RESEARCH PAPER

Using computer-assisted method to teach children with intellectual disabilities handwashing skills

Kup-Sze Choi¹, Pui-Kwan Wong¹ & Wai-Yee Chung²

¹School of Nursing, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong and ²Department of Health and Physical Education, The Hong Kong Institute of Education, Tai Po, New Territories, Hong Kong

**Purpose:** To motivate children with intellectual disabilities (ID) to learn handwashing and improve their performance by using computer-assisted teaching method. **Method:** A teaching program was implemented using a computerized teaching station with faucet, soap dispenser and towel dispenser as user interface. In response to the children's actions, animations were shown on the computer screen of the teaching station. A controlled study was conducted to compare the effectiveness of the proposed method (study group) with that of the convention teaching method (control group). Both groups of subjects attended a 30-min handwashing lesson twice per week for 2 months. Their performance was evaluated using a handwashing task checklist and a learning motivation questionnaire, and by measuring the completion time and assessing their hand cleanliness. **Results:** The computer-assisted teaching program improved the handwashing performance and learning motivation of the subjects. The study group appeared to outperform the control group. Observations reflected that the subjects were highly motivated to learn handwashing with the computerized teaching station. **Conclusion:** The proposed method has the potential to facilitate the teaching and learning of handwashing skills for children with ID.

**Implications for Rehabilitation**

- Children with intellectual disabilities are prone to contracting infectious diseases.
- Proper handwashing can reduce the risk of infection.
- Handwashing skills are taught in special schools but outbreaks continue to occur.
- Computer-assisted teaching method has potential to improve the children's learning motivation and handwashing performance.

of the institutionalized was also found to be 3–4 times higher than in those who had never been institutionalized [3].

Unhygienic lifestyle and poor self-care skills are among the predisposing factors that make children with ID more susceptible to infectious diseases [7–10]. As handwashing is an easy and effective way to prevent infection and the transmission of diseases, it is important to teach them to wash their hands properly. Handwashing has been included as an essential part of the self-care curriculum in special schools. Conventionally, the children learn these skills by imitating the handwashing demonstrated by teachers, and by watching videos showing the techniques. However, infectious disease outbreaks continue to occur in special schools, suggesting that there is a need to improve the teaching methods.

**Introduction**

Children with intellectual disabilities (ID) are at high risk for infectious diseases [1]. According to Patja et al., the relative risk of infection was 3.2 when compared with the general population [2]. Studies have demonstrated that people with ID have a higher prevalence for a number of infectious diseases [3], including hepatitis [4,5], intestinal parasitic infection [6] and Helicobacter pylori infection. The infection risk

**Backgrounds**

In Hong Kong, the venue of the study presented in this paper, the prevalence rate of ID is around 1.0–1.3% of the population. According to a survey conducted by the Census and Statistics Department in 2007, which involved 7800 institutionalized people with ID, 8.1% of them aged below 15 years; 23.5% were educated to primary level and 31.6% reached secondary level [11].
The degree of disability is assessed by specialists of the Education Bureau and the Child Assessment Service team of the Department of Health. Special schools are established to meet the needs of children with different levels of ID. Self-care is an important subject in the curriculum to empower the children to live independently, where the teaching of personal hygiene and handwashing techniques is a main focus. However, there were still 11 infectious diseases outbreaks occurred in special schools from 2001 to 2007, affecting a total of 199 students [12]. This is related in part to the methods being used to teach handwashing and thus calling for more effective teaching approaches.

Computer-assisted teaching
Computer technology has been used to facilitate the teaching of independent living skills for people with ID [13]. For example, they learn routes by performing spatial navigation in virtual environment [14], practise decision making with the aid of interactive computer graphics [15], and learn to work together by pointing at virtual targets with computer mouse [16]. Computer-assisted teaching approaches provide a flexible learning platform and make situated learning possible by enabling people with ID to appreciate real situations through interactions in simulated scenarios. The approaches also provide them with a better sense of control over the learning process, which is helpful to improve their motivation and attention span [17–19].

In this study, the use of a computer-assisted approach for teaching children with ID handwashing techniques was explored. A computerized teaching station was designed based on the pedagogical strategies of task analysis and forward chaining. The handwashing process was divided into a number of sequential tasks which were taught one by one in order. The purpose of the study was to evaluate the effectiveness of this approach in comparison with the conventional method. The performance of the subjects was evaluated by using a handwashing task checklist and a learning motivation questionnaire as the instruments, and by measuring the completion time and assessing hand cleanliness using florescent gel. The details will be discussed in the next section.

