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Helping hands: an innovative tele-assistance system for clinical skill development with health science students

Final Report 2016

University of Tasmania

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List of acronyms used

AR	Augmented Reality
AMC	Australian Maritime College, UTAS
CRH	Centre for Rural Health, UTAS
HMD	Head Mounted Display
IP	Intellectual Property
IT	Information Technology
OLT	Office for Learning and Teaching
TCEN	Tasmanian Clinical Education Network
THO	Tasmanian Health Organisation
UTAS	University of Tasmania
UV	Ultra Violet
WiFi	Wireless networking technology
WIL	Work-Integrated Learning

Executive summary

Context

Within health curricula, the learning of clinical skills typically begins in the classroom with an explanation of a procedure and the context of its application. The student then practices the skill in a safe, controlled environment (a skills laboratory), often using a manikin. Students are then provided opportunities to apply that skill to a real patient whilst on placement. This can be highly stressful for students who may feel nervous or overwhelmed by the experience and who are often fearful of making a mistake that may cause harm to the patient (Pulido-Martos, Augusta-Landa & Lopez-Zafra, 2011). Continued guidance and support is necessary to develop confidence and mastery of these skills. The application of Augmented Reality (AR) technology has the potential to contribute to learning outcomes in this area (Lee, 2012; Yuen, Yaoyuneyong & Johnson, 2011).

In this project, we customised and piloted the application of a wearable, hands-free, low cost, AR audio-visual guidance system (*Helping Hands)* that enabled health science students (nurses, doctors, and others) to learn and practice clinical procedures with real-time virtual guidance provided by a procedural expert (an instructor) located remotely at another site. The project contributes to the acquisition, development and performance of practical skills by students whilst undertaking work-integrated learning (WIL) placements in hospitals and other health care settings.

Aim

To improve how health science students learn clinical skills whilst on placement in health care settings by applying and customising an AR tele-assistance system to make remote guidance and instruction more accessible.

Approach

The project took a four stage approach:

- Stage 1 determined the **user requirements** of the system and assessed potential technical challenges. Workshops were held with an end-user reference group and data from the workshops was used as the basis for customisation of the technology and to prioritise user requirements.
- Stage 2 was a **feasibility** trial to ensure that clinical skill outcomes were not being compromised by using the innovative AR approach. The hypothesis that there would be no significant difference in outcomes for students undertaking *Helping Hands* instruction compared to “usual instruction” was tested under supervised, simulated conditions in a clinical skills simulation laboratory using handwashing (a fundamentally important basic skill) as the test procedure. The confidence of student participants to perform the handwashing procedure was assessed prior to and following the intervention (usual instruction or *Helping Hands*). The learning (clinical skill) outcomes were assessed by surveying the students and instructors and by using an empirical measure of handwashing success (*Glitterbug*).

- Stage 3 was a **usability** trial where *Helping Hands* was used with students in a patient care area (for example, a hospital), ensuring that patient safety and ethical standards were paramount.
- This report is part of the final stage of the project (Stage 4) which involves the **dissemination** of the findings of the project, its impact on student learning and its potential for further development and uptake across the sector through partnership with other universities and clinical sites.

Key project deliverables

The project has developed and piloted the innovative *Helping Hands* tele-assistance guidance system that allows video images of the learner's activity (procedure) space to be mixed with that of the instructor's hand movements. The instructor can see how a student is performing the procedure in real-time and is able to superimpose their hand movements on the student's should correction or assistance be required to enhance learning.

In developing the *Helping Hands* system the project has demonstrated proof of concept (that is, the concept has been translated into practice), conducted workshops for a reference group of interested end-users, conducted a feasibility trial in a clinical skills laboratory and conducted a usability trial in a hospital setting.

The *Helping Hands* system consists of two units (the student's unit and the instructor's unit) that are connected through WiFi/Internet or the 3G communication network. The student wears a head mounted display (HMD) unit whilst working on a patient or conducting a procedure (Figure 1).

Figure 1. Student wearing HMD unit working on a manikin.

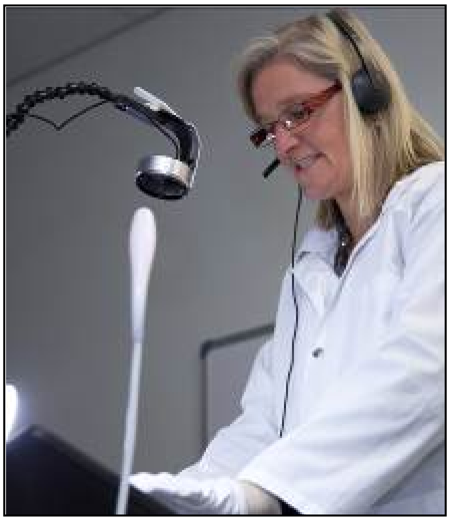

Figure 1. Instructor watching display screen.

The focus of attention, the procedure, is captured by the camera mounted on the HMD. The microphone and headphone enable verbal communication with the instructor. The student's unit also has a near-eye display from which the student can see the image sent from the instructor. The instructor's unit consists of a screen, camera and headset (microphone and headphones). The instructor watches the real-time image from the HMD-mounted camera of the student conducting the procedure on a display screen (Figure 2). A camera mounted on a support arm over the display screen captures the instructor's hand gestures which are then sent to the student's near-eye display.

Impact (outcomes and projected future impact)

Helping Hands is a wearable solution that addresses the need for a hands-free, portable, remote audio and visual guidance system that has broad applicability across the health arena. The application of this technology in learning and teaching scenarios represents a significant step in simulated learning. The project has application across all health care settings with a significant benefit for WIL environments in which staffing levels are lower and those where students may find access to an on-site instructor more difficult (such as in rural and remote areas). The technology developed by this project allows procedural experts to share their skills and acumen with one or more novices without the need to be in the same physical location as the learner. This can represent a significant saving in time, resources and a more effective utilisation of expertise.

In a broader context, the technology has potential for use in many other health care situations such as emergency childbirth, road trauma, expeditionary medicine and remote area medicine, where front-line medical staff may need to call upon a distant procedural expert. The technology also has potential for use in clinical situations necessitating a high level of biosecurity such as those found in bio-containment patient care units, or during the treatment of highly contagious diseases. The technology also has potential for non-health care uses where remote instruction is required.

