual patients. To validate the Simodont dental trainer, multiple studies have been performed.5-9

In this thesis, the academic circumstances of simultaneous development, implementation, and evidence collection have been described. Development and stepwise implementation enables the creation of evidence, and several components of the Simodont dental trainer are evaluated for improvement and future development of the technology. During this study the Moog Simodont dental trainer (Moog Inc., Nieuw-Vennep, the Netherlands) was incorporated stepwise into the curriculum, in addition to contemporary teaching methods.

OUTLINE OF THIS THESIS

To be able to treat virtual patients and offer educational training on teeth with realistic anatomy in a virtual world, the development and evaluation of virtual teeth are required. In the first part of this thesis, these topics are described. Chapter 2 describes the development and origin of virtual teeth, with and without pathology. Chapter 3 evaluates the opinions of dental professionals and students on the learning possibilities and appearance of virtual teeth compared to contemporary educational means, such as plastic teeth and extracted human teeth.
The second part of this thesis describes the validation of assumptions for the development of a virtual reality learning environment and evaluation of the experiences of working in the Simodont dental trainer VRE. Chapter 4 discusses the evaluation of working with three-dimensional (3D) versus two-dimensional (2D) vision in the Simodont dental trainer, and their impact on the satisfaction of users. Chapter 5 describes the evaluation of working with and without force feedback in the VRE, and the consequences for dental students on their performance and experiences. Chapter 6 describes the effects on performance when working with a variation in force feedback, during a test on the Simodont dental trainer.

The final part of this thesis, Chapter 7, describes the ‘on-the-fly’ method, which was applied during all previous studies of this thesis. It describes the simultaneous innovation, development, and execution of research in an academic environment while implementing the system in education.
REFERENCES