Methods
Participants
Two special schools agreed to participate in the study. They are located, respectively at the Yuen Long and Shum Shui Po district of Hong Kong, each serving around 200 students with mild degree of ID. Both offer primary and secondary education, with one class for each level (covering 12 levels in total) and less than 20 students in each class.

Students under the age of 18, with mild intellectual disability and attending primary one to three were recruited. Those with upper extremity deficiency; with visual or hearing impairment that could not be remedied using corrective aids; unable to communicate (e.g. due to autism); and those who had already learned handwashing, were excluded. The study was approved by the Human Subjects Ethics Sub-committee of the research institution. Parents or guardians of the subjects were provided with information sheets about the study. Informed consent was obtained.

Conventional teaching method
Handwashing is taught in local special schools according to the guidelines defined by the Curriculum Development Council of the Education Bureau [20]. In the guidelines, the handwashing process is divided into five steps: (1) wet hands with water, (2) apply soap to hand surfaces, (3) rub hands, (4) rinse hands with water, and (5) dry hands with a towel. Teaching begins by showing children with ID videos that demonstrate the process and techniques of handwashing. Teachers then show the children how to wash their hands in each step and ask them to imitate. While the children are encouraged to carry out the demonstrated techniques by themselves, the teacher may also provide suitable prompting or assist by holding and manoeuvring their hands to practise in the correct ways. Positive verbal reinforcement is given when a task is completed. When the children’s performance is satisfactory, the training is then followed by practice in real settings, where they practise turning faucet on and off, applying liquid soap to their hands, and drying their hands with paper towel. Finally, the students are allowed to perform the whole handwashing process. Hints are given if they pause for over 10 s in a step. They are considered as successful learners if they can wash their hands independently with fewer than 3 hints.

Modified handwashing procedure
However, the local teaching guidelines oversimplify the handwashing process without specifying the exact hand and finger movements, which is likely to affect the level of cleanliness. In the Handwashing Techniques with Soap and Water of the World Health Organization (WHO) Guidelines on Hand Hygiene in Health Care (on page 101) [21], the entire handwashing process is delineated thoroughly with 11 steps. While the detailed WHO guidelines are a better reference for proper handwashing, teachers of the participating schools considered that the guidelines might be too complicated for their students. This could produce opposite effect since the children probably avoid failure or situations beyond their abilities [22].

A field trial was therefore used to investigate the children’s compliance with the WHO guidelines. It was conducted during the self-care class of a participating school. Five students were required to follow the steps in the class and their performance was observed by the researchers and the teacher on duty. It was found from the observation that the students were not able to properly perform rotational rubbing and finger interlocking (Step 5, 6 and 7 in the WHO guidelines) and they were frustrated by the difficult hand movements required. For this reason, the handwashing procedure was modified for this study by replacing these three steps with simpler hand movements (e.g. translational movements), as illustrated in Figure 1. The replacements were also designed to increase the contact area during handwashing so as to improve cleanliness.

The validity of the modified handwashing procedure was assessed by asking a student from the participating schools,
with fluorescent gel applied to his hands, to follow the steps to perform handwashing. Under ultraviolet (UV) light inspection, the fluorescent stains were found to be mostly washed away. Furthermore, the handwashing process was videotaped and sent to a panel of two infection control nurses for review. The panel's evaluation on the modified handwashing procedure was positive. They also agreed that it was more important to encourage the children to wash their hands instead of forcing them to strictly follow the difficult steps, although the modified procedure might not be as effective in cleaning finger tips and wrists. Hence, the modified handwashing procedure was adopted in both the conventional and the computerized teaching methods in this study.

Game design
An important objective of the teaching program was to motivate the children to learn handwashing by making the learning process a fun experience. To this end, the teaching program was implemented as a single-player educational video game consisting of two levels. In level one, the principle of task analysis was realized by requiring the children to follow the handwashing steps one by one. The process was associated with amusing animations of hurdling and canoeing, which were referred to as the hurdling game and the canoeing game, respectively. At the beginning of each step, a video clip showing the required procedures in the step was played in the top right corner of the computer screen (see Figure 2a and 2d). The children were then required to mimic the procedures shown in the video clip with guidance and verbal encouragement provided by the teacher. Computer animations were displayed selectively depending on whether or not the procedures were correctly followed. For example, in the hurdling game, an animated runner successfully jumping over a hurdle was shown on the screen if the attempt was correct (see Figure 2b). Otherwise, the animated runner would fail to jump the hurdle (see Figure 2c) and the teacher could then give explanations about the mistakes.