Key findings

- Clinical skill outcomes are not compromised by using the *Helping Hands* technology: there was no significant difference between the students undertaking "usual instruction" compared with those using *Helping Hands* in a clinical skills simulation laboratory.
- A tele-guidance system such as *Helping Hands* is readily acceptable by end-users.
- Where WiFi, Internet and/or the 3G network is available the *Helping Hands* technology is able to augment current student training, and potentially provide a sophisticated back up for trained medical personnel while making significant savings in time, resources and the utilisation of expertise.
- Future refinements to *Helping Hands* would be to increase the portability of the student's unit and resolution of wireless connectivity issues. The project team anticipate that these issues could be overcome by adapting current off-the-shelf technology (for example, Google glasses, iPhone, and Skype) in collaboration with commercial product design experts.
- Further development and testing of the technology, protocols and their impact on learning on different groups and in different settings should be undertaken.

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Chapter 1. Project context

1.1. Introduction

This report details the context, approach, outputs and evaluation of an Office for Learning and Teaching (OLT) seed project to customise and pilot the application of a wearable tele-assistance system to enable health science students (nurses, doctors, and so on) to learn and practice clinical procedures with real-time virtual guidance provided by an instructor located remotely at another site. The project has application across all health care settings with significant benefit for work-integrated learning (WIL) environments in which staffing levels are lower and students may find access to an on-site instructor more difficult. In 2014, a prototype of the system had been developed with funding from the Tasmanian Clinical Education Network (TCEN).

1.2. Context

Within health curricula, the learning of clinical skills typically begins in the classroom with an explanation of the procedure and the context for its application. The student then practices the skill in a safe, controlled environment (a skills laboratory), often using a manikin. Students are then provided opportunities to apply that skill to a real patient whilst on placement. This can be highly stressful for students who may feel nervous or overwhelmed by the experience and often fearful of making a mistake that may cause harm to the patient (Pulido-Martos,Augusto-Landa, Lopez-Zafra, 2011). Continued guidance and support is necessary, an area in which the application of Augmented Reality (AR) technology has great potential (Lee, 2012; Yuen, Yaoyuneyong, Johnson, 2011).

In health, AR systems have been successfully used to train surgeons, doctors, nurses and students across a variety of skill areas (vide: Botden, de Hingh & Jakimowicz, 2009; Ericsson, 2004; Feifer, Al-Ammari, Kovac, Delisile, Carrier & Anidjar, 2011; Mather, 2010; Nilsson & Johansson, 2008).). Whilst work is being undertaken in AR (vide: Munnerley, Bacon, Fitzgerald, Wilson, Hedberg, Steele & Standley, 2014), our review found no report on the gesture-based learning and teaching innovation we have named *Helping Hands* or the impact this may have on learning outcomes.

The project built upon an existing tele-assistance guidance system that has been developed to address the remote guidance needs on physical task performance (Alem, Huang & Tecchia, 2011). The technology can be used to augment the learner's workspace with the presence of the unmediated, guiding gestures of a remote instructor. This tool allows video images of the learner's activity (procedure) space to be mixed with that of the instructor's hand movements. The instructor can see how a student is performing the procedure in real time and is able to superimpose their hand movements on the student's field of vision for the student to visualise if correction or assistance is required to enhance learning.

1.3. Project aim

The aim of the project was to contribute to the acquisition, development and performance of practical skills by students whilst undertaking work-integrated learning (WIL) placements in hospitals and other health care settings by applying and customising a wearable, hands-free, low cost AR tele-assistance system to make remote guidance and instruction more accessible.

1.4. The *Helping Hands* system

1.4.1. Introduction

The *Helping Hands* technology that has been developed and tested by the project has two units that are connected through WiFi/Internet or 3G communication network. The student wears a head mounted display (HMD) unit (Figure 3) whilst conducting a procedure. The focus of attention, the procedure, is captured by the camera mounted on the HMD unit. The HMD microphone and headphones enable verbal communication with the instructor. The unit also has a near-eye display from which they can see the image sent from the instructor. The instructor looks at a large display screen which displays the real-time image of the procedure from the student's HMD unit (Figure 4). A camera mounted on a support arm over the display screen captures the instructor's hand gestures which are transmitted to the student's near-eye display in real-time.

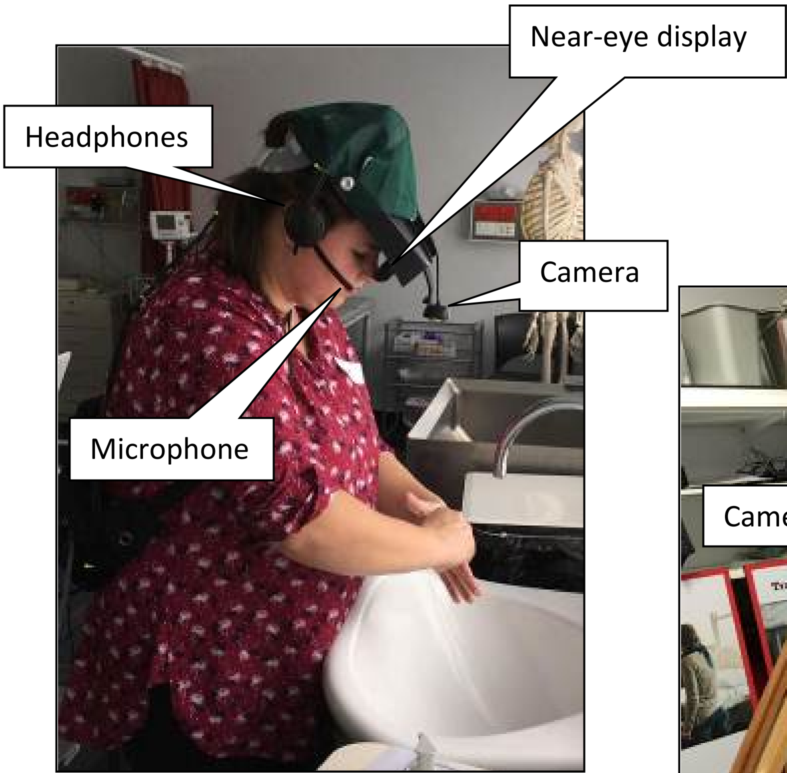

Figure 2. The student's unit. (HMD microphone, headphones, camera and near-eye display).

