Results of Students’ learning Clinical Skills using a Haptic Dental Simulator 2009 - 2016

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King’s College London
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hapTEL Interdisciplinary team and partners
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Dr. Barry Quinn ((Lead Clinician, KCL)
Dr. Arash Shahriar-rad (Doctoral/Post-Doctoral Researcher)

King’s College Staff and Post-graduate students
Dental, Medical and Nursing clinicians; psychologists; sociologists; robotics specialists and educational researchers

University of Reading - Cybernetics team
Birmingham City University Engineering

In collaboration with
Generic Robotics – Dr. Alistair Barrow and colleagues

Goals and issues for Dental Education
Developing the learner to become a practising professional
Undergraduate Dental Education
Using tactile devices
Manipulative skills
Spatial reasoning skills
Changing the way Professionals work e.g. in teams with DCPs
Increasing size of student cohorts
Need to provide satisfactory and sufficient feedback to students

Clinical concepts and skills for undergraduate dental students
• Caries removal
• Depth of the cavity
• Angle of entry into the tooth
• Speed of the bur
• Different tactile sensations in cutting between different tissues
• Cavity design
• Time available for the task and the actual time taken

Graphic models
### Teeth and mouth model

![Teeth and mouth model](image)

- Teeth and mouth model

### Specific goals for caries removal

- Remove as much caries as possible.
- Retain the enamel and dentine.
- Avoid drilling into the pulp.
- Complete the task in a reasonable time

### Traditional

- Removal of artificial decayed material on a plastic tooth
- Three sessions: Two attempts per session

### hapTEL

- Removal of virtual decayed material on a virtual tooth located in a jaw
- Three sessions: as many attempts as they wish within a given time per session

### Traditional vs. hapTEL

<table>
<thead>
<tr>
<th></th>
<th>Traditional</th>
<th>hapTEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Removal of artificial decayed</td>
<td>• Three sessions: Two</td>
<td>• Three sessions: as many</td>
</tr>
<tr>
<td>material on a plastic tooth</td>
<td>attempts per session</td>
<td>attempts as they wish</td>
</tr>
<tr>
<td></td>
<td></td>
<td>within a given time per session</td>
</tr>
</tbody>
</table>

### hapTEL Workstation (Curriculum Version)

![hapTEL Workstation](image)

- 3D Display Monitor
- Shutter glasses
- Camera
- Skills station
- Haptic handpiece
- Pod
- Haptic device
- Foot Controls

### Learning activities and objectives for BDS Year 1 - students

hapTEL virtual dental work-stations were used to teach BDS-Year-1 dental students basic clinical skills:

- Operating on a virtual tooth shown on the horizontal screen – simulating the patient in a dental chair;
- Adopting the correct posture;
- Holding the hand-piece correctly;
- Using the hand-piece with the correct angle;
- Applying the right amount of pressure;
- Completing the task in the allotted time.

### Student cohorts (2008 – 2016) N = 897

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Student numbers</th>
<th>Number of Sessions</th>
<th>Total hours</th>
<th>Assessment</th>
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<tbody>
<tr>
<td></td>
<td>48 96</td>
<td>144</td>
<td>132</td>
<td>126</td>
</tr>
<tr>
<td></td>
<td>3 3/3</td>
<td>3/3</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>6 6/4</td>
<td>6/4</td>
<td>8</td>
<td>2</td>
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</table>

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Pre-post tests</th>
<th>Log files</th>
<th>Log files</th>
<th>Log files</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
</tbody>
</table>
Cavity Preparation Tasks

- Task 1 – Floating virtual tooth to orientate with the equipment and learn how to use the components.
- Task 2 – Floating virtual tooth with small occlusal carious lesion in outer third of dentine.
- Task 3 – Lower left 6 situated in the mouth, similar lesion to Task 2
- Task 4 - Lower left 6 situated in the mouth, with larger carious lesion more than half-way through the dentine.
- Task 5 - Lower left 6 situated in the mouth, with larger carious lesion within 0.5mm of the virtual pulp chamber

Dr. Quinn demonstrating to the students how to use the hapTEL work station

2008 – 2011 Study Design
(Large scale trials)

The students should learn how to:
- wear the correct PP equipment;
- sit in the appropriate position;
- collaborate with the ‘dental nurse’ (work in pairs);
- select the appropriate speed of the drill;
- hold the hand-piece correctly;
- feel the different virtual tissue densities;
- respond to feedback when cutting virtual healthy dental tissues: enamel and dentine;
- control the pressure to avoid going into the pulp;
- complete the operation in a reasonable time.