The process was repeated sequentially in the same manner for all the handwashing steps. To increase the children's sense of satisfaction, medals were awarded based on the number of successfully completed steps. Bronze, silver and gold medals were awarded, respectively, to those who had succeeded in 2–4, 5–6, and over 6 steps, respectively. The hurdling game was played repeatedly until 3 gold medals were accumulated. To enhance the training intensity while maintaining the children's attention, they practise handwashing techniques again with the canoeing game, where the settings and requirements were the same as the hurdle game except for the computer animations (see Figure 2d to 2f). The children were required to win another 3 gold medals from the canoeing game in order to reach the next level of the game.

The second level of the game was called the windsurfing game. Here, the concept of forward chaining was applied to teach the children the proper sequence of handwashing steps. The training began by arbitrarily selecting two consecutive handwashing steps and showing the corresponding video clips on two sides of the screen at random (see Figure 2g). The children were required to identify which of the two steps came first. Computer animations were then displayed based on the correctness of the choice. If it was correct, an animated surfer performing buoy rounding would be shown on the screen (see Figure 2h); otherwise, the surfer was trapped by waves (see Figure 2i) and the teacher could explain why the choice was wrong. The process was repeated by asking the children to pick the correct step from another pair of video clips, until three successful attempts were achieved to finish one round.
of the game. Here, a metric defined by dividing three (i.e., the number of successes required) by the total number of attempts was used for performance evaluation. It ranged from 0 to 1 and was expressed as a percentage. The higher this value was, the better the children performed. Bronze, silver and gold medals were awarded if the value was below 20%, between 20% and 40%, and over 60%, respectively. The children were required to get three gold medals by playing the canoeing game for several rounds, and the whole teaching program was completed by then.

Computerized teaching station
A computerized teaching station with interface mimicking real handwashing settings was built to provide a realistic teaching environment. As shown in Figure 3, the station was in the form of a movable cabinet on which a faucet, a liquid soap dispenser, a paper towel dispenser, and a sink were mounted (note that there was no supply of water, liquid soap and paper towel). Sensors were attached to the first three components. The sensors detected whether the faucet was turned on or off, whether the button on the soap dispenser was pressed, and whether the cloth fixed inside the towel dispenser was pulled. A computer screen was fixed on the wall directly facing the user, and a computer was put inside the cabinet.

The computer software was developed based on the game design described in the previous section using Microsoft Visual Studio and C/C++ programming language. It provided instructions in the form of text and audio clips before the games started. Video clips demonstrating the procedure in each individual handwashing step were taken and integrated into the software. Computer animations for the hurdling, canoeing, and windsurfing games were prepared by using Autodesk Maya.

In the hurdling and canoeing games, for steps involving the use of faucet, liquid soap dispenser and paper towel dispenser, the actions of the children were automatically detected by the sensors which generated signals to determine the animation to be displayed. If there was no action detected within 10 s after the video clip was shown, the software would consider it an unsuccessful attempt. For steps requiring the children to wash their hands in certain ways, e.g., rubbing palms or fingers, it relied on the teacher to assess whether the procedures were performed correctly, and to notify the software by pressing on designated buttons of the keyboard. In the windsurfing game, a two-button keypad was made to enable the children to pick the correct answer. If no choice was made within 10 s, the software would consider it as an incorrect attempt.

Research assistants
Seven undergraduate nursing students were employed as research assistants (RAs) to teach the subjects handwashing and to collect data in the study. They were divided into the
teaching team and the assessment team, with 3 and 4 members, respectively. In order to prevent measurement bias, the assessment team was blinded from the teaching method used to teach the subjects. Pre-study training in the form of lectures, hands-on practice and on-site rehearsals was provided for both teams. The teaching team received training on both the conventional and the computer-assisted teaching methods using the modified handwashing procedure, whereas the assessment team was trained on demographic data collection, completion of the handwashing task checklist and the learning motivation questionnaire, handwashing time measurement, as well as cleanliness assessment using fluorescent gel. Both teams had to successfully demonstrate the expected skill levels to the researchers in field trials before they were allowed participate in the study. To this end, examination was conducted by requiring the RAs in the teaching team to teach two groups of five subjects using the conventional and computerized method, respectively; and by requiring those in the assessment team to collect data for one group of the subjects. In the first three sessions of the study, the researchers monitored the performance of the RAs on site and point out any problems as needed. Spot checking were also conducted during the study.

