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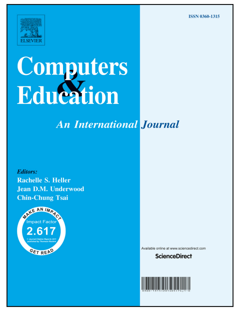


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PII: S0360-1315(18)30250-1

DOI: 10.1016/j.compedu.2018.09.014

Reference: CAE 3457

To appear in: *Computers & Education*

Received Date: 9 April 2018

Revised Date: 10 September 2018

Accepted Date: 23 September 2018

Please cite this article as: Yip J., Wong S.-H., Yick K.-L., Chan K. & Wong K.-H., Improving quality of teaching and learning in classes by using augmented reality video, *Computers & Education* (2018), doi: https://doi.org/10.1016/j.compedu.2018.09.014.

# Improving Quality of Teaching and Learning in Classes by using Augmented Reality Video

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Conflict of interest

The authors declare that they have no conflict of interest.

# Improving Quality of Teaching and Learning in Classes by using Augmented Reality Video

**Abstract**

This study contributes to enhancing students' learning experience and increasing their understanding of complex issues by incorporating an augmented reality (AR) mobile application (app) into a sewing workshop in which a threading task was carried out to facilitate better learning relative to a conventional approach. Participants included 46 freshmen. One group of students was provided with a handout, while the other was asked to view an AR video. Questionnaires were then administered, and the results showed a significant difference between the two groups in terms of their understanding of the task. This finding was consistent with the post-test scores and the time required to learn the threading task. Several feedback items indicated higher learning efficiency with the use of AR videos.

**Keywords:** education; understanding by processing; augmented reality; videos

## 1. Introduction

The most common form of teaching is direct information transfer from the teacher to the students. Traditionally, large classes in post-secondary educational settings are taught in the form of a lecture, which is unidirectional; teaching is presented through PowerPoints, handouts, websites and so on. In some circumstances, when three-dimensional (3D) concepts are presented, students may find it difficult to gain a thorough understanding when only a two-dimensional medium is used for teaching (Stull, Gainer and Hegarty, 2017). According to the ability-as-enhancer hypothesis, learners with high spatial ability would benefit from 3D visualizations in learning. This hypothesis further proposes that learners with low spatial would perform less optimally with 3D concepts since most of these learners have difficulties in mentally constructing visualizations (Huk, 2006). Even students with a normal spatial ability have to exert more effort when learning 3D concepts compared to other types of concepts. Some researchers have indicated that high-quality teaching and learning requires active engagement with students (Billings & Halstead, 2015; Lam & Muldner, 2017). However, when conventional teaching methods are used to teach 3D concepts, students often lose interest, engage less during lessons, or miss classes. This view was supported by Mulryan-Kyne (2010), who found that many students tend to skip class and even purchase the lecture notes instead of attending class if they have had issues with the teaching concepts. Inevitably, student ratings of these courses are substantially low.

Additionally, Mintah (2014), Mulryan-Kyne (2010) and Yelkpieri, Namale, Esia-Donkon and Ofosu-Dwamera (2012) indicated that it is much more difficult for teachers to focus individually on each student and address his/her specific needs when class sizes are large. As a result, not all students can follow the pace of teachers well. Yelkpieri et al. (2012) indicated that smaller group learning encourages students to fully participate in the classroom, and it is much easier for teachers to assess their taught lessons in small classes than in large ones. However, students may still find it difficult to control their own pace of study in class and to review more difficult content through other learning mediums after class aside from handouts.

Recently, virtual technology has become one of the most popular trends in daily life. It is used for entertainment purposes as well as in the fields of physics, medicine and education (Friess, Oliver, Quak & Lau, 2016). For example, virtual technology can transport students and immerse them into a different setting through virtual reality (VR) or allow them to view pop-up images through augmented reality (AR). According to Milgram et al. (1995), there are three kinds of technologies: AR, VR and augmented virtuality (AV). AR augments natural feedback with simulating cues to the operator. In VR, participants are “immersed in a completely synthetic world” (p.283). In AV environments, the “primary world being experienced is predominantly virtual” (p.283). In addition, AR allows the amalgamation of computer graphics, in which visuals and multimedia information are overlaid onto a real-world scene (Healey & Jenkins, 2000). Sometimes, a hybrid form of these technologies refers to virtual spaces with both images and real physical objects (Regenbrecht et al., 2003). In summary, AR is closer to the real world; digital graphics, sounds and haptic feedback are added and superimposed onto the natural world in AR. In contrast, VR and AV provide a completely contained digital experience.

The concept of AR technology is not new. Studies on AR technology in educational settings have highlighted many advantages in teaching and learning (Akçayır and Akçayır, 2017; Radu, 2012). One of the reasons of why AR technology is so widely used is because it no longer requires expensive hardware and equipment. This technology can be used with computers and mobile phones. One significant advantage of using AR technology in education is the enhancement of students’ learning achievement (Chang, Hou, Pan, Sung, & Chang, 2015; Ferrer-Torregrosa et al., 2015). It can also provide immediate and relevant information such as videos and

3D images to students in order to facilitate their processing skills and increase their learning motivation and level of understanding (Chiang, Yang & Hwang, 2014; Yoon, Elinich, Wang, Steinmeier, & Ticker, 2012).

Nevertheless, the use of AR technology in education is not without its challenges. For instance, the difficulty and time consumption of using AR applications are commonly reported (Gavish et al., 2015), particularly without well-designed interfaces (Munoz-Cristobal el al, 2015). Although many AR technologies have been developed for education, only a few of them have been developed for real classroom environments (Cuendet, Bonnard, Do-Lenh, & Dillenbourg, 2013). The aim of this study is therefore to show how AR technology is implemented in classroom and laboratory settings in the discipline of textiles and clothing. It offers an alternative approach in pedagogy for students' learning, with the purposes of enhancing their learning experience and increasing their level of understanding of complex issues through the effective use of augmented multimedia. A combination of different types of multimedia sources, including 3D spatial models, images, textual information, videos, animations and sound is adopted, to superimpose digital contents into student learning environments through AR application but only AR video is focused in this study. Although the use of AR in education offers many learning benefits, the focus of this study is primarily on the effectiveness of the pedagogical design through a complicated knitting process involving three different types of knitting needles, knitting movements, and threading processes. The effect of this technology was compared with a conventional teaching approach to determine whether it increased students' attentiveness and, as a result, facilitated motivation and aroused students' interest in learning in this discipline.

## 2. Methodology

### *2.1 Traditional video vs. AR video*

Video clip is one of traditional methods of presenting teaching materials in classroom. The advantages of traditional video clips brings advantages for students, such as increasing memory, comprehension, and deeper learning, comparing with just using handouts (Berk, 2009). However, there are few limitations of playing traditional videos that cannot be ignored. According to previous studies of Krammer et al. (2006) and Sherin (2004), traditional videos just show the limited excerpt from a reality based on the focus and the angle of the camera. Some information may not be fully captured by the camera even though it has been happening in classroom or laboratory. To cope with such situation, AR video has been developed and applied in education that provides superimposed and 360-degree graphics on the real environment for students with tapping their fingers. Unlike the approach of using traditional videos (or QR codes), where users can click each link (or scan each code) individually, students using AR technology were only required to move their mobile phone slightly to activate the next AR symbols once they completed their previous learning task. In order to shift the mode of learning from passive to active and engaged learning, the education goal of this study is to foster a habit in students to view learning as a vital component of their everyday life, and relevant not only in the formal educational context, but also in everyday work, socialising, and play.