All Cavity Preparation Tasks

Screen view of the hand-piece and Tasks 1 and 2 single floating tooth

Students in the hapTEL lab in their PPE equipment
Students working in partnership as the dentist and the dental nurse

Feedback to the student

- Tactile feedback from the device
- Visual feedback from the amount of decayed material removed from the tooth
- Log files recording:
  - Amount of Enamel Remaining (%)
  - Amount of Dentine Remaining (%)
  - Amount of Caries Removed (%)
  - Pulp Exposure (%)

Evaluation methods

The students’ learning evaluated by:
- A set of psychometric instruments used by the original hapTEL team
- Discipline specific measures to determine the students’ knowledge of impact of haptic use on the enhancement of manual dexterity skills, clinical procedures
- Attitudinal - feedback questionnaires to canvas perceptions and learner experience.
- Staff experience and technical support issues.
- Feedback on: system design, operational issues and realism of the simulator

A student log file of performance on Task 4

Data from HapTEL logs
Task/Cavity=4
User Name: H031
Material Logs
Enamel: Remaining 98.13%
Dentine: Remaining 98.69%
Caries Removed 80.12%
Pulp exposed: Yes
Pulp: Removed 0.203%
Timing Logs
Total Duration: 149.69 seconds
Time at first contact: 8.79 seconds
Time spent Drilling: 126.80 seconds

Student’s photo of the caries removal results for Cavity 3 – lower 6th in a jaw

<table>
<thead>
<tr>
<th>Task</th>
<th>All tasks</th>
<th>Task 2</th>
<th>Task 3</th>
<th>Task 4</th>
<th>Task 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median delay to first contact - seconds</td>
<td>25.4</td>
<td>20.7</td>
<td>35.1</td>
<td>23.4</td>
<td>20.7</td>
</tr>
<tr>
<td>Median time spent drilling - seconds</td>
<td>130.8</td>
<td>94.2</td>
<td>103.6</td>
<td>193.9</td>
<td>158.8</td>
</tr>
<tr>
<td>Median caries removed - %</td>
<td>83.7</td>
<td>66.6</td>
<td>89.7</td>
<td>88.1</td>
<td>86.9</td>
</tr>
<tr>
<td>Median enamel remaining - %</td>
<td>96.8</td>
<td>93.4</td>
<td>96.8</td>
<td>96.5</td>
<td>99.4</td>
</tr>
<tr>
<td>Median dentine remaining - %</td>
<td>97.6</td>
<td>98.5</td>
<td>99.0</td>
<td>96.5</td>
<td>94.9</td>
</tr>
<tr>
<td>Attempts exposing pulp - n (%)</td>
<td>86 (67.7)</td>
<td>25 (38.1)</td>
<td>16 (44.4)</td>
<td>24 (92.3)</td>
<td>21 (95.5)</td>
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</tbody>
</table>
Table showing sample of 10 students’ Cavity 3 results

<table>
<thead>
<tr>
<th>Task</th>
<th>% of healthy enamel remaining</th>
<th>% of healthy dentine remaining</th>
<th>% of caries removed</th>
<th>Pulpal exposure</th>
<th>% of pulp removed</th>
<th>Time at first contact - secs.</th>
<th>Time spent drilling - Secs.</th>
<th>Total duration - Secs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>93.00%</td>
<td>99.00%</td>
<td>98.00%</td>
<td>yes</td>
<td>0.50%</td>
<td>17.50</td>
<td>277.96</td>
<td>313.02</td>
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<td>2</td>
<td>91.88%</td>
<td>97.77%</td>
<td>94.50%</td>
<td>yes</td>
<td>0.02%</td>
<td>14.11</td>
<td>99.63</td>
<td>117.71</td>
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<tr>
<td>3</td>
<td>97.03%</td>
<td>96.99%</td>
<td>91.58%</td>
<td>yes</td>
<td>0.30%</td>
<td>17.81</td>
<td>131.81</td>
<td>159.76</td>
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<tr>
<td>4</td>
<td>98.34%</td>
<td>96.79%</td>
<td>82.44%</td>
<td>yes</td>
<td>0.72%</td>
<td>21.11</td>
<td>430.44</td>
<td>671.30</td>
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<tr>
<td>5</td>
<td>96.56%</td>
<td>99.57%</td>
<td>96.77%</td>
<td>no</td>
<td>0.00%</td>
<td>91.48</td>
<td>485.24</td>
<td>581.60</td>
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<tr>
<td>6</td>
<td>97.91%</td>
<td>98.92%</td>
<td>83.69%</td>
<td>yes</td>
<td>0.63%</td>
<td>146.53</td>
<td>52.19</td>
<td>200.72</td>
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<tr>
<td>7</td>
<td>90.53%</td>
<td>97.30%</td>
<td>89.61%</td>
<td>yes</td>
<td>0.87%</td>
<td>9.03</td>
<td>203.28</td>
<td>212.31</td>
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<tr>
<td>8</td>
<td>97.87%</td>
<td>99.75%</td>
<td>94.00%</td>
<td>no</td>
<td>0.00%</td>
<td>11.48</td>
<td>270.26</td>
<td>281.74</td>
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<tr>
<td>9</td>
<td>96.24%</td>
<td>96.71%</td>
<td>94.44%</td>
<td>yes</td>
<td>0.39%</td>
<td>26.88</td>
<td>302.86</td>
<td>339.74</td>
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<tr>
<td>10</td>
<td>96.29%</td>
<td>99.81%</td>
<td>96.42%</td>
<td>no</td>
<td>0.00%</td>
<td>31.73</td>
<td>363.89</td>
<td>395.62</td>
</tr>
</tbody>
</table>