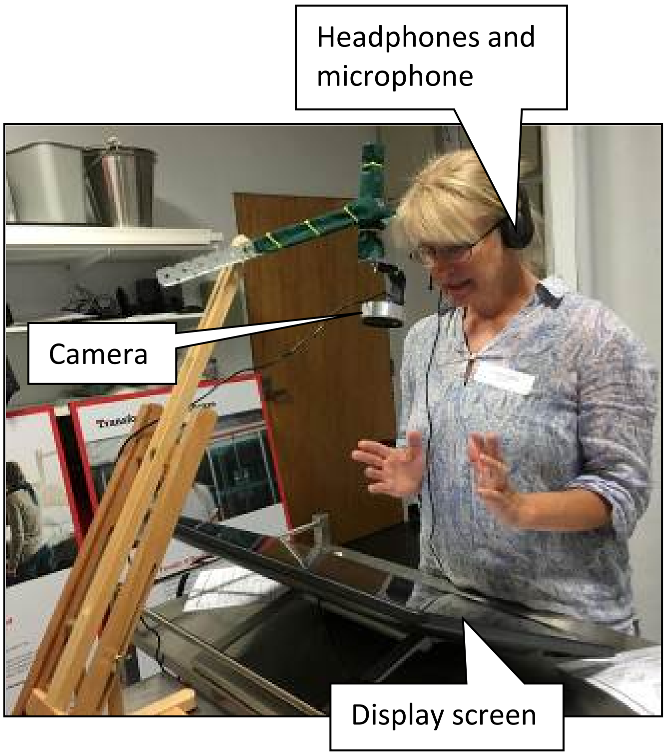

Figure 3. The instructor's unit. (display screen, camera, headphones and microphone).

This wearable solution addresses the need for a hands-free, portable, remote audio and visual guidance that has broad applicability across the health arena. The application of this technology in learning and teaching scenarios represents a significant step in simulated learning as it allows instructors (procedural experts) to share their skills and acumen with one or more novices without the need to be in the same physical location as the learner. This can represent a significant saving in time, resources and more effective utilisation of expertise.

1.4.2. Equipment specifications

Table 1 lists the equipment specifications for the *Helping Hands* system. We used C++ as the programming language.

Student
Webcam - Microsoft L2 LifeCam HD-3000
Logitech H340 USB Headset
Toshiba Satellite L50D Laptop
Vuzix Wrap 1200DX
Shoulder Bag
HDMI Extender
Belkin 1.8M USB Extension Cable
HDMI Cable (3M)
Instructor
Wimberley Plamp
Webcam - Microsoft L2 LifeCam HD-3000
Hoya 62mm HD Circular Polarising filter
Hub USB 2.0 (10 port)
Logitech H340 USB Headset
Dell 27 Touch Monitor – P2714T
HP Pavilion 15-P017AX Laptop
Targus 7 Port USB 2.0 Hub

Table 1. Equipment specifications for *Helping Hands*.

2. Project approach

2.1. Design

The project involved the customisation and piloting of the application of a wearable tele-assistance system to enable health science students (nurses, doctors, and others) to learn and practice clinical procedures with real-time, virtual guidance provided by an instructor located remotely at another site. The project was implemented across four stages as described in Table 2.

Stage	Purpose	Timeframe
Stage 1	Determination of user requirements	*Jan - Jun 2015*
Stage 2	A test of the feasibility of the approach	*Jun - Aug 2015*
Stage 3	A test of the usability of the approach	*Oct 2015 – Mar 2016*
Stage 4	Dissemination of the project findings	*Continuing*

Table 2. Project implementation.

The results and findings from each stage were used to inform subsequent stages. The methodology used in stages one to three is discussed in more detail below. This report is part of the final stage (dissemination) and the dissemination strategies and progress are discussed further in Chapter 4 of this report. Ethics approval for the project was obtained from the Tasmanian Health and Medical Human Research Ethics Committee (Appendix B).

2.2. Stage 1 (user requirements) methodology

2.2.1. Summary

The first stage of the project determined the user requirements of the system and assessed potential technical challenges such as: brightness, contrast of the images, depth perception, field of vision, potential pixilation and connectivity. An end-user reference group was established that included current students, recent graduates, skills instructors, clinical educators, clinical supervisors, preceptors and technical engineers. Reference group members were invited to workshops for a project briefing, to test the technology and to provide advice on user training requirements. Participants were asked to provide feedback on the aim, procedures and outcomes of the project via discussion and a structured questionnaire. Data from the workshop was used as the basis for customisation of the system and to prioritise user requirements.

2.2.2. Detail

The reference group members were recruited from the University of Tasmania (UTAS) and industry and included current students, recent graduates, skills instructors, clinical educators, clinical supervisors, preceptors and technical engineers. The workshops were held in the clinical nursing laboratory (UTAS, Newnham campus, Launceston, Tasmania). Reference group members had to be over 18 years old, consenting adults with skill and expertise relevant to the project aims. Nine persons with expertise relevant to the project were recruited as the reference group and attended the workshop, a list of reference group members can be found in the acknowledgements section of this report. At the workshop the reference group members were:

- Briefed about the technology including the background and expected usage, trial procedures and expected outcomes.
- Invited to test the technology (Figure 5).
- Invited to complete a structured questionnaire (Reference Group Questionnaire, see Appendix C) and to provide feedback via discussion.

Narrative feedback from workshop participants was analysed using simple content analysis. Responses to the questionnaire items were tallied and examined using descriptive statistical methods. The data was analysed and then used to customise the *Helping Hands* technology and the approach to Stages 2 and 3 of the project.

Figure 4. Reference group members testing equipment.

2.3. Stage 2 (feasibility trial) methodology

2.3.1. Summary

The aim of the feasibility trial was to determine whether clinical learning outcomes were being compromised by using *Helping Hands* instruction. The null hypothesis that there would be no significant difference ($p<0.05$) in outcomes for students undertaking *Helping Hands* instruction compared to “usual instruction” was tested under supervised, simulated conditions in a clinical skills simulation laboratory.

The procedural skill of handwashing was used as a test procedure. Handwashing was chosen as it is an essential skill that is learnt in a student's first year and reinforced regularly. Student participants were recruited and randomly allocated to one of two groups. Their handwashing technique and confidence in their handwashing technique was assessed prior to and following the intervention (usual instruction or *Helping Hands*). Learning outcomes were assessed by: surveying students and instructors; through a checklist (Kogan, Holmboe & Hauer, 2009) and photographic images of participants' hands after using *Glitterbug*, which, under ultraviolet (UV) light, highlights hand surface areas missed during the handwashing procedure (www.glitterbug.com), Figure 6.