### *2.2 Research framework*

To apply AR to the learning environment, a mobile application (app) called ITC VR AR was developed by the Institute of Textiles and Clothing (ITC) of The Hong Kong Polytechnic University (PolyU). This app can be installed through the App Store (for iPhone users) or Google Play (for Android users) without cost. Multimedia sources such as 3D spatial models and videos are shown when certain symbols are scanned by the AR tool in ITC VR AR. VR videos with a 360° view can also be watched through a VR tool, but is not included as part of this study and will not be discussed here.

To reduce selection bias and obtain more accurate results, a randomized controlled trial (RCT) was run. Study participants were randomly allocated to two different groups: either the intervention group, which adopted AR videos in learning, or the control group, which used conventional handouts. The same teaching materials and resources (i.e., handouts and AR videos) were made available to all students after the trial so that they could enjoy the same benefits of undergoing different forms of learning; i.e., no students was excluded from the possibility of receiving good pedagogy.

Conceptual learning and spatial learning are the two focuses of the learning evaluation in this study, in accordance with Hakan and Fatih (2015). To evaluate the effectiveness of using AR technology in education, students' level of understanding regarding the characteristics of three main types of knitting needles as well as their knitting movements were examined by comparing students who read a handout versus those who used the mobile app.

A simple test on the different types of knitting needles was given on 15 September

2017 in two of the tutorial classes of Intimate Textiles and Accessories with two groups of Year 3 students. The students were required to answer questions about knitting needles. Then, one group of students was provided with a handout (Group A) with instructions, while the other group of students (Group B) was asked to download the mobile app ITC VR AR prior to the AR learning process. After the performance of the two groups was analysed, the students were administered a threading task in sewing workshops from 26 to 29 September 2017. Both the handout and AR videos were used as a trial, with the same structure as the simple test on the different types of knitting needles. Their performance was then assessed, and they were given a questionnaire.

### *2.3 Simple Test on Different Types of Knitting Needles*

To evaluate whether AR videos are able to produce better learning outcomes for students, a simple test on three main types of knitting needles – compound, latch and bearded needles – was given. The test comprised two sections: one on basic terminology and the other on understanding knitting action. The former contained five multiple-choice questions assessing basic knowledge of the three types of needles, with a maximum score of 5 points. The latter required the students to place the steps of the knitting procedure that used the compound and bearded needles in the correct order. The steps were provided so the students were just required to indicate the order by using a letter (A, B, C, etc.). Every two connected and correct answers were given a score of 1. A full score of 12 was given if the needle movement steps were arranged correctly and sequentially. No exact wordings were used on the test paper to prevent students from merely finding or even copying the answers with similar terms from the handout without actually understanding them well.

An RCT was run to prevent bias and increase the accuracy of the results. A flow diagram of this simple test is provided in Figure 1.

#### *2.3.1 Subject Group*

Forty-four Year 3 students who were studying at the ITC and had been learning about the principles behind the use of different types of knitting needles and their characteristics in their tutorial class called Intimate Textiles and Accessories were invited to participate in the simple test. To ensure that all students did not have prior adequate knowledge of knitting process, knitwear design specialism students were excluded because they may have already studied similar topics in earlier years of study. Therefore, only 43 students took part in the simple test.

To randomly allocate the study participants into the two groups, all students were randomly allocated into different Intimate Textiles and Accessories classes by the PolyU computer system, which randomly selected the tutorial class designated Group A (received handouts) or Group B (viewed AR videos). Therefore, all participants were blind to the study in that they did not have information about the learning tool until they started their tutorial class. All students who took part in the study were female, with 22 and 21 students in Groups A and B, respectively.

### *2.3.2 Learning Process*

The same test was prepared for both groups of students. A handout with instructions on the use of the three main types of knitting needles was provided to each student in Group A. A part of the handout is shown in Figure 2.

Group B students were required to download and install the ITC VR AR mobile app to learn how needles move and operate in a knitting machine (Figure 3). A sheet showing a knitting machine with 4 AR symbols was provided to the Group B students. The aim of this sheet is to provide an overview for students to understand exactly the process happened in which part of the machine and enable them to understand how the machine works as a whole. Once the symbol was scanned by the installed app on the digital device, related videos appeared on the screen. These videos were short and within a minute in length. The students were allowed to control the video by tapping on the buttons at the bottom of the screen and learn at their own pace by tapping the pause button.

During the trial, both groups of students were allowed to answer the questions with their learning tool (handout or AR video) and even use an electronic dictionary if needed. To ensure fairness, no discussion among the students was allowed. Since there was no time limit, the students were encouraged to try their best to understand the contents and answer all of the questions. The students were to raise their hand when they completed the test. Their score was provided after the test. The aim was to assess the learning outcomes of both groups and determine the effectiveness of using AR videos for educational purposes.

### *2.4 Threading Task*

After the learning performance of students who took the simple test was analysed, another trial on basic terminology and understanding of the threading process was designed to evaluate the learning efficiency of using AR videos. The results obtained in the simple test on the knitting needles led to the use of a threading task to further determine the learning outcome of using AR videos.

To obtain a better idea on how well the students understood the threading process of an industrial sewing machine, a threading task was designed and administered to two groups of ITC freshmen through either a handout or an AR video. An RCT was also run to avoid bias and obtain more accurate results. The flow diagram of this task is shown in Figure 4.

#### *2.4.1 Subject Group*

All 97 freshmen who were studying at ITC and had not yet learned how to operate a professional sewing machine were invited to participate in a sewing workshop for the threading task. Six sessions with different timeslots were offered to the students, and they could choose one of the six. A voluntary research trial (threading task) would be held during the sewing workshop, which was mentioned on the poster. Forty-six freshmen registered and enrolled in the trial.

To avoid bias and ensure the accuracy of this study, the students were randomly allocated into groups. Those who enrolled in Sessions 2, 3 or 5 were placed into Group A, whereas students who signed up for Sessions 1, 4 or 6 were placed into Group B. All participants were blind to the study such that no one knew there were two different learning tools for the threading task. As a randomized method was used for the subject distribution, the number of students in Groups A and B was not the same in this study. There were 27 (4 males and 23 females) and 19 (all females) students in Groups A and B, respectively.

#### *2.4.2 Learning Process*

##### *2.4.2.1 Pre-test for freshmen*

To evaluate the learning efficiency and ensure accuracy in analysing the learning performance of the students, a pre-test was carried out before the students received the handout or downloaded the AR videos. The aim was to assess their inherent sewing knowledge and ability, which could help gauge whether there was similarity with their actual performance. The students were required to thread a flat sewing machine (Figure 5) without any prompting or instructions. Regardless of their allocated group, all students had to finish the task but were not given a time limit. They raised their hand when they completed the threading. The time required for each student to finish the task was recorded, whereas the score depended on each threading step. The threading task was separated into 16 steps, and a score of 16 was the maximum.

#### *2.4.2.2 Post-test for Freshmen*

After the students received their score for the pre-test, all of them took part in a post-test. A traditional handout with instructions on how to thread a sewing machine was provided to Group A, which is shown in Figure 6.

Group B students were asked to download the same app, ITC VR AR, as that used in the previous simple test on knitting needles. The students scanned a symbol on the sewing machine, and the AR component of the app displayed a video that would allow them to learn about threading (Figure 6). The entire threading process was shown on the video. As with the videos in the simple test on knitting needles, there were buttons on the bottom left of the screen that could be tapped, such as a pause and replay button, so that the students learned at their own pace.