Handwashing task checklist

Development

A handwashing task checklist was developed in this study to assess the subjects’ compliance with the handwashing procedure. The checklist was designed to record whether they had performed the 10 specific tasks during the process of handwashing: (1) turn on the water faucet and wet hands with water, (2) apply soap thoroughly to hands, (3) rub hands palm to palm, (4) rub hands palm to dorsum, (5) interface fingers, (6) rub thumbs, (7) rub little fingers, (8) rinse foam under running water, (9) dry hands with paper towel, and (10) turn off the water faucet without contaminating the hands. One point was given for each correctly performed task, and the total score of the whole checklist was 10.

Evaluation

The content validity of the checklist was reviewed by an advanced practice nurse specializing in infection control. She was provided with the checklist as well as a videotape showing a child with ID washing her hands with the modified handwashing procedure. The advanced practice nurse agreed that all the items in the checklist were relevant and valid. Besides, the inter-rater reliability was evaluated with a field trial involving five children from the participating schools (note that the learning motivation questionnaire described in the next section was also evaluated in this field trial). They were asked to perform handwashing and assessed independently by two RAs. A pre-post-test was conducted using the checklist before and after the children were taught about the handwashing procedure. The scores given by the two RAs for the five students were found to be the same, and the inter-rater reliability was therefore unity. The mistakes made by the students were indeed easily identifiable, which resulted in high inter-rater reliability.

Learning motivation questionnaire

Development

The effect of the computerized teaching method on the children’s learning motivation was evaluated with a questionnaire. The questionnaire was designed to measure their attitudes to the learning process and about washing hands. Simple wordings and text in large font sizes were employed. A four-point Likert scale was adopted, with appropriate emoticons shown to help the children to appreciate the differences between the choices. The children could score 1 to 4 points for each question; the higher the score, the stronger the motivation. The first version of the questionnaires contained 27 questions.

Evaluation

The questionnaire was reviewed by a panel of three teachers who were experienced in teaching children with mild to moderate level of ID. The panel assessed the content validity by rating the level of relevance of each question using a 7-point Likert scale, with 1 being least relevant and 7 being the most. After the initial review, questions with an average score below 4 were discarded, leaving 15 questions for the questionnaire. The questionnaire was then evaluated in the same field trial as described in the previous section. The five children were asked to respond to the learning motivation questionnaire after they had learned handwashing and assessed by the handwashing task checklist. In the field trial, four of the questions was found to be too difficult for the children to comprehend and therefore removed. The number of
questions was finally reduced to 11, and the highest possible total score of the questionnaire was 44 (see Appendix). The final version of the learning motivation questionnaire was reviewed by the same panel again and the content validity index was 0.91. A further field trial was then conducted to specifically determine the test-retest reliability with two students from the participating schools. The students were asked to respond to the questionnaire after receiving handwashing training with the conventional and the computerized method, respectively. They were asked to respond to the questionnaire again 2 weeks later. The Pearson correlation coefficients for the two students were 0.894 and 0.923, respectively, and the reliability coefficient was 0.9085, suggesting that the questionnaire was a reliable instrument.

Cleanliness assessment
Cleanliness of the hands after handwashing was quantitatively measured using fluorescent gel. A single squirt of gel was applied to the children's hands before handwashing. They were asked to rub their hands to spread the gel uniformly, which was checked using a handheld UV light source. The children then used liquid soap to wash their hands. The amount of fluorescent gel and liquid soap were measured using an electronic balance. After completion, photos of the palm and back of both hands (i.e. 4 photos) were taken under a standardized setting using an eight-megapixel digital camera. The area of the hand and the area covered by the residual fluorescent stain were measured manually with the aid of graph paper, and the percentage of the cleansed area was calculated as a proportion of the total area of the hand. The average percentage of the cleansed areas obtained from the four photos was then calculated and used as a metric to quantify the level of cleanliness.