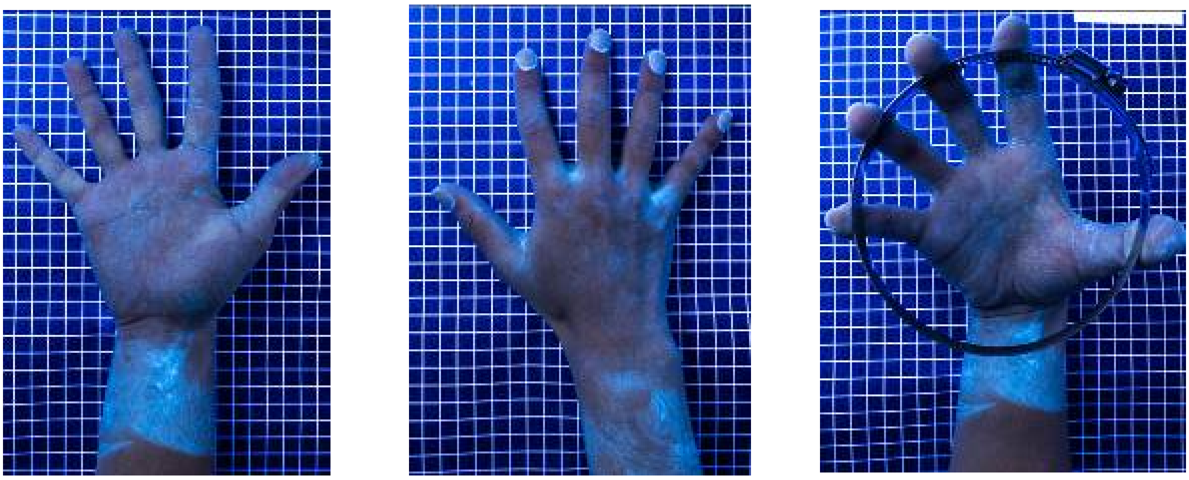

Figure 5. Palmar and dorsal surfaces, and fingertips photographed under UV light. Areas incompletely washed are highlighted with *Glitterbug*.

2.3.2. Detail

The feasibility trial was conducted at the UTAS clinical nursing laboratories at the Newnham campus. Students enrolled in the Bachelor of Nursing at a UTAS campus were recruited to act as the 'students' and a casual research assistant with experience in teaching handwashing was appointed as the 'instructor'. The students had to be consenting adults and have completed normal instruction for handwashing as prescribed by the relevant curriculum. The project recruited a total of 15 students who were allocated to a control or experimental (*Helping Hands*) group.

The feasibility trial involved:
Pre-intervention testing of all the student participants. The pre-intervention questionnaire asked students: the time since most recent previous instruction on handwashing, how many weeks of clinical experience had they undertaken (known at UTAS as professional experience placement or PEP) and their confidence in performing the skill (Appendix D). *Glitterbug* was applied to the hand surfaces of the students who then washed and dried their hands. After this, their hands were photographed under UV light (photographs of the palmar and dorsal surfaces and the fingertips were taken, Figure 6). Student participants were blinded to this ie. they were unable see and were not informed which surface areas had been missed.

- The control group received the “usual” instruction (that is, one instructor per two to four students, with student dyads peer instructing each other and two students per basin). The intervention group received the *Helping Hands* instruction (individual instruction delivered to student via the *Helping Hands* technology only, one student per basin).
- When the student participants felt that they were confident in performing the handwashing procedure *Glitterbug* was applied to their hand surfaces. The students were then asked to wash their hands again. After washing their hands, their hands were photographed again under UV light. They were then surveyed using a post-intervention questionnaire to ascertain: the usefulness of the instructional method and their post-intervention confidence in performing the skill.
- A questionnaire was administered to the instructor/s post intervention (see Appendix E) to ascertain the usefulness of the instructional method.
- The two groups (control and *Helping Hands*) were compared on the outcome variable and content analysis was performed on the narrative comments from the questionnaires. The outcomes of the data analysis were used to refine the technology for the usability trial (Stage 3).

The questionnaire and checklist data were analysed using descriptive and non-parametric statistics primarily to identify any difference in entry characteristics between the two groups (usual instruction and *Helping Hands* instruction). The primary outcome variables of the feasibility study was “confidence” and the “effectiveness of handwashing” which was assessed empirically by the number of “missed surfaces” of the hand as detected by photographic images of residual *Glitterbug*. A 1cm^2 grid was used to assess the photographic images of student participants’ hand surfaces (pre and post intervention) to identify any “missed surfaces” when the hands were viewed under UV light. Statistical analyses were undertaken to assess differences ($p<0.05$) and a content analysis was conducted on narrative comments.

All student participants were offered usual instruction or *Helping Hands* instruction on completion of the trial (to ensure that they did not feel they had missed out or had been disadvantaged with respect to learning the handwashing skill).

2.4. Stage 3 (usability trial) methodology

2.4.1. Summary

The usability trial aimed to examine how well the equipment worked in different clinical locations and with different end users. Issues due to connectivity (such as pixelation, network access issues, and so on) were anticipated.

2.4.2. Detail

Four nursing students located at the Mersey Community Hospital in Latrobe (Tasmania) and 13 paramedic students at UTAS’s Sydney campus (Rozelle) were recruited for instruction in the handwashing procedure by an instructor located at the UTAS campus in Launceston

(Tasmania). Initially the aim was to recruit from six to eight nursing students at rural/remote teaching sites (hospitals). However timetabling issues and the academic calendar made access to that number of students in hospital settings very difficult. The paramedic students were invited to participate in addition to the four hospital-based students as they met the inclusion criteria (consenting adults, enrolled in a UTAS health science course, had completed a course of normal instruction for handwashing as prescribed by the relevant curriculum) and increased the diversity of professional disciplines sampled. The trial was conducted in the high dependency simulation laboratory at the Sydney campus.

A protocol for using the *Helping Hands* equipment had been developed from the reference group workshops and the feasibility trial (detailed in section 3.3.2. of this report) and was used by the instructor during the usability trial. The students were instructed in the handwashing technique using *Helping Hands* and completed a Student Usability Questionnaire (Appendix F) after the instruction.

Chapter 3. Project outputs and findings

3.1. Introduction

The aim of the project was to customise a wearable, hands-free, low cost audio-visual guidance system with broad applicability across health care environments. A prototype (Mark I) had been developed prior to the project with funding from the TCEN. Mark I was trialled at the reference group workshops and feedback from the workshops was used to guide improvements to the *Helping Hands* software, hardware and equipment.

3.2. Reference group results

Two reference group workshops were held (30/07/2016 and 15/08/2016). Participants were provided with an overview of the project aims, purpose and intent of the technology. A demonstration of the prototype was undertaken prior to inviting group members to trial the equipment as both instructor and learner. Each participant provided verbal and written survey feedback. The survey responses were anonymous. The results were obtained by pooling the groups and theming the feedback provided.