During the post-test, both groups of students were allowed to thread a machine by using their learning tool (handout or AR video). As with the simple test on knitting needles, they were allowed to consult an electronic dictionary. When the students finished threading, their time spent carrying out the task and their score were recorded.

### *2.4.3 Questionnaire*

A short questionnaire was designed to collect feedback on both types of learning experiences as well as students' opinions on the designed mobile app and the traditional handout. A specific set of questions was created and tailored for each group of students to avoid bias. All key words in the questionnaire did not suggest that there were two different learning tools. Thus, the eleven questions in both questionnaires were basically the same.

The questionnaires were distributed to all 46 students (4 males and 42 females) who enrolled in the sewing workshop. The return percentage of the questionnaires was 100%.

Five of the eleven questions in the questionnaire focused on personal information. The other six asked about the learning experience of the threading task, including the challenges that the students encountered with their learning tool, the difficulty level of the task with the provided learning tool, six factors related to learning (including learning interest, engagement, active learning, level of understanding, pace of learning, and academic outcome), and the extent to which the participants would like to have the respective learning tool applied in their sewing class or even extended to other lessons.

Four of the questions that focused on learning experience and used a 5-point scale were found to be highly reliable (10 items; $\alpha = 0.85$) and significantly correlated, $r = 0.85$ and $p = 0.000$. By using intraclass correlation coefficient (ICC) statistics, the range of the average measure of the 10 items at the 95% confidence interval was found to be 0.775 to 0.908. The detailed results of each question will be provided and discussed later.

### *2.5 Data Analysis*

The IBM SPSS Statistics programme, which is a software package for logical batched and non-batched statistical analysis, was used to analyse the data.

In terms of the simple test on the knitting needles, an independent sample t-test comparison was conducted to determine whether there were any differences between Groups A and B regarding the scores for basic terminology or understanding of the knitting action. The data analysis showed the influence of the learning methods and determined whether there were any significant relationships between learning performance and teaching approach. The results are very important for designing the threading task since they can help assess whether AR videos lead to better learning performance through either basic terminology or understanding of knitting action.

The threading task, which was designed on the basis of the results of the simple test on knitting needles, was administered to the freshmen through either a handout or an AR video. An independent sample t-test was used to determine the difference in learning performance between the two groups of students. As the time required by each student to complete the threading task was also collected, the efficiency of the threading process based on understanding the task with the two different types of learning tools was compared with data from Groups A and B. Moreover, the responses to the questionnaire helped assess the effectiveness of the AR videos and acquiring feedback from the users.

## 3 Results

### *3.1 Learning Outcomes of Simple Test on Knitting Needles*

The results of the forty-two Year 3 students were analysed, with 21 in Group A and 21 in Group B. According to Table 1, the total scores of the participants ranged from 2 to 14 ($M = 5.24$, $SD = 2.56$). The scores were non-normally distributed, with a skewness of 1.34 ($SE = 0.37$) and kurtosis of 2.24 ($SE = 0.72$). Regardless whether the focus is the score of basic terminology or understanding of the knitting action, the absolute value of the score is less than 1.96 or greater than -1.96. Moreover, $p < 0.001$ in the Shapiro-Wilk test shows strong evidence of non-normality.

Apart from analysing the total scores of the two groups, the scores for basic terminology or understanding of knitting action were also separated in the data analysis to easily assess learning performance with the use of the two learning tools. The results are provided in Table 2.

In terms of basic terminology, a score of 5 was the maximum. The final score ranged from 0 to 5 ($M = 3.05$, $SD = 0.18$). The results of this test did not follow a normal distribution, with a skewness of -0.51 ($SE = 0.37$) and kurtosis of 0.08 ($SE = 0.72$). Therefore, a Mann-Whitney U test, which is a non-parametric test, was the most appropriate statistical test, and it was used to analyse the outcomes regarding the basic terminology between the two groups.

In Table 2, the Mann-Whitney U test indicates that the learning performance of basic terminology of Groups A and B was similar, where $U(42) = 195.5$, $Z = -0.65$, and $p = 0.51$, and the difference between the two groups was small ($r = -0.1$). There was no significant difference between the two groups.

As for the understanding of knitting action, a score of 12 was the maximum. However, no one received the maximum score. In line with Table 1, the scores ranged from 0 to 9 ($M = 2.19$, $SD = 0.35$). As the results had a non-normal distribution, with a skewness of 1.27 ($SE = 0.37$) and kurtosis of 1.27 ($SE = 0.72$), the Mann-Whitney U test was also used for the data analysis.

As shown in Table 2, the Group B students (median = 3.00, mean rank = 27.57) scored higher on understanding knitting action in comparison to the Group A students, who learned the task from handouts (median = 1.00, mean rank = 15.43). Meanwhile, the Mann-Whitney U value was found to be statistically significant, $U= 93$ ($Z = -0.65$), $p = 0.001$, and the trend of the difference between the two groups was $r = -0.50$.

### *3.2 Learning Performance of Threading Task*

The threading task determined the students' ability to learn to thread an industrial sewing machine. The data analysis results are shown in Tables 3 and 4.

For both the pre-test and post-tests, 16 was the maximum score. As shown in Table 3, the range of the scores on the pre-test and the time required (in seconds) was 1 to 13 ($M = 4.91$, $SD = 2.64$) and 70 to 591 ($M = 264.30$, $SD = 107.52$), respectively. Neither followed a normal distribution since the skewness of the scores was 0.79 ($SE = 0.35$) with a kurtosis of 0.78 ($SE = 0.69$), whereas the time required had a skewness of 0.80 ($SE = 0.35$) and kurtosis of 1.24 ($SE = 0.69$). A Kruskal-Wallis test, which is a non-parametric test, was therefore applied to carry out the data analysis.

Table 4 shows that there was no statistically significant difference between the two groups in terms of their learning performance in the pre-test ($H (1) = 0.13$, $p = 0.719$), with a mean rank of 22.91 (median = 4) for Group A and 24.34 (median = 5) for Group B, which is an extremely small difference between the two groups ($r = -0.053$). In addition, no significant time difference was found between them ($H (1) = 1.10$, $p = 0.294$), with a mean rank of 25.24 (median = 264 and 21.03 (median = 240) for Groups A and B, respectively. In comparing the two groups, the difference between them was also very small ($r = -0.15$).

The range of the scores in the post-test was 4 to 16 ($M = 9.78$, $SD = 2.96$), and the time required ranged from 64 to 1002 seconds ($M = 357.28$, $SD = 188.14$) (Table 3). Since the assumption of normality in distribution was not satisfied due to the skewness and kurtosis values, the Kruskal-Wallis test was used for the data analysis.

The scores of the post-test showed a statistically significant difference between the two groups ($H (1) = 20.96$, $p < 0.001$), with a mean rank of 15.94 (median = 8) for Group A and 34.24 (median = 12) for Group B, as shown in Table 4. A significant difference was found between them ($r = -0.67$). A significant difference was also found for the time required ($H (1) = 23.98$, $p < 0.001$), with a mean rank of 31.63 (median = 420) and 11.95 (median = 207) for Groups A and B, respectively. The difference between the two groups was also significant ($r = -0.722$).

### *3.3 Questionnaire*

A questionnaire was distributed to all students in both groups for the threading task. All questionnaires were completed and returned.