Research design
An experimental study was conducted with two groups of children with ID to evaluate the effectiveness of the proposed computer-assisted method. The two participating schools were randomly assigned as the control and study group, where the conventional and computer-assisted methods were adopted, respectively. 19 students were recruited for the control group, and 10 students for the study group. Pre-post test design was adopted in the study. The effectiveness of the two methods were assessed by (1) determining the subjects' learning motivation, (2) evaluating their handwashing performance, (3) measuring the completion time (defined as the time lapsing between the faucet being turned on and off), and (4) checking their hand cleanliness. As mentioned earlier, since experimental bias might be introduced if teaching and assessment were both carried out by the same person, two separate teams of RAs were arranged to teach handwashing and collect data, respectively. The assessment team was blinded from the method used to teach the subjects. In groups of five or six, the subjects attended a 30-min handwashing lesson, twice per week for 2 months. The post-test was conducted in the same way as the pre-test.

Results

Demographic data
Twenty-nine subjects aged between 6 and 11, with an average age of 8.5 (SD = 1.4), took part in the study. Fifteen (51.7%) of them were male. The subjects were all receiving primary school education: 5 (17.2%) in primary one, 13 (44.8%) in primary two, and the rest in primary three. Statistical results indicated that there was no significant difference in gender ($\chi^2 = 0.018$, p = 0.893), age ($\chi^2 = 4.671$, p = 0.097), or education level ($\chi^2 = 3.164$, p = 0.679) between the two groups. Only one subject provided the intelligent quotient (IQ) score, which was therefore not analyzed. However, the subjects had reportedly been diagnosed with a mild grade of ID, and the corresponding IQ range is 50–70.

Handwashing tasks
The performance of the subjects in each handwashing task is shown in Table I. For the pre-test, the independent t-test showed that there was no statistically significant difference in scores between the two groups for each individual task. They both performed best in tasks T1 and T3 and worst in T10. After the intervention, the mean scores of the control group in tasks T2, T5, T6, T7, T8, and T10 were found to increase significantly. However, the mean score for task T3 decreased, although the decrease was not significant (p = 0.083). The mean score of the study group increased in 9 tasks after learning handwashing using the computerized teaching station, with statistical significance achieved for tasks T2, T4, T5, T6, T8, and T10. Like the control group, the post-test score of the study group in task T3 also decreased (p = 0.343), but not significantly so. Besides, the study group obtained higher scores in 7 of the 10 tasks, and the performance was significantly better in task T4, "rub hands palm to palm" (p = 0.010) and T7, "rub little fingers" (p = 0.046). On the other hand, the total score increased significantly by 3.95 and 4.10 (out of 10) for the control and study groups, respectively. The score of the study group was higher than that of the control group in both the pre-test (4.70 vs 4.05) and post-test (8.80 vs 8.00), but the difference was not significant.

Learning motivation
The subject's learning motivation before and after attending handwashing lessons is presented in Table II. In the pre-test, no significant difference in scores was found between the two groups for all the items of the questionnaire except item Q11, where the study group had a higher mean score (p = 0.034). The post-test results indicated that for the control group, the mean scores of 8 items increased, 2 decreased and 1 remained unchanged after the handwashing lessons; whereas for the study group, the mean scores of 7 items increased, 3 decreased and 1 remained unchanged. However, statistical significance was not achieved for either group. The post-test score of the study group was higher than that of the control group for all the items except item Q5, but again, the difference was not statistically significant.

The total learning motivation score of both groups increased after attending their respective handwashing lessons, but the
Table I. Performance evaluated with the handwashing task checklist.