The reference group comments related to:

- **The scope of application.** At the individual level *Helping Hands* was seen as useful when the instructor is physically absent and for non-experienced operators. At the systems level *Helping Hands* was seen as useful for rural and remote practice and for rare procedures. *Helping Hands* was seen as a useful tool in oral/dental health applications, student assessment, student learning with manikins, assessment of patients remotely, that is, disaster management or emergencies and health manufacturing (for example, laminar flow).
- **Equipment design.** The following suggestions and critiques were made of the equipment design:

Suggestions

- Magnification to aid teacher visualisation
- Enable instruments to be visualised
- Enable cord length to fit a tall person
- Enable prescription and/or safety glasses to be worn
- Widen the scope of the camera, that is, provide a fish eye perspective

Critique

- Simplify equipment
- Decrease bulkiness of equipment
- Increase robustness of equipment
- Improve speed
- Correct lighting issues
- Correct segmentation
- Enable clearer audio
- Tethered with cords

- **The advantages and disadvantages for human interaction** (see Table 3).
- **Other comments** related to strategies to engender patient acceptability of the technology such as instructions for use, including instructions for ensuring appropriate behaviour when interacting with patients. The reference group members indicated that they believed technological interventions are generally accepted by patients.

Advantages	
Learner	***Context***
• Increase confidence • Reduce fear • Enable visualisation • Promote reflection • Increase understanding • Enable critique • One-on-one instruction • Reinforce skills • Refine skills • Check and provide feedback in real-time	• Enable second opinion or follow-up • Enable immediate feedback as used in real-time • Enable assessment of procedure • Enable assessment of patients • Examine learner technique • Useful for novice • Provide support/backup • Clarify gaps or misconceptions • Promote safe practice • Efficient use of resources • Provides teaching and learning partnership • Patient can feel 'special'
Disadvantages	
Learner	***Context***
• Increase anxiety, could be frightening, particularly for children or dementia patients • Identifies the learner • Lack of presence • Task orientated • Opportunity for disconnect between learner and patient	• Complicated to set up • Requires training • Requires Information Technology (IT) competence to troubleshoot • Technology dependence, risk with IT failure • Looks intimidating • Time consuming

Table 3. Summary of reference group comments regarding human interaction and other comments.

The feedback from the reference group workshops was used to inform the changes made to the *Helping Hands* equipment, develop the Mark II student's and instructor's units and develop a user protocol.

Appendix G contains the notes taken by the project leader summarising the feedback from the reference group workshops and the response to these notes by the project software developer and has been included an exemplar of the dynamic development nature of the project. A continuous feedback of information between project team members at the different stages of the project ensured that the *Helping Hands* system developed met the end-user requirements as far as was possible within time and resource constraints.

3.3. Feasibility trial results

For the feasibility trial, student participants were requested to complete a short questionnaire before and after their allocated mode of hand-washing instruction. This included a self-assessment of their confidence in performing the procedure and, in the post-test questionnaire, to recall the steps involved. The participants allocated to the experimental (*Helping Hands*) group were also asked to rate the use of the system (using a

5-point Likert type scale) and to provide written comments (again, post-test only). Hand surfaces were independently assessed for areas “missed” during hand washing and these areas quantified using a grid technique with photos of both left and right hand surfaces..

No statistical difference in mean “confidence” scores was detected between groups either before (0.65, 13, p=0.53) or after receiving hand washing instruction (0.40, 13, p=0.69). This suggests that participants were similarly confident in their technique regardless of the method of instruction they received. A secondary finding was that the experimental (*Helping Hands*) group demonstrated a greater improvement in confidence than the control group. There was a change in mean score from 2.8 to 3.4 (p=0.05) compared with 3.0 to 3.3 (p=0.47) for the control group. This change could be attributed to the more direct, 1:1 method of instruction provided to participants in the *Helping Hands group* compared with the “usual instruction” provided to the control group where the instructor guided 2 to 4 students.

An analysis of the “missed” surfaces indicated no difference in number of areas missed by either group following instruction, that is, the null hypothesis was accepted (Mann-Whitney U test, p=0.35).

Ratings of the (*Helping Hands*) system by those allocated to this group were generally very positive (Table 4).

Experimental (*Helping Hands*) Group (n=9)	**Mean (sd)**
I found that the system was easy to learn	4.3 (1.3)
I found that the system was easy to use	4.1 (1.3)
I found that the system was useful way to receive guidance	4.3 (1.3)
I was satisfied with my own task performance	4.2 (0.8)
I was satisfied with the interaction between myself and the instructor	4.4 (1.3)
I felt that I was engaged with the instructor during the procedure	4.4 (1.3)
I found the visual instruction easy to follow	4.4 (1.3)
I found the verbal instruction easy to follow	4.6 (1.3)

Table 4. Ratings of the *Helping Hands* system by participants.
(Scale: 1 =strongly disagree to 5 = strongly agree with statement)

3.3.1. Equipment modifications made as a result of feedback from the reference group workshops and the feasibility trial

As a result of feedback from the reference group workshops and the feasibility trial, a number of modifications and improvements in the equipment and operation of *Helping Hands* were made before the usability trial (Figures 7 and 8). The version used in the reference group workshops and feasibility trial (Stages 1 and 2) is Mark I and the version used in the usability trial (Stage 3) is Mark II.

Figure 6. Mark I. Student and instructor’s units.

Figure 7. Mark II. Student and instructor's units,

3.3.2. Equipment user protocol

An equipment user (Instructor/student) protocol was developed as a result of feedback from the reference group workshops and the feasibility trial. The protocol was then used in the usability trial (Table 5).

Instructor side	Student side
Don head phone. Ensure all equipment is connected, switched on and camera mounted correct distance from screen.	Reassure, provide explanation to patient/ others in area
Ensure audio and visual connection working adequately with student side.	Ensure all equipment is connected and switched on.
Advise student that should they wish to view visual screen, flick eyes up to view (do not move head – as this will move the head-mounted camera and change view sent to instructor).	Safety: Explore range and freedom of movement, potential hazards
Rehearse/establish communication protocol such as basic requests e.g. please advise, proceed, "stop" [what you are doing and look at the screen] and student preferences	Don head gear and adjust to fit firmly but comfortably, don bum/shoulder bag. Check range of movement.
Provide briefing on procedure.	Visual screens (glasses) should not be in direct line of site – flick eyes up to view (do not move head – this will move the head-mounted camera). Ensure images, including HH images from the instructor, can be seen clearly.
Place hands on (not above) screen to provide visual cues	Ensure visual connection is working and camera is capturing work field (adjust if necessary)
Provide debrief and follow-up as required	Ensure audio is working (check with instructor-side)
	Rehearse/establish basic requests (for example, please advise, proceed, stop)

Table 5. Equipment user protocol.