All enrolled Year 1 freshmen (46 students) were in the 18-20 age range except for one student in Group B who was between 21 to 23 years old. In total, only 2 students in Group A were enrolled in the Fashion and Textile Design specialty, while the rest had not yet chosen their major. Regardless of the group or specialty, the students had not yet learned to thread an industrial sewing machine until they attended this sewing workshop, although 4 students in Group B had previously attempted to do so out of curiosity.

In terms of the question that asked students about the challenges they faced with their learning tool for threading (Question 2), Table 5 shows that almost all Group A students (96.3%) had difficulty understanding how to thread the sewing machine based on the handout, whereas this was true for only about one quarter (26.3%) of the students in Group B. Moreover, about one quarter, or 22.2%, of the Group A students felt that learning from a handout was boring, but no one in Group B felt that way about the videos, and about a quarter of them (26.3%) even felt that the threading task was not difficult at all with the use of the AR videos.

In terms of the difficulty level of the threading task with the provided learning tool, students were asked to rate on a 5-point Likert-scale, with 1 denoting not difficult and 5 very difficult. Compared to the students in Group B ($M = 1.89$, $SD = 0.46$), students in Group A ($M = 3.85$, $SD = 0.86$) indicated that they experienced more difficulties in learning the threading task, and the difference between the groups was significant: $t(41.41) = 9.95$, and $p <0.001$.

Moreover, students were required to rate how much they agreed about the advantages of using the learning tool for the six factors related to the threading task on a 5-point scale, where 1 was strongly disagree and 5 was strongly agree.

Table 6 shows that there was a significant difference between the two groups for all six factors related to learning ($p < 0.05$), including learning interest, engagement, active learning, level of understanding, pace of learning, and academic outcomes. A total score was computed by summing up all of the scores of the six factors, and it was analysed for evaluation purposes. A significant difference was found between Groups A ($M = 18.89$, $SD = 4.54$) and B (25.47, $SD = 3.66$), $t(43.11) = -5.43$, and $p < 0.001$.

Apart from collecting the ratings on the learning tools, two questions were asked to determine the extent that the participants would like to have the respective learning tool applied in their sewing class or even extended to other lessons. A Likert scale of 1 to 5 was used for both questions, in which 1 was strongly disagree and 5 was strongly agree.

In terms of applying their respective learning tool in sewing class, Group B students ($M = 4.11$, $SD = 0.57$) more strongly agreed that it was a good idea to use AR videos in class as opposed to Group A students on the use of the handout ($M = 2.52$, $SD = 0.75$) (Table 6). There was a significant difference between the two groups,

$t$ (43.75) = -8.15, and $p < 0.001$.

As for extending the respective learning tools to other classes, Group B students demonstrated more support for doing so with the AR videos (M = 3.89, SD = 0.46) in comparison to the students in Group A with the traditional handout (M = 2.56, SD = 0.80). A statistically significant difference between the two groups was obtained; see Table 6, $t$ (42.55) = -7.18, and $p < 0.001$.

## 4 Discussion

A simple test on three types of knitting needles was provided to Year 3 students during a tutorial class. The test showed that the scores for basic terminology were similar for the two groups of students, that is, those who were given a traditional handout versus those who watched AR videos. Group B students received higher marks for their understanding of the knitting action, and the difference was statistically significant. This implies that teaching with the use of AR videos can not only help students gain a conceptual understanding at the same level as traditional handouts but also facilitate a better understanding of complex issues, such as 3D processes, and spatially related learning and processing. Therefore, the threading task, which is a processing task, was designed for freshmen students to further evaluate their learning performance and the learning effectiveness and efficiency of AR videos as a teaching tool.

As mentioned in Section 3.2, the pre-test result acquired for the threading task showed that the ability of the two groups to thread a sewing machine was similar since the scores and time required to do so were similar, without a significant difference. This ensured that students learned from the same baseline and helped obtain more accurate results for further evaluation. Regardless of the learning method, the threading skills of the students improved after one of the learning tools was used. There was a significant difference between the pre-test and post-test scores.

In terms of the post-test scores, better threading performance was found in Group B, with a significant difference between that group and Group A, which means that learning with the use of AR videos resulted in better information processing skills and thus increased understanding. Meanwhile, students exerted less effort in learning because the time required to grasp the information was also less than that required with the handout of Group A, and the difference was significant. These results were consistent with the feedback collected in the sewing workshop. Group B students indicated that it was not difficult to learn and understand the contents by watching videos, but the students in Group A did not feel the same way about the handout. This shows that the handout was less effective. According to the collected data, students in Group A (using handout only) demonstrated less interest, lower engagement, less active learning, poorer understanding, and more difficulties in controlling the pace of learning, which resulted in lower academic outcomes. The results also implied that the use of AR videos resulted in satisfaction with the learning experience and higher learning efficiency, especially for process learning-related activities. These results were also supported by a study carried out by Vergara, Rubio and Lorenzo (2017), who found that the use of virtual learning tools in education has positive impacts on students, including improvement in the level of understanding and increased motivation to learn. Furthermore, Ullrich, Shen, Tong and Tan (2010) and Di Serio, Ibáñez and Kloos (2013) indicated that students' interest in learning and level of engagement in learning activities improved as a result of using mobile device technology.

Students in Group B also supported the use of AR videos for their sewing class and other courses. In contrast, students in Group A did not feel the same way about the handout. Although applying traditional videos could lead to partial benefits of AR technology, the use of AR videos in current settings offers significant added benefits. First, virtual object is overlaying into real world by using AR which provides three-dimensional images showing a thorough and clear needle movement as well as the threading process, which cannot be done via traditional videos. Threading is a complicated task that students usually learn best in a 3D demonstration at the laboratory. The AR technology provided students a 3D experience so that they could "visualize" the real-world scenarios easily.

Second, the AR videos provided convenience to students as they could review the multimedia information at home or anywhere else simply with their mobile application and AR symbols. The use of AR videos provided considerable convenience to students in the process of learning. Unlike the approach of using traditional videos (or QR codes), where users can click each link (or scan each code) individually, students using AR technology were only required to move their mobile phone slightly to activate the next AR symbols once they completed their previous learning task. The multimedia information was superimposed on the handout; therefore, students could easily correlate the information in one goal.

In addition, the AR videos encouraged high levels of interactivity between students and the learning materials. The current design of the mobile application allowed students to select their learning process by choosing any sequence of the AR symbols provided. Particularly in the textile industry, many manufacturing processes require in-depth understanding of machine motion. Knitting is one typical example that involves a series of dynamic processes (e.g., needles, yarn guide); students often have difficulties in understanding the sequence of the process even in traditional videos. Also, the multimedia resources triggered with AR technology interact with the motion of users immediately. For instance, users can zoom in and out to see the graphics or videos and these interaction cannot be operated in traditional videos. The design of the AR app in the current study encouraged students to interact with their learning materials and to take responsibility for their own learning. There is another consideration in the pedagogical design of the current AR application. Currently, there are two types of arrangements in playing the AR videos. When students move their mobile devices away from the AR symbols, the AR videos (or other medium) either continues to play or stops until the mobile app detects the AR symbol again. Each arrangement has its own purpose in terms of pedagogical design. The former arrangement encourages continuous learning, and it is particularly useful when the task requires students to learn with non-stop instructions. Thus, the AR videos of threading in the sewing machine were adopted in the current study. Students would be better off in their learning without any interruption even if the application moves outside the range where AR symbols cannot be detected. In other circumstances when students are required to take control of their learning (e.g., pace of learning, multi-tasking), pausing AR videos would be more suitable if they paused when students moved their mobile device away from the AR symbols. Therefore, this consideration should be taken into account when designing the AR application and AR symbols. While AR videos offer many advantages, some of the Group B students felt that there was room for improving the videos, such as adding subtitles and reducing the speed of the video. In addition, the lower satisfaction with the learning experience for the group of students who were using a handout may reflect the handout design, such as its size, its clarity, and the layout of the graphics. Technical problems, such as the stability of camera tracking, were also one limitation in the application of AR technology (Wu, et al., 2013) and therefore should not be neglected.