<table>
<thead>
<tr>
<th>Task</th>
<th>Time</th>
<th>Control group</th>
<th>Study group</th>
<th>Between groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>p</td>
</tr>
<tr>
<td>T1</td>
<td>Pre</td>
<td>1.00</td>
<td>0.00</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>1.00</td>
<td>0.00</td>
<td>–</td>
</tr>
<tr>
<td>T2</td>
<td>Pre</td>
<td>0.11</td>
<td>0.32</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>0.95</td>
<td>0.23</td>
<td>–</td>
</tr>
<tr>
<td>T3</td>
<td>Pre</td>
<td>1.00</td>
<td>0.00</td>
<td>0.083</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>0.84</td>
<td>0.38</td>
<td>–</td>
</tr>
<tr>
<td>T4</td>
<td>Pre</td>
<td>0.68</td>
<td>0.48</td>
<td>1.000</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>0.68</td>
<td>0.48</td>
<td>–</td>
</tr>
<tr>
<td>T5</td>
<td>Pre</td>
<td>0.21</td>
<td>0.42</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>0.79</td>
<td>0.42</td>
<td>–</td>
</tr>
<tr>
<td>T6</td>
<td>Pre</td>
<td>0.05</td>
<td>0.23</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>0.68</td>
<td>0.48</td>
<td>–</td>
</tr>
<tr>
<td>T7</td>
<td>Pre</td>
<td>0.05</td>
<td>0.23</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>0.58</td>
<td>0.10</td>
<td>–</td>
</tr>
<tr>
<td>T8</td>
<td>Pre</td>
<td>0.11</td>
<td>0.32</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>1.00</td>
<td>0.00</td>
<td>–</td>
</tr>
<tr>
<td>T9</td>
<td>Pre</td>
<td>0.79</td>
<td>0.42</td>
<td>0.187</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>0.95</td>
<td>0.23</td>
<td>–</td>
</tr>
<tr>
<td>T10</td>
<td>Pre</td>
<td>0.05</td>
<td>0.23</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>0.53</td>
<td>0.51</td>
<td>–</td>
</tr>
<tr>
<td>Total score (out of 10)</td>
<td>Pre</td>
<td>4.05</td>
<td>1.47</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>8.00</td>
<td>1.80</td>
<td>–</td>
</tr>
</tbody>
</table>

Handwashing tasks:
- T1. Wet hands with water
- T2. Apply soap thoroughly to hands
- T3. Rub hands palm to palm
- T4. Rub hands palm to dorsum
- T5. Interlace fingers
- T6. Rub thumbs
- T7. Rub little fingers
- T8. Rinse bubbles under running water
- T9. Dry hands with paper towel
- T10. Turn off water faucet without contaminating hands

Increase was not statistically significant. The study group outperformed but the score was not significantly better than that of the control group either pre-test (38.90 vs. 37.11; p = 0.191) or post-test (40.05 vs. 38.26; p = 0.055).

Completion time
Refer to Table III, the results of independent t-test showed that there was no significant difference in completion time between the two groups for either the pre-test (p = 0.204) or the post-test (p = 0.243). However, it is clear from the results of the paired t-test that the completion time after attending the handwashing lessons increased significantly for both the control group (from 27.25 s to 164.79 s) and the study group (from 19.31 s to 137.59 s).

Cleanliness
As reported in Table III, no significant difference in the amount of fluorescent gel applied was observed between or within the two groups, before and after the handwashing lessons. The between-group difference in the amount of liquid soap applied was also insignificant. Both groups used more liquid soap in the post-test, but the change was only significant for the study group (p = 0.009). Regarding hand cleanliness, the study group performed significantly better than the control group in the pre-test (p = 0.008). Significant improvement was observed for both the control group (from 27.58% to 55.95%) and the study group (from 12.05% to 60.71%), but the between-group difference in the post-test result was not significant (p = 0.613).

Discussion
In this study, it was hypothesized that the proposed computer-assisted training method could motivate children with ID to learn handwashing and improve their performance. The results from the handwashing task checklist, learning motivation questionnaire and hand cleanliness assessment showed that the performance of both groups improved after administering the respective training methods. The study group appeared to outperform the control group but was not significantly better. These findings suggest that the computer-assisted method is able to achieve a level of effectiveness similar to that of the conventional method. Nevertheless, the study did not reach a definite conclusion because of the small sample size, which was partly due to concerns from parents and schools that the children’s performance might be compared with others, despite the guarantee of data confidentiality. Given that the study lasted for a period of 2 months, the long-term effect
Table II. Learning Motivation Score.