3.4. Usability trial results

The results of the usability trial are detailed in Appendix H. In summary, the overall findings of both groups were similar, students reported that in general, the system was easy to learn and a useful way to receive guidance.

Sydney students were more satisfied with their performance and interaction with the instructor than Mersey students. Students at Sydney reported that the visual and verbal instructions were easier to follow than those located at the Mersey.

Qualitative comments from both groups were generally encouraging, however, more positive comments were received from Sydney students. This can be attributed to a strong internet connection at the Sydney campus which resulted in very clear audio and visual display (Figure 9). Connectivity between Sydney and Launceston was excellent. There was little or no lag in audio and the pixilation issues encountered at Mersey were not apparent at the trial at Sydney.

Figure 8. Screen image received at Launceston from Sydney

The Sydney students focussed on issues associated with the head mounted display. These included its bulkiness, adjustability for different head sizes and how this impacts on audibility. Comments also included the size of the screen, infection control issues with cleaning the equipment and time to prepare for receiving instruction.

Sydney and Mersey students perceived the impact of the use of this technology on patients similarly. Both groups indicated there could be positive and negatives feelings by patients. Both groups suggested ensuring patients were informed about the reasons for the use of the technology and had an understanding of why it could be used: it could be viewed as positive for their care.

Both groups were very encouraging and enthusiastic about the use of the technology as an educational tool in the future.

3.5. Factors identified as affecting the success of *Helping Hands*

- The system can be used by a broad range of health disciplines and is a system that lends itself for use by interprofessional, multidisciplinary teams.
- There was broad support for the system from all end users (industry and students).

I think that this is an amazing opportunity for technological advancement in the medical field. I support it and would be very pleased to see the use of this in the future.

Thanks, was great. I hope to use this tech in future especially when or if I'm in a rural location.

- Wireless (WiFi) connectivity. The issue of WiFi connectivity became critical to the success of the project. There are two aspects to the issue of wireless connectivity. The first is the technical issue of the presence or absence of the WiFi signal (coverage) and the strength of the signal. The second issue is an administrative one, whereby different organisations are using different WiFi systems which may not be compatible (differing user protocols and firewalls, and the like). Image clarity became a problem in institutions with poor connectivity and detracted from the *Helping Hands* learning experience.
- The portability of the technology allowed us to test its use at different locations without major logistical/transport challenges. All the necessary equipment could be packed into a small bag or case.
- The enthusiasm and support provided by the project reference group in embracing the concept and providing constructive feedback throughout the process.
- Student participants were enthusiastic about the potential of the system and provided comprehensive feedback through the post trial questionnaires.

3.6. Project deliverables

In developing the *Helping Hands* equipment the project has:

- Demonstrated proof of concept, that is the concept (a portable AR tele-assistance system for clinical skills development) has been turned into reality (the *Helping Hands* system).
- Conducted two workshops for a reference group of interested end-users.
- Conducted a feasibility trial in a clinical skills laboratory.
- Conducted a usability trial in a hospital setting.

The *Helping Hands* project to develop a tele-assistance system for clinical skills development has:

- Delivered a working student and instructor unit.
- Demonstrated that the learning outcomes of students are not being compromised by using this innovative approach.
- Developed a tool which enables skills to be practised where this was not previously possible due to constraints on time and access to expert staff.

- Demonstrated that the technology is well-received by the end-users (students and instructors).
- Developed a relatively low cost (<$5,000), wearable hands-free system prototype.

3.6.1. Further opportunities

- Further development and testing of the technology and its impact on learning for different groups
- Further development and testing of the technology and its impact in different settings/locations and with other learning organisations
- Further development and testing of the technology and its impact within a range of higher education and health care settings
- Develop and test user protocols to enhance user experience and improve learning outcomes for different procedures/tasks
- Develop and test user protocols to enhance user experience and improve learning outcomes for different levels of learner.
- Further refinement of the system to make it more portable (in terms of bulkiness of equipment and system connectivity).
- Explore opportunities for commercialisation of the system, in collaboration with industry design partners.

Chapter 4. Project impact, dissemination and evaluation

4.1. Project impact

Helping Hands is a wearable solution that addresses the need for a hands-free, portable, remote audio and visual guidance system that has broad applicability across the health arena. The application of this technology in learning and teaching scenarios represents a significant step in simulated learning. The project has application across all health care settings with a significant benefit for WIL environments in which staffing levels are lower and those where students may find access to an on-site instructor more difficult (such as in rural and remote areas). The technology developed by this project allows procedural experts to share their skills and acumen with one or more novices without the need to be in the same physical location as the learner. This can represent a significant saving in time, resources and a more effective utilisation of expertise.

In a broader context the technology has potential for use in many other health care situations such as emergency childbirth, road trauma, expeditionary medicine and remote area medicine, where front-line medical staff may need to call upon a distant procedural expert. The technology also has potential for use in clinical situations necessitating a high level of biosecurity such as those found in bio-containment patient care units, or during the treatment of highly contagious diseases. The technology also has potential for non-health care uses where remote instruction is required.

The project team is considering approaching product design experts to explore the potential for a collaborative development project to further develop the technology and overcome some of the connectivity issues by adapting current off-the-shelf technology (for example, Google glasses, iPhone, Skype).

4.2. Project dissemination

The project has completed the usability trial (Stage 3) successfully and is at the final dissemination stage (Stage 4).

Currently the project has delivered two presentations to TCEN members (Launceston, 2015 and Campbell Town, 2014). Also, short articles have been published in the Australian Nursing & Midwifery Journal (Barnett, T., Huang, W. & Mather, C. (2015) Rural and remote tele-assistance for procedural skills: the 'helping hands' project. *Australian Nursing & Midwifery J.*, 23, 4, p35) and also in the CRH *Bulletin* (Dec 2015). The project team is currently planning several publications intended for relevant research journals and presentations at conferences.

4.3. Project evaluation

Evaluation was ongoing throughout the project with findings from the reference group and subsequent stages informing later stages. The reference group were informed of the progress of the project throughout the life of the project and a summary of comments from the reference group workshop was presented to TCEN members for their comment at a symposium presentation in Launceston.