## 5 Conclusions

Overall, the use of AR videos, compared with the use of handouts in classes, provides better learning results in terms of learning performance and efficiency and in terms of providing a satisfying learning experience. These findings showed that AR videos enhanced students' learning experience and increased their understanding of complex concepts in terms of spatially related learning and processing. Undoubtedly, the research findings relied heavily on the design of the handouts and AR videos; however, one important focus on this teaching innovation should rest on the impact of student learning, the level of understanding, and learning motivation. Nevertheless, the relatively small sample size in this study may be a concern, as fewer than 100 students took part in the two experiments. Future studies could consider a longer time span or extend their focus across subjects. Other limitations of this study could be overcome in future studies by adding subtitles, reducing the speed of the video, and capturing the steps in detail in order to improve the learning experience. Although it can be argued that normal videos may achieve similar outcomes, the use of AR videos definitely provided convenience to students in learning; thus, the advantages of the pedagogical design should not be neglected. The study focused on the evaluation of an AR application in education and showcased the pedagogical design in the discipline of textiles and clothing. The innovation of adopting an AR application in this study had a positive impact on student learning and achievement, particularly for learning a complicated task/concept, i.e., threading. As no similar studies have been conducted in relation to instruction on knitting and sewing, it is hoped that this study may open new avenues for research in similar disciplines to further improve the quality of teaching and learning.

## Conflict of interest

The authors declare that they have no conflict of interest.

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**Acknowledgment**

The work is supported by funding from the TDG 2015-16 Rollover Fund entitled "Improving Quality of Teaching and Learning in Large Classes by using Virtual Learning Scenarios" (Code: 498R). The work is also supported by ITC internal funding (Code: 1-ZVLJ).

Table 1. Results of Normality Test of Simple Test on Knitting Needles

| | N | Mean | | Std. Deviation | Skewness | | Kurtosis | | Tests of Normality Shapiro-Walk | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Stat | Stat | Std. Error | Stat | Stat | Std. Error | Stat | Std. Error | Stat | df | Sig. |
| **Scores for Basic Terminology** | 42 | 3.048 | 0.177 | 1.147 | -0.505 | 0.365 | 0.082 | 0.717 | 0.919 | 42 | 0.006 |
| **Scores for Understanding in Knitting Action** | 42 | 2.191 | 0.35 | 2.266 | 1.271 | 0.365 | 1,270 | 0.717 | 0.851 | 42 | <0.001 |
| **Total Scores** | 42 | 5.238 | 0.4 | 2.564 | 1.344 | 0.365 | 2.243 | 0.717 | 0.883 | 42 | <0.001 |

Table 2. Results of Mann-Whitney U Test of Simple Test on Knitting Needles

**Ranks**

| | Group | N | Mean Rank | Sum of Ranks |
|---|---|---|---|---|
| Basic Terminology | A (Handouts) | 21 | 22.69 | 476.50 |
| | B (AR video) | 21 | 20.31 | 426.50 |
| | Total | 42 | | |
| Understanding in Knitting Action | A (Handouts) | 21 | 15.43 | 324.00 |
| | B (AR video) | 21 | 27.57 | 579.00 |
| | Total | 42 | | |

**Test Statistics**

| | Basic Terminology | Understanding of Knitting Action | Total Score |
|---|---|---|---|
| Mann-Whitney U | 195.5 | 93.000 | 131.500 |
| Wilcoxon W | 426.5 | 324.000 | 362.500 |
| Z | -0.65 | -3.271 | -2.268 |
| Asymp. Sig. (2-tailed) | 0.513 | 0.001 | 0.023 |

Grouping Variable: Group

Table 3. Results of Normality Test on Threading Task

| | N | Mean | | Std. Deviation | Skewness | | Kurtosis | | Tests of Normality Shapiro-Walk | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Stat | Stat | Std. Error | Stat | Stat | Std. Error | Stat | Std. Error | Stat | df | Sig. |
| **Pre-test** | 46 | 4.913 | 0.389 | 2.64 | 0.788 | 0.35 | 0.779 | 0.688 | 0.944 | 46 | 0.027 |
| **Required time on pre-test** | 46 | 264.3 | 15.852 | 107.52 | 0.799 | 0.35 | 1.235 | 0.688 | 0.949 | 46 | 0.041 |
| **Post-test** | 46 | 9.782 | 0.436 | 2.958 | 0.023 | 0.35 | -0.495 | 0.688 | 0.971 | 46 | 0.309 |
| **Required time on post-test** | 46 | 357.28 | 27.74 | 188.14 | 1.134 | 0.35 | 1.8 | 0.688 | 0.926 | 46 | 0.006 |

Table 4. Results of Kruskal-Wallis Test on Threading Task

**Ranks**

| | Group | N | Mean Rank |
|---|---|---|---|
| Pre-test | A (Handouts) | 27 | 22.91 |
| | B (AR video) | 19 | 24.34 |
| | Total | 46 | |
| Required time (pre-test) | A (Handouts) | 27 | 25.24 |
| | B (AR video) | 19 | 21.03 |
| | Total | 46 | |
| Post-test | A (Handouts) | 27 | 15.94 |
| | B (AR video) | 19 | 34.24 |
| | Total | 46 | |
| Required time (post-test) | A (Handouts) | 27 | 31.63 |
| | B (AR video) | 19 | 11.95 |
| | Total | 46 | |

**Test Statistics**

| | Pre-test | Required time (pre-test) | Post- test | Required time (post-test) |
|---|---|---|---|---|
| Chi-Square | 0.129 | 1.100 | 20.960 | 23.984 |
| df | 1 | 1 | 1 | 1 |
| Asymp. Sig. | 0.719 | 0.294 | <0.001 | <0.001 |

Grouping Variable: Group

Table 5. Challenges with Threading Task

| Challenge/Group | A (Handout) | B (AR videos) |
|---|---|---|
| Lack of engagement | 29.6% | 10.5% |
| Lack of interest | 22.2% | 0% |
| Hard to understand | 96.3% | 26.3% |
| Hard to control learning pace | 29.6% | 10.5% |
| Task not difficult | 0% | 26.3% |
| Other | 2.7% | 36.8% |

- Separate questionnaires were provided to Groups A and B
- Participants were allowed to select more than one response