<table>
<thead>
<tr>
<th>Question</th>
<th>Time</th>
<th>Control Group</th>
<th>Study Group</th>
<th>Between Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>p</td>
<td>Mean</td>
</tr>
<tr>
<td>Q1</td>
<td>3.68</td>
<td>0.48</td>
<td>1.000</td>
<td>3.40</td>
</tr>
<tr>
<td></td>
<td>3.68</td>
<td>0.48</td>
<td></td>
<td>3.70</td>
</tr>
<tr>
<td>Q2</td>
<td>3.32</td>
<td>0.82</td>
<td>0.137</td>
<td>3.60</td>
</tr>
<tr>
<td></td>
<td>3.63</td>
<td>0.60</td>
<td></td>
<td>3.90</td>
</tr>
<tr>
<td>Q3</td>
<td>3.11</td>
<td>1.05</td>
<td>0.858</td>
<td>3.20</td>
</tr>
<tr>
<td></td>
<td>3.16</td>
<td>0.77</td>
<td></td>
<td>3.60</td>
</tr>
<tr>
<td>Q4</td>
<td>3.58</td>
<td>0.51</td>
<td>0.331</td>
<td>3.70</td>
</tr>
<tr>
<td></td>
<td>3.74</td>
<td>0.56</td>
<td></td>
<td>3.80</td>
</tr>
<tr>
<td>Q5</td>
<td>3.21</td>
<td>0.71</td>
<td>0.058</td>
<td>3.30</td>
</tr>
<tr>
<td></td>
<td>3.68</td>
<td>0.58</td>
<td></td>
<td>3.50</td>
</tr>
<tr>
<td>Q6</td>
<td>3.58</td>
<td>0.51</td>
<td>0.542</td>
<td>3.40</td>
</tr>
<tr>
<td></td>
<td>3.68</td>
<td>0.48</td>
<td></td>
<td>3.90</td>
</tr>
<tr>
<td>Q7</td>
<td>3.63</td>
<td>0.50</td>
<td>0.259</td>
<td>3.60</td>
</tr>
<tr>
<td></td>
<td>3.42</td>
<td>0.69</td>
<td></td>
<td>3.80</td>
</tr>
<tr>
<td>Q8</td>
<td>3.26</td>
<td>0.73</td>
<td>0.137</td>
<td>3.60</td>
</tr>
<tr>
<td></td>
<td>2.95</td>
<td>0.78</td>
<td></td>
<td>3.40</td>
</tr>
<tr>
<td>Q9</td>
<td>3.26</td>
<td>0.65</td>
<td>0.804</td>
<td>3.60</td>
</tr>
<tr>
<td></td>
<td>3.32</td>
<td>0.75</td>
<td></td>
<td>3.50</td>
</tr>
<tr>
<td>Q10</td>
<td>3.21</td>
<td>0.86</td>
<td>0.331</td>
<td>3.70</td>
</tr>
<tr>
<td></td>
<td>3.47</td>
<td>0.70</td>
<td></td>
<td>3.70</td>
</tr>
<tr>
<td>Q11</td>
<td>3.26</td>
<td>0.81</td>
<td>0.287</td>
<td>3.80</td>
</tr>
<tr>
<td></td>
<td>3.53</td>
<td>0.77</td>
<td></td>
<td>3.70</td>
</tr>
<tr>
<td>Total score(out of 44)</td>
<td>37.11</td>
<td>3.38</td>
<td>0.225</td>
<td>38.90</td>
</tr>
<tr>
<td></td>
<td>38.26</td>
<td>3.38</td>
<td></td>
<td>40.50</td>
</tr>
</tbody>
</table>

Questions on the learning motivation questionnaire
Q1. I am happy to learn handwashing in class.
Q2. I like to learn how to wash my hands.
Q3. I wash my hands after learning handwashing in school.
Q4. I like to learn handwashing with my classmates.
Q5. I like to learn handwashing by watching videos.
Q6. I am praised when I know how to wash my hands.
Q7. I love to learn new things.
Q8. I still want to go to school even if I make mistakes in class.
Q9. I like to learn handwashing from a "big sister" (i.e. the research assistant who taught handwashing).
Q10. I feel happy knowing how to wash my hands.
Q11. My parents want me to learn handwashing.

Table III. Completion time and cleanliness evaluation with fluorescent gel.

<table>
<thead>
<tr>
<th>Measures</th>
<th>Control group</th>
<th>Study group</th>
<th>Between groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>p</td>
</tr>
<tr>
<td>Completion time (s)</td>
<td>27.25</td>
<td>19.98</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>164.79</td>
<td>73.67</td>
<td></td>
</tr>
<tr>
<td>Fluorescent gel (grams)</td>
<td>0.89</td>
<td>0.52</td>
<td>0.983</td>
</tr>
<tr>
<td></td>
<td>0.89</td>
<td>0.90</td>
<td></td>
</tr>
<tr>
<td>Liquid soap (grams)</td>
<td>0.15</td>
<td>0.56</td>
<td>0.009</td>
</tr>
<tr>
<td></td>
<td>2.16</td>
<td>2.94</td>
<td></td>
</tr>
<tr>
<td>Cleanliness (%)</td>
<td>27.58</td>
<td>13.73</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>55.95</td>
<td>16.30</td>
<td></td>
</tr>
</tbody>
</table>

of the computer-assisted education program on handwashing is also uncertain. Further work should be conducted to investigate whether the proposed method is helpful in making proper handwashing a habit for children with ID.