The technology (both hardware and software) was refined for portability and usability throughout the project with the Stage 3 trial being the test of usability. Technological changes varied from solving software and connectivity issues to ergonomic issues such as ensuring the student headset could be worn comfortably by students with varying hairstyles. The attitudes of end-users (instructors and students) towards using this type of technology as a learning instrument was also canvassed and every effort was made to make any changes that were suggested.

4.4. Where to from here?

The project has opened up the possibility of:

- Further development and testing of the technology and its impact on learning on different groups and in different settings.
- Development and testing of user protocols to enhance user experience and improve learning outcomes for different procedures/tasks and for different levels of learner.
- Exploration of the possibility of commercialisation of the system and the adaptation of current off-the-shelf technology (for example, Google glasses, iPhone, Skype) in collaboration with commercial product design experts.
- Further refinement of the system to make it more portable in terms of weight and bulkiness of equipment and connectivity through WiFi/Internet or the 3G communication network.

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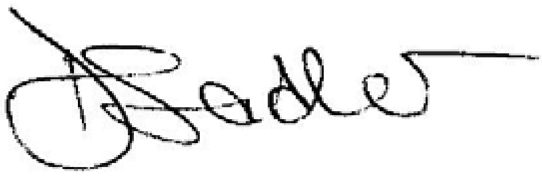
Appendix A

Certification by Deputy Vice-Chancellor (or equivalent)

I certify that all parts of the final report for this OLT grant provide an accurate representation of the implementation, impact and findings of the project, and that the report is of publishable quality.



Name: Professor David Sadler

Date: 16th March 2016

Appendix B

Ethics approval letter.

Office of Research Services
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Email Human.Ethics@utas.edu.au
www.research.utas.edu.au/human_ethics/

HUMAN RESEARCH ETHICS COMMITTEE (TASMANIA) NETWORK

UTAS

22 June 2015

Assoc Prof Tony Barnett
Centre for Rural Health, School of Health Sciences
University of Tasmania

Sent via email

Dear Assoc Prof Barnett

REF NO: H0015041
TITLE: Helping Hands: an innovative tele-assistance system for clinical skill development with health science students

Document
Tasmanian HREC Low Risk Application Form
TSRAC Study Protocol Pro Forma
Certificate of Participation
Hospital Invitation Letter
Instructor Consent Form
Instructor Invitation Letter
Instructor Questionnaire
Reference Group Consent Form
Reference Group Consent Form
Reference Group Questionnaire
Student Consent Form - Stage 2 and Stage 3
Student Information Sheet - Stage 2 and Stage 3
Student Invitation Letter - Stage 3
Student Questionnaire Post Intervention
Student Questionnaire Pre Intervention
Student Questionnaire Usability Study
Student Recruitment Poster

The Tasmanian Health and Medical Human Research Ethics Committee considered and approved the above documentation on **22 June 2015** to be conducted at the following site(s):

Tasmanian Rural Hospital sites (to be determined)

Please ensure that all investigators involved with this project have cited the approved versions of the documents listed within this letter and use only these versions in conducting this research project.

This approval constitutes ethical clearance by the Health and Medical HREC. The decision and authority to commence the associated research may be dependent on factors beyond the remit of the ethics review process. For example, your research may need ethics clearance from other organisations or review by your research governance coordinator or Head of Department. It is your responsibility to find out if the approvals of other bodies or authorities are required. It is recommended that the proposed research should not commence until you have satisfied these requirements.

All committees operating under the Human Research Ethics Committee (Tasmania) Network are registered and required to comply with the *National Statement on the Ethical Conduct in Human Research* (NHMRC 2007 updated 2014).

Therefore, the Chief Investigator's responsibility is to ensure that:

(1) The individual researcher's protocol complies with the HREC approved protocol.

(2) Modifications to the protocol do not proceed until **approval** is obtained in writing from the HREC. Please note that all requests for changes to approved documents must include a version number and date when submitted for review by the HREC.

(3) Section 5.5.3 of the National Statement states:

Researchers have a significant responsibility in monitoring approved research as they are in the best position to observe any adverse events or unexpected outcomes. They should report such events or outcomes promptly to the relevant institution/s and ethical review body/ies and take prompt steps to deal with any unexpected risks.

The appropriate forms for reporting such events in relation to clinical and non-clinical trials and innovations can be located at the website below. All adverse events must be reported regardless of whether or not the event, in your opinion, is a direct effect of the therapeutic goods being tested. http://www.research.utas.edu.au/human_ethics/medical_forms.htm

(4) All research participants must be provided with the current Patient Information Sheet and Consent Form, unless otherwise approved by the Committee.

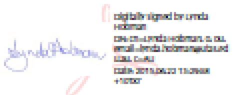
(5) The Committee is notified if any investigators are added to, or cease involvement with, the project.

(6) This study has approval for four years contingent upon annual review. A *Progress Report* is to be provided on the anniversary date of your approval. Your first report is due **22 June 2016.** You will be sent a courtesy reminder closer to this due date.

(7) A *Final Report* and a copy of the published material, either in full or abstract, must be provided at the end of the project.

Should you have any queries please do not hesitate to contact me on (03) 6226 6254.

Yours sincerely



Lynda Hobman
Administration Officer (Integrity and Ethics)
Research Integrity and Ethics Unit
Office of Research Services
University of Tasmania

Appendix C

Reference Group Questionnaire

Helping Hands tele-assistance project

Date: ___________ Name: ____

Instructions: please respond honestly to each of the following items

1) Do you think the technology will help students learn? Please explain.

____

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____

2) Do you have suggestions to improve the usability of this technology?

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3) In your opinion, what are the advantages and disadvantages of using technology like this in hospital or clinical setting? Are there other applications that come to mind?

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4) What impact do you think this may have on a patient should they see a clinician or student wearing the headset when performing a procedure?

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5) Do you have any other comments?

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____

Thank you for completing this survey.

Appendix D

Student Questionnaire: Feasibility Trial, Pre-intervention

Helping Hands tele-assistance project

Date: __________ Name: ____

Gender M☐ F☐ Location: ___________________________________

Instructions: Please fill in the blank or circle *one* answer for each of the following questions.

1) Have you previously received instruction on handwashing Y / N

2) How long ago was your last instruction in handwashing (in either the workplace or at the university)?

   __________ weeks or

   __________ months or

   __________ years

   __________ Don't know, too long ago to remember.

3) As part of my course, I have undertaken __________ weeks of clinical experience.

4) How confident are you in washing your hands correctly?