Example of results for 2015

- 66.6% of caries was removed on average in Session 1 compared with 86.9% for the most difficult Task 5 (Session 2).
- 58.1% of students exposed the pulp while working on a simple caries lesion (Task 2), compared with a more complex cavity (Task 3) in which the pulp was minimally exposed by a minority of students (44.4%).

HapTEL Results over 7 Years

Students’ learning
- Consistent improvement in students’ caries removal skills
- Comparable improvement in skills compared with the traditional phantom head impact
- High level of commitment to learn with the hapTEL workstations (100% turn out).

Curriculum integration
- Trials with clinical tutors provided enhancements to the system
- Medical, Nursing, DCPS and Dental tutors aim to use the systems with more students
- Comparisons between the dental and injection system with 3rd year Dental students provided positive feedback on both systems

Phases in hapTEL - evaluations

- 2008: Dental Year 1 student trials with original hapTEL simulator for teaching cavity preparation
- 2009: Development of injection system and new cavity preparation system by Generic Robotics
- 2010: Trials with dental, medical, nursing and dental care professional students
- 2011: Identification of additional procedures for Health Care teaching - giving injections
- 2012: Dental Care professional Tutor evaluations of original dental simulator - Portsmouth Dental Academy
- 2013: hapTEL simulator for teaching cavity preparation integrated into the curriculum
- 2014: hapTEL simulator for teaching cavity preparation integrated into the curriculum
- 2015: hapTEL simulator for teaching cavity preparation integrated into the curriculum
- 2016: hapTEL simulator for teaching cavity preparation integrated into the curriculum
**Tutor trials with Dental Care professionals (Portsmouth Academy) – Original dental system**

- Concept excellent (all).
- 3D image excellent (all).
- User operation of software could be a little more intuitive (all).
- Left hander had trouble with handpiece orientation.
- Mirror extremely hard to use/orientate (would be good for a second person to the mirror; i.e. Dental nurse) (those that tried).
- Force feedback from handpiece felt very good.
- Using loops on anything lower than level 7 extremely hard to see. Viewing tooth progress icon great idea.
- Results file could be easier to access.
- Could do with hand rest on top of ring as having to stabilise handpiece (dentists)
- Handpiece felt slightly restrictive/heavy (dentist)
- Massive scope for development

**Technology Strategy Board project injections – July 2013 – June 2014**

**Injection procedure**

- Determining any allergies of the patient
- Locating landmarks (on the skin) and associated anatomy
- Technique for safe IM injection
- Safe medicine management / administration
- Recognition of poor practice / technique

**Processes and concepts associated with administering injections**

- Determining any allergies of the patient
- Locating landmarks (on the skin) and associated anatomy
- Technique for safe IM injection
- Safe medicine management / administration
- Recognition of poor practice / technique

**Nursing students using the Injection system**

**Nursing students using the injection system**
Expansion into other functions across Health – Care departments

hapTEL Dentistry

hapTEL for Dental care Professionals

hapTEL and new procedures

hapTEL injections- Nursing - students

hapTEL injections- Medical students

hapTEL for Dental care Professionals

hapTEL injections- DCP

Application of haptic simulators for Robotics students

Conclusions from these studies

The results show that a haptic system simulating simple dental procedures can enhance dental-undergraduate students’ cavity preparation skills with only 2-3 hours practice by improving

- Students’ hand-eye coordination
- Students’ fine and gross motor skills and through formative assessment provided by the dynamic feedback on students’ performance of cavity preparation and log-files of their performance

Conclusions: Implications for haptics in Health Care Education

In order for haptic TEL or other TEL resources to be absorbed into the curriculum and make a positive contribution to students’ learning:

1. University teachers need to be involved in the innovation from the beginning.
2. TEL needs to complement the traditional teaching practices
3. TEL needs to be seen to enhance the evolving curriculum.
4. Extensive ongoing support for teachers is needed to maximise its potential.

New dental-injection/cavity system

hapTEL and new procedures

hapTEL injections- Nursing - students

hapTEL injections- Medical students

hapTEL for Dental care Professionals

hapTEL injections- DCP

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THANK YOU for your interest

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