Table 6. Results of Independent Sample T-test

**Group Statistics**

| Question | | Group | N | Mean | Std. Deviation |
|---|---|---|---|---|---|
| 1 | Difficulty | A (handouts) | 27 | 3.85 | 0.86 |
| | | B (AR video) | 19 | 1.89 | 0.46 |
| 2 | Learning Interests | A (handouts) | 27 | 2.56 | 0.80 |
| | | B (AR video) | 19 | 3.68 | 0.67 |
| | Engagement | A (handouts) | 27 | 2.52 | 0.80 |
| | | B (AR video) | 19 | 3.47 | 0.90 |
| | Active Learning | A (handouts) | 27 | 2.48 | 0.75 |
| | | B (AR video) | 19 | 3.79 | 0.85 |
| | Understanding Level | A (handouts) | 27 | 2.85 | 0.86 |
| | | B (AR video) | 19 | 3.68 | 0.82 |
| | Learning Pace | A (handouts) | 27 | 2.89 | 0.93 |
| | | B (AR video) | 19 | 3.89 | 0.66 |
| | Academic outcomes | A (handouts) | 27 | 2.70 | 0.61 |
| | | B (AR video) | 19 | 3.32 | 0.67 |
| | **TOTAL SCORES** | A (handouts) | 27 | 18.89 | 4.54 |
| | | B (AR video) | 19 | 25.47 | 3.66 |
| 3 | Sewing Class | A (handouts) | 27 | 2.52 | 0.75 |
| | | B (AR video) | 19 | 4.11 | 0.57 |
| 4 | More Lessons | A (handouts) | 27 | 2.56 | 0.80 |
| | | B (AR video) | 19 | 3.89 | 0.46 |

**Independent Samples Test**

| Question | | | T-test for Equality of Means | | | | |
|---|---|---|---|---|---|---|---|
| | | | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference |
| 1 | Difficulty | Equal variances not assumed | 9.95 | 41.41 | <0.001 | 1.96 | 0.20 |
| 2 | Learning Interests | Equal variances not assumed | -5.18 | 42.56 | <0.001 | -1.13 | 0.22 |
| | Engagement | Equal variances not assumed | -3.69 | 35.84 | 0.001 | -0.96 | 0.26 |
| | Active Learning | Equal variances not assumed | -5.36 | 35.66 | <0.001 | -1.31 | 0.24 |
| | Understanding Level | Equal variances not assumed | -3.32 | 40.14 | 0.002 | -0.83 | 0.25 |
| | Learning Pace | Equal variances not assumed | -4.29 | 44.00 | <0.001 | -1.01 | 0.23 |

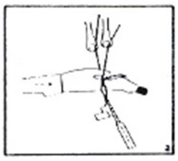
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Academic outcomes | Equal variances not assumed | -3.16 | 36.42 | 0.003 | -0.61 | 0.19 |
| | **TOTAL SCORES** | Equal variances not assumed | -5.43 | 43.12 | <0.001 | -6.58 | 1.21 |
| 3 | Sewing Class | Equal variances not assumed | -8.15 | 43.75 | <0.001 | -1.59 | 0.20 |
| 4 | More Lessons | Equal variances not assumed | -7.18 | 42.55 | <0.001 | -1.34 | 0.19 |

**3 Types of Knitting Needle**

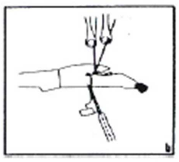
- Compound Needle
- Latch Needle
- Bearded Needle

## 1. The knitting action with Compound Needles

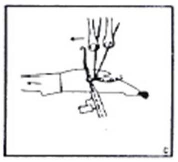
'a' starting position, with the needles at the knockover just after completing the production of the previous course. The sinker moves forward in order to hold the fabric in the throats. At the same time, the guide bars shog sideways to position the guides close to the needles to be wrapped during this cycle. o°



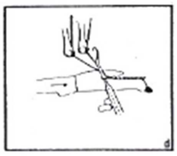
'b' the main parts of the needles start to rise so that the needle hooks open. The underlap shogging movement is now completed. 60°



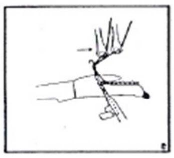
'c' the needles are in the clearing position, with the previous loops lying on the stem of the needle. The closing elements rise slightly but do not protrude out of the grooves of the needles. The sinkers move backwards to relax the hold on the fabric. The guide bars start to swing the guides in between the needles onto the hook side. 120 °



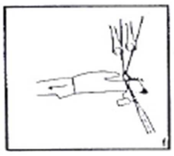
'd' illustrates the guides in the extremity of the swing. The guides of both guide bars are now shogged, usually one needle space, on the hook side of the needles thus creating an overlap. The closing elements continue their upward movement inside the loops, resting on the needle stem. 185 °



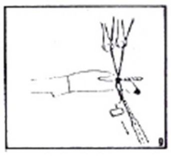
The swing back and completion of overlapping is in position 'e'. Since the guides swing out of the needle line, in a space adjacent to the one entered, the yarn if left wrapped inside the needle hooks. The sinkers move in, to tighten the hold on the fabric, while the main body of the needle starts to descent. 240°