   ☐ Not confident at all

   ☐ Somewhat confident

   ☐ Quite confident

   ☐ Very confident

   ☐ I am unsure

Thank you for completing this questionnaire

Appendix E

Instructor Questionnaire: Feasibility Trial

Helping Hands tele-assistance project

Date: __________ Name: ____

Gender M☐ F☐ Location: ___________________________________

Feasibility study (clinical lab, post-intervention) ☐ Usability study (field test) ☐

If you instructed students using the “Helping Hands” tele-assistance equipment, please respond to each of the following items (where relevant):

	Strongly disagree				**Strongly Agree**
Overall:	**1**	**2**	**3**	**4**	**5**
I found that the system was easy to learn					
I found that the system was easy to use					
I found that the system was useful for guiding the student					
I was satisfied with my own task performance					
I was satisfied with the interaction between myself and the student					
I felt that I was engaged with the student during the procedure					
I found it easy to visually direct the student					
I found it easy to verbally direct the student					

1) How did you feel when providing instruction to a student?

____

____

____

____

____

2) How did the student respond to the instruction and feedback you provided? Please provide examples.

____

____

____

____

____

3) Do you think the technology will assist students to learn? If so, Please explain how you think it will assist.

____

____

____

____

____

4) Please suggestion how this technology could be improved

____

____

____

____

____

5) In your opinion, what are the advantages and disadvantages of using technology like this in a hospital or clinical setting? Are there other applications that come to mind?

____

____

____

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6) What impact do you think this may have on a patient should they see a clinician or student wearing the headset when performing a procedure?

____

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____

7) Any other comments?

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Thank you for completing this survey.

Appendix F

Student Questionnaire: Usability Trial

Helping Hands tele-assistance project

Date: __________ Name: ____

Gender M☐ F☐ Location: ___________________________________

Instructions: Please fill in the blank or circle *one* answer for each of the following questions.

1) Have you previously received instruction on handwashing Y / N

2) How long ago was your last instruction in handwashing (in either the workplace or at the university?

__________ weeks or

__________ months or

__________ years

__________ Don't know, too long ago to remember.

3) As part of my course, I have undertaken __________ weeks of clinical experience.

4) Tele-assistance system

	Strongly disagree			Strongly agree	
Overall:	**1**	**2**	**3**	**4**	**5**
I found that the system was easy to learn					
I found that the system was easy to use					
I found that the system was useful way to receive guidance					
I was satisfied with my own task performance					
I was satisfied with the interaction between myself and the instructor					
I felt that I was engaged with the instructor during the procedure					
I found the visual instruction easy to follow					
I found the verbal instruction easy to follow					

5) How did you feel when receiving instructions?

6) How did you respond to the instruction and feedback provided?

7) Do you have suggestions to improve the usability of this technology?

8) In your opinion, what are the advantages and disadvantages of using technology like this in a hospital or clinical setting?

9) What impact do you think this may have on a patient should they see a clinician or student wearing the headset when performing a procedure?

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10) Any other comments?

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Thank you for completing this survey.

Appendix G

Project leader's notes from working Group workshops, project software engineer's response.

Reflection of instructors head on computer screen? lighting – *Project Web Technology & Development Officer* to investigate. Image of hand a little broken/fractured (fixed when system operating for a while).
This should not be problem once the full synchronisation is achieved and parameters are fine tuned for the colour of instructor's hand – by default the parameters are set to generic "Caucasian skin tone" as recommended in the literature.

Learner-side cabling is messy (need to make longer to allow for greater movement and combine into one - *Project Web Technology & Development Officer*).
Could possibly be avoided completely – see below.

Instructor may need to tell learner to "stop. Watch how I am doing it" or similar so that the learner does not become too confused.

Could the audio output be adjusted to allow for differences in hearing between ears? Should we have just the one earplug for the learner? (would allow external noise e.g. response from patient to be heard better).
Volume can be adjusted on the computer. Single ear piece with microphone would be possible – using Bluetooth model would also eliminate one cable to the headset. These headsets usually have "on the piece" volume adjustment.

An elasticised head band on the learner side may be more comfortable and allow for easier adjustment to different head sizes. Would modification of a dental loupe work? A single visual screen off the side may work better than glasses.
I was also thinking around the line of avoiding glasses and having look at screen. Again – one (thickest) cable could be eliminated. By using Bluetooth based camera (they are not as easy available as USB, but they are) last cable could be avoided and headset could be fully wireless.

Could there be a zoom capability on the camera (allow instructor to see close-ups)?
There is no way of operating camera zoom remotely without completely rewriting the application – so it would have to be function on student's sides, requiring student to operate it. Not sure how well would that work, but can investigate.

A fixed camera on the learner side may work better for dentists (could be on a swing arm or attached to light).
Definitely.

Not able to visualise stainless steel instruments if used by the instructor (adjust settings maybe or instructor use white instruments).
Instructor's screen pointer (mouse) cannot be seen from the learner side – useful to point out finer features/aspects in the learner's visual field.
These two points are caused by the "segmentation" function. It could be possible to do segmentation on two different colours, but that increases computing demand on instructor's side and not sure how that would work. That's one of the reasons I wanted to talk with you about the need for the segmentation at all…

Waist mounted bag would be better than an off-the-shoulder bag.
This could possibly be avoided completely if (as actually already suggested above):

1. Screen on the side was used instead of glasses.
2. Bluetooth based audio piece used.
3. Bluetooth based camera used.

The only drawback of 2 and 3 is that these have to be charged before use.

Appendix H

Summary of results: Usability Trial.

Mersey Community Hospital (n=4)	Strongly disagree			Strongly agree	
Overall:	**1**	**2**	**3**	**4**	**5**
I found that the system was easy to learn				4	
I found that the system was easy to use			2	2	
I found that the system was useful way to receive guidance				2	2
I was satisfied with my own task performance		1		3	
I was satisfied with the interaction between myself and the instructor		2		1	2
I felt that I was engaged with the instructor during the procedure		1		1	2
I found the visual instruction easy to follow		3	1		
I found the verbal instruction easy to follow		1		2	1

Table 6. Summary of the feedback on *Helping Hands* feasibility trial, Mersey Community Hospital.

Sydney campus (n=13)	Strongly disagree			Strongly agree	
Overall:	**1**	**2**	**3**	**4**	**5**
I found that the system was easy to learn				4	9
I found that the system was easy to use			3	7	3
I found that the system was useful way to receive guidance				5	8
I was satisfied with my own task performance				3	10
I was satisfied with the interaction between myself and the instructor				3	10
I felt that I was engaged with the instructor during the procedure				4	9
I found the visual instruction easy to follow			1	2	10
I found the verbal instruction easy to follow			1	2	10

Table 7. Summary of the feedback on *Helping Hands* feasibility trial, Sydney.