The results show that the time taken by both groups to complete handwashing increased significantly from about 20 s to over 2 min after the intervention. Since the subjects were able to perform more handwashing tasks after the training, increasing from about 4 tasks to 8 or more, it was reasonable that they spent more time on handwashing. However, it was observed that some subjects forget to turn off the faucet at the end of handwashing or took additional time to recall a few of the required tasks in the process, which could also lead to an increase in the overall completion time. In both groups, task T10, "turn off the faucet without contaminating the hands", was often missed.

While hand cleanliness improved significantly in both groups after the interventions, the performance of one subject
in the control group deteriorated, which contradicted with the improvement as recorded by the handwashing task checklist. It was suspected that the subject had not applied enough force to wash her hands.

The teachers of the self-care subject in the participating schools agreed that the proposed computer-assisted method was a user-friendly and attractive approach for teaching children with ID. Although the between-group difference in learning motivation score was not significant, it was evident from observations that the subjects in the study group demonstrated strong learning motivation. They were delighted to use the computerized teaching station to learn handwashing, and could remember the scenarios and animations. Some were even able to recite the scripts and remind others to wash their hands.

Regarding the usability of the computerized teaching station, the current design is not suitable for children using a wheelchair. The cabinet below the water sink provides no room for wheelchair access. Besides, as children with ID often have poor eyesight, the size of the video clips shown on top of the computer animations is considered rather small for these children. The teachers suggested using two separate screens mounted side by side on the station, say, with one displaying the video prompts while the other showing the animations in response to the children’s actions. While the computerized training is water free and avoids the potential issue of wetting the children or messing up the surroundings, it is pointed out that since children with ID are usually weak in making associations, they may not be able to properly transfer the skills acquired from “dry” training into real handwashing. This did not seem to be a problem for the subjects in this study however.

In this study, hand cleanliness was evaluated manually by estimating the area of the hand and the area covered by fluorescent gel after handwashing with the aid of graph paper. This was both time-consuming and error-prone. By using pattern recognition techniques, a computer program could be developed to identify the hand from the photo and compute its area, as well as the area covered by the remaining fluorescent gel.

**Conclusions**

The study demonstrated the effectiveness of using the proposed computer-assisted method to teach children with ID how to wash their hands properly. The effect was similar to that of the conventional method. The computerized teaching station, together with the interactive animations, is attractive to the children and provides them with a realistic environment to practise handwashing. It has the potential to facilitate the teaching and learning of handwashing skills, thus reducing the spread of infectious diseases. Future work includes the improvement of system design based on the findings obtained from this study and further clinical trials to demonstrate the long-term effect of the computer-assisted teaching method.

**Acknowledgements**

This work was supported in part by The Hong Kong Polytechnic University (Project No. G-US09 and 87RF).

Using computer to teach children with ID handwashing

**Declaration of interest:** The authors report no declarations of interest.

**References**


Appendix

Learning Motivation Questionnaire

Q1. I am happy to learn handwashing in class.

A. Very agree
B. Agree
C. Disagree
D. Very disagree

Q2. I like to learn how to wash my hands.

A. Very agree
B. Agree
C. Disagree
D. Very disagree

Q3. I wash my hands after learning handwashing in school.

A. Very agree
B. Agree
C. Disagree
D. Very disagree

Q4. I like to learn handwashing with my classmates.

A. Very agree
B. Agree
C. Disagree
D. Very disagree

Q5. I like to learn handwashing by watching videos.

A. Very agree
B. Agree
C. Disagree
D. Very disagree

Q6. I am praised when I know how to wash my hands.

A. Very agree
B. Agree
C. Disagree
D. Very disagree

Q7. I love to learn new things.

A. Very agree
B. Agree
C. Disagree
D. Very disagree

Q8. I still want to go to school even if I make mistakes in class.

A. Very agree
B. Agree
C. Disagree
D. Very disagree

Q9. I like to learn handwashing from a “big sister”.

A. Very agree
B. Agree
C. Disagree
D. Very disagree

Q10. I feel happy knowing how to wash my hands.

A. Very agree
B. Agree
C. Disagree
D. Very disagree

Q11. My parents want me to learn handwashing.

A. Very agree
B. Agree
C. Disagree
D. Very disagree

N.B. Score assignment: A = 4 points, B = 3 points, C = 2 points, and D = 1 point.