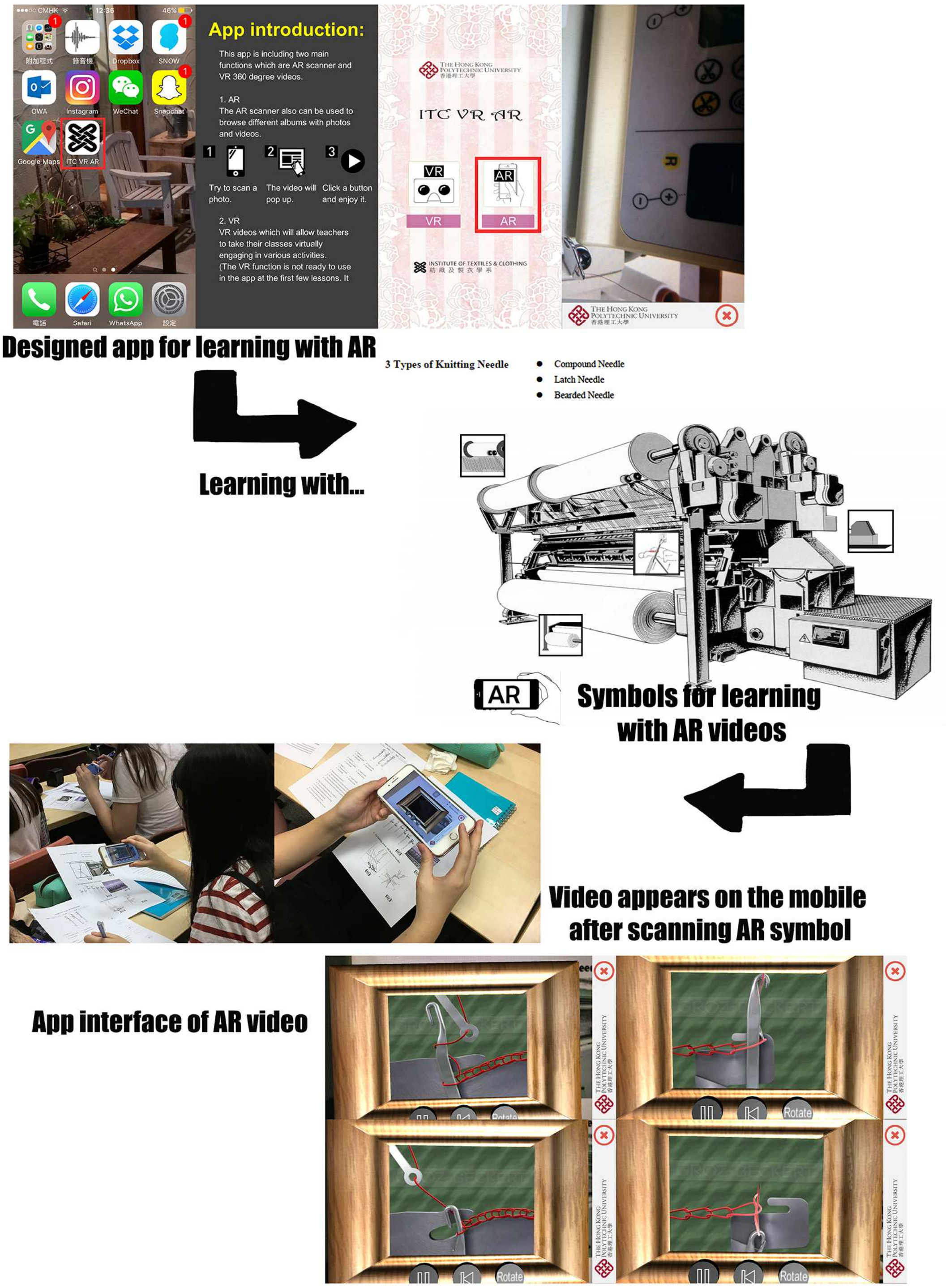


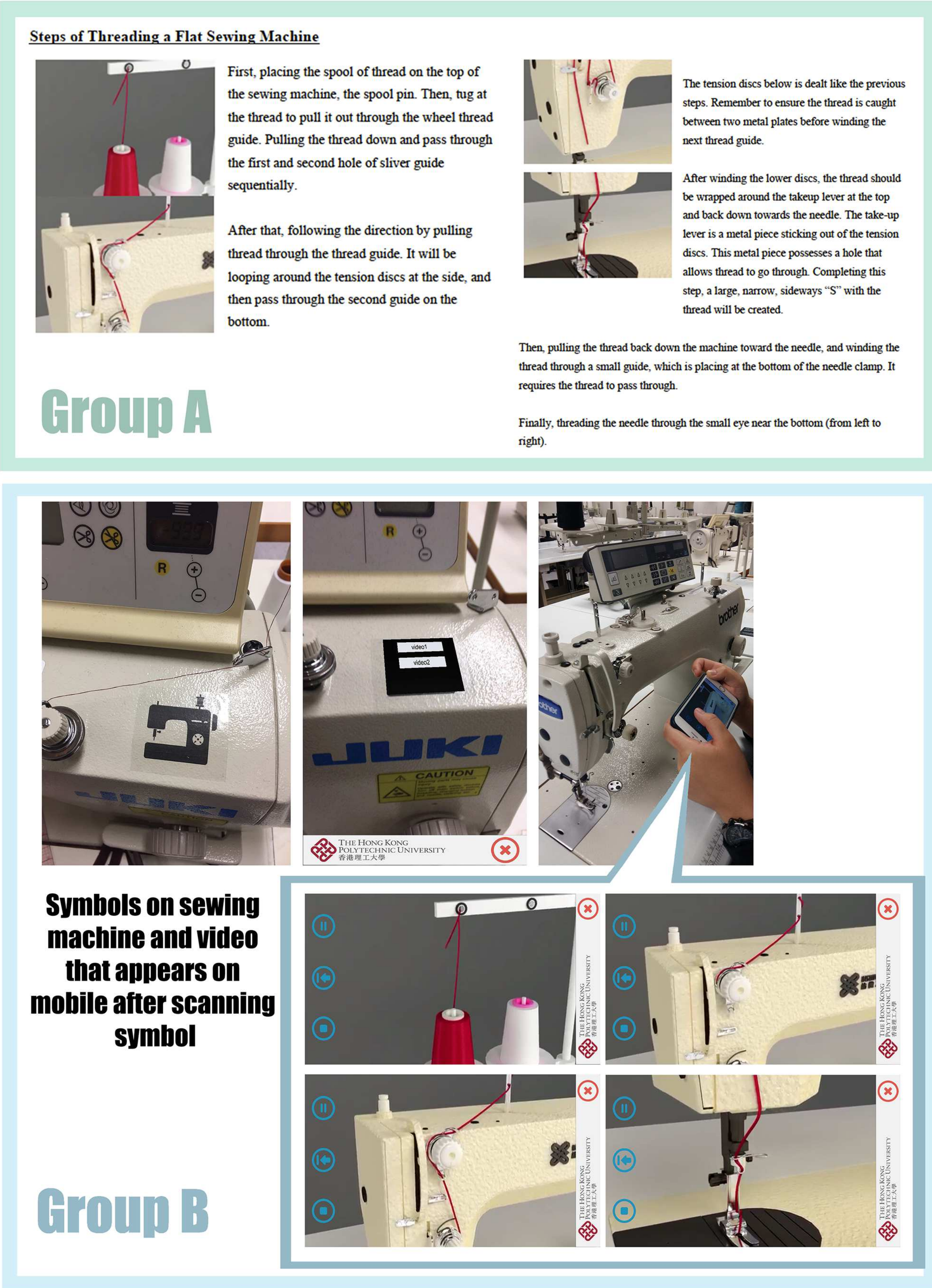
In position 'f', the needles continue to descend. The rate, however, in which the two parts of the needle descend is not equal. The main body of the needle is gaining on the closing element, so that the hook is being closed. The previous loops rest outside the closed hook on the closing element, while the newly wrapped yarn is trapped within the closed hook. The sinkers now move backwards to position their bellies under the hooks. In the same position of the knitting cycle, the guide can start the new underlap shogging movement, which position them in front of the needle to be wrapped during the next knitting cycle. 315°

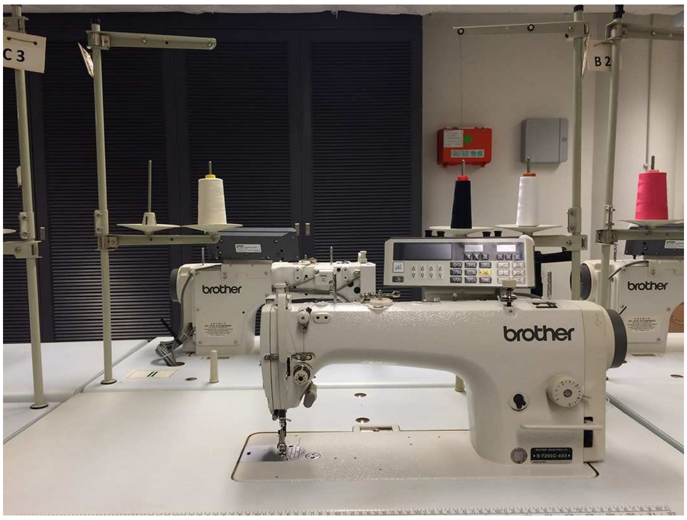


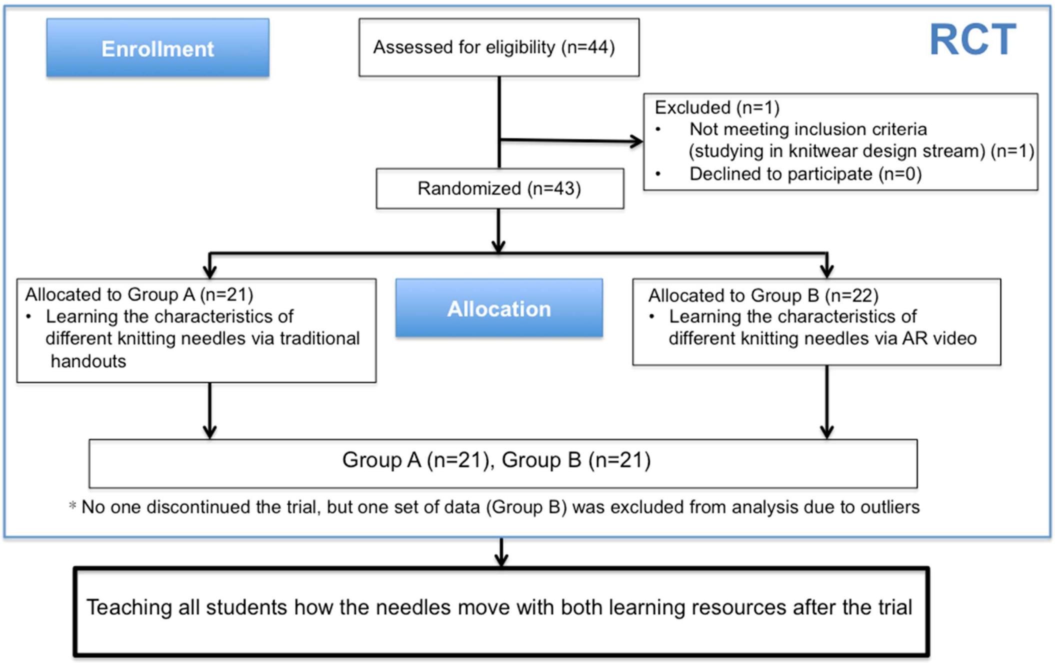
'g' shows the last step of current course production with the needles descending with their closing elements into the knockover position. The guide bars are now in the midst of the underlap shogging movement. 330°

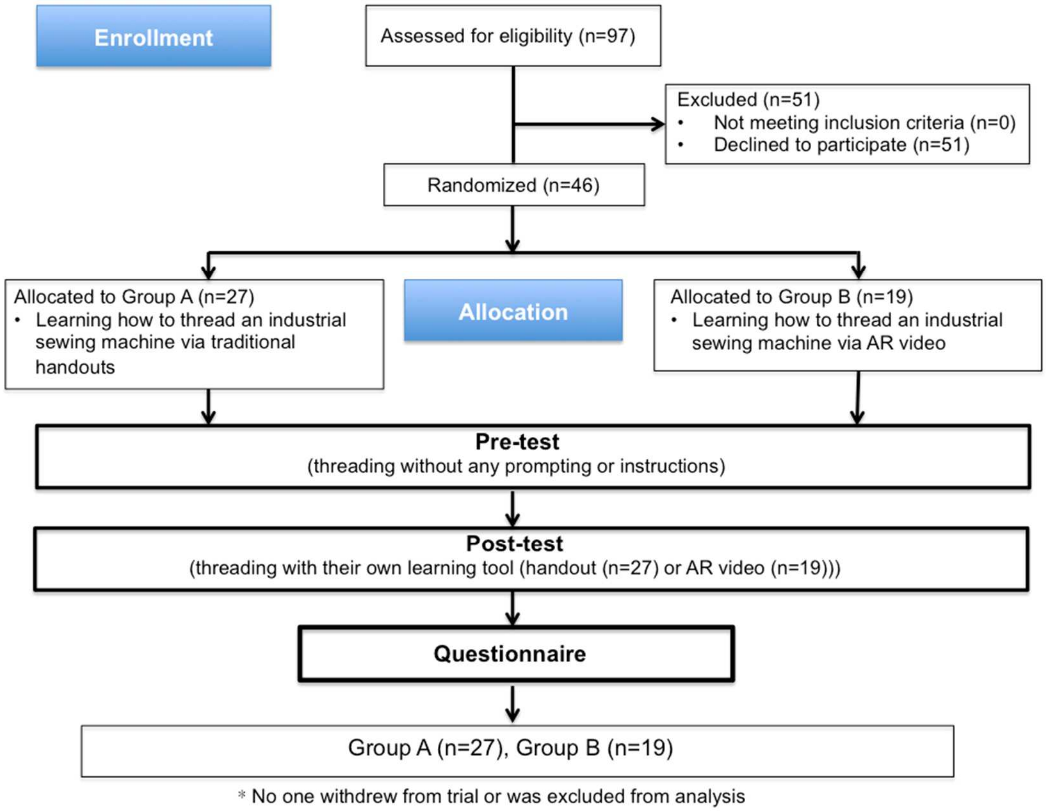



App introduction:
This app is including two main functions which are AR scanner and VR 360 degree videos.
1. AR
The AR scanner also can be used to browse different albums with photos and videos.
Try to scan a photo.
The video will pop up.
Click a button and enjoy it.
2. VR
VR videos which will allow teachers to take their classes virtually engaging in various activities.
(The VR function is not ready to use in the app at the first few lessons. It
ITC VR AR
VR
AR
Designed app for learning with AR
Learning with...
3 Types of Knitting Needle
Compound Needle
Latch Needle
Bearded Needle
Symbols for learning with AR videos
Video appears on the mobile after scanning AR symbol
App interface of AR video
Rotate


Steps of Threading a Flat Sewing Machine
First, placing the spool of thread on the top of the sewing machine, the spool pin. Then, tug at the thread to pull it out through the wheel thread guide. Pulling the thread down and pass through the first and second hole of sliver guide sequentially.
After that, following the direction by pulling thread through the thread guide. It will be looping around the tension discs at the side, and then pass through the second guide on the bottom.
The tension discs below is dealt like the previous steps. Remember to ensure the thread is caught between two metal plates before winding the next thread guide.
After winding the lower discs, the thread should be wrapped around the takeup lever at the top and back down towards the needle. The take-up lever is a metal piece sticking out of the tension discs. This metal piece possesses a hole that allows thread to go through. Completing this step, a large, narrow, sideways "S" with the thread will be created.
Then, pulling the thread back down the machine toward the needle, and winding the thread through a small guide, which is placing at the bottom of the needle clamp. It requires the thread to pass through.
Finally, threading the needle through the small eye near the bottom (from left to right).
Group A
video1
video2
JUKI
CAUTION
THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學
brother
Symbols on sewing machine and video that appears on mobile after scanning symbol
Group B


C 3
B 2
brother
brother
brother


Enrollment
Assessed for eligibility (n=44)
RCT
Excluded (n=1)
• Not meeting inclusion criteria (studying in knitwear design stream) (n=1)
• Declined to participate (n=0)
Randomized (n=43)
Allocated to Group A (n=21)
• Learning the characteristics of different knitting needles via traditional handouts
Allocation
Allocated to Group B (n=22)
• Learning the characteristics of different knitting needles via AR video
Group A (n=21), Group B (n=21)
* No one discontinued the trial, but one set of data (Group B) was excluded from analysis due to outliers
Teaching all students how the needles move with both learning resources after the trial


Enrollment
Assessed for eligibility (n=97)
Excluded (n=51)
• Not meeting inclusion criteria (n=0)
• Declined to participate (n=51)
Randomized (n=46)
Allocated to Group A (n=27)
• Learning how to thread an industrial sewing machine via traditional handouts
Allocation
Allocated to Group B (n=19)
• Learning how to thread an industrial sewing machine via AR video
Pre-test
(threading without any prompting or instructions)
Post-test
(threading with their own learning tool (handout (n=27) or AR video (n=19)))
Questionnaire
Group A (n=27), Group B (n=19)
* No one withdrew from trial or was excluded from analysis

## Highlights:

- Difficult to get thorough understanding of 3D concepts via 2D medium like handouts
- AR can offer better delivery of basic knowledge, even for issues in high complexity
- Less effort and time is required to grasp the information in learning
- AR videos brings better learning experience and higher learning efficiency
- AR videos are convenient for students to review the information at home or anywhere