The effect of mobile phone screen size on video based learning

Nipan Maniar
University of Portsmouth, Portsmouth, United Kingdom
Email: nipan.maniar@port.ac.uk

Emily Bennett, Steve Hand and George Allan
University of Portsmouth, Portsmouth, United Kingdom
Email: {emily.bennett, steve.hand, george.allan}@port.ac.uk

Abstract - **This paper investigates the effect of mobile phone screen size (1.65 inches - 2.75 inches) on video based learning. It first examines the educational benefits of video as a teaching medium and surveys the usage and issues related with video based learning. After which, it investigates the value of video for mobile learning. It reports on an empirical investigation that studied the effect that screen-size has on video-based m-learning. Findings indicate that regardless of the screen size of a mobile phone, students tended to have a positive overall opinion of m-learning and watching the video significantly increased their knowledge of the subject area. However, if an m-learning environment that relies heavily on video based material is displayed on a mobile device with a small screen, such as an average mobile phone, then the effectiveness of the learning experience may be inhibited. Paper identifies the underlying reasons why mobile phone screen size may be a problem for video based m-learning. The implications of this finding are discussed.**

Index Terms – **video based learning, Video-based learning, screen size, mobile learning, mobile devices, type of media, delivery media**

I. INTRDUCTION

"The widespread use of mobile phones [and other mobile devices] enables a long awaited dream: learning at any place, at any time." [1, p.307]. This highly ubiquitous form of learning, termed mobile or *m-learning*, may benefit university students in particular [2, 3].

The development of digital media technology in the twenty first century has led to a rapid development of moving images as an educational medium. Higher education is experiencing a paradigm shift in how video-based learning resources are delivered. Internet technologies have enabled the delivery of interactive video-based learning while technologies like handhelds have enabled the flexibility of learning while on the go.

However, the success of m-learning is also limited to the hardware and software constraints of mobile devices:

- lack of data input capability
- low storage
- low bandwidth
- limited processor speed
- short battery life
- lack of standardisation
- limited interoperability
- compatibility issues
- low screen resolution
- small screen size

Indeed, with advances in the technology, most of the above stated constraints may be solved, but what about the screen size?

Screen size of a typical mobile phone is approximately 1.65 inches diagonally comparing to the screen size of a PDA (2.75 inches), laptop (12 inches), desktop computer (17 inches), television (25 inches), projectors (100 inches) and theatre screens (50 feet).

Two underlying reasons why screen size is a problem are human visual perception and attention [4]. Human visual perception limits the level of small detail they can see which also affects their attention span. To overcome this problem, user can zoom in to make the video bigger. However, the user then has to keep all the visual information in their head and build up an impression of the whole picture. Their ability to do this will be limited by the capabilities of the human attention span. What if a video tailor-made to suit television screen has to be delivered on a mobile phone?

A study carried out by Knoche et al. (2006) suggested that screen size affects the viewer's quality of experience [5] i.e. visual perception and attention, when delivering television programmes on a mobile phone.

The study also suggested that mobile TV programmes such as football and soaps should be tailor-made to the screen environment with extensive use of close-ups to raise viewers' quality of experience. However, there is little evidence on the effect that mobile phone screen size has for delivering video programmes aimed for teaching and learning purposes.

There have been suggestions that screen size is critical to the success of effective learning [7, 8]. This is also supported by empirical work that demonstrated screen size can affect the general usability of a mobile device, for example [9, 10, 11]. However no work has specifically investigated the effect that mobile device screen sizes have on video-based learning.

To tailor-make content for mobile phones may be a solution, but there are no such algorithms or guidelines to convert existing television programmes into mobile viewing format. Mobile phone operators are investing considerably in the delivery and design of mobile video content [6], but there is no such investment made by educational institutions for recycling educational videos designed for mobile learning.

The aim of this project is to identify the need and issues related to recycling video-based learning resources for mobile learning television.

This paper is the first step towards investigating the effect that screen size has on video-based m-learning by addressing two research questions stated below. Section II investigates the usage of video within education. In Section III, a pilot study is carried out to confirm educational values of video-based learning. An empirical investigation is carried out in Section IV to investigate the effect that screen size has on video-based learning, followed by the conclusion in Section V and future work in Section VI.

The overall goal that this paper is to investigate whether screen size constrains video-based mobile learning.

To achieve this, the following research questions were addressed:

Research Question 1: *Does a learner's subjective opinion of learning via video differ based on the screen size?*

Research Question 2: *Does a larger screen size result in a significantly higher amount of information learnt via video, compared with a smaller screen size?*

II. USAGE OF VIDEO WITHIN EDUCATION

Educational theories suggest that video *may* be inherently more effective than other media, such as text or static graphics. For example:

The Media Debate – Different types of media

The Media Debate asks whether one type of media naturally facilitates more effective learning than another [12, 13, 14]. It centers upon the opposing viewpoints of Clark and Kozma. Clark [15] argued that the type of media does not affect learning, instead learning is affected by the way in which the media is used. This viewpoint suggests that video-based learning material will not necessarily be more effective because it should be possible to design a text or audio based application in such a way that it facilitates an equivalent level of learning.

In contrast to Clark, Kozma [16] argued that different types of media *"possess particular characteristics that make them both more and less suitable for the accomplishment of certain kinds of learning tasks"*. It is predicted by the 'Cone of Experience' that people learn more when using a type of media that provides concrete, as opposed to abstract, information. This suggests that video-based learning material may be intrinsically more effective in some areas. The findings of empirical work that studied e-learning applications displayed on a PC monitor also suggest that learning from a video can be more effective than learning from text or audio [17, 18].

Dual-code theory – Recall and Retention

Paivio [19, 20] argues that information that is provided by both auditory and visual channels should increase recall and retention. Studies by Mayer & Anderson [21] have also shown that visual information helps to process and remember verbal information and vice versa.

Cue-summation theory

Cue-summation theory claims that learning performance in the combined audio and pictures was better than in the combined audio and text, if the numbers of available cues or stimuli are increased [22].

Criticism of relying on theory

Relying upon such theories to justify the usage of video is *too simplistic*.

The effects of video on learning are surprisingly inconsistent. Sometimes video is an effective teaching medium, sometimes it isn't an effective teaching medium. It is essential to pin-point "why, when and how can video be an effective teaching medium?" to address the research questions. This is because it is important to identify appropriate video-based learning resources, which can be delivered on mobile devices.

A. Why use video-based learning resources?

When used appropriately, video can be a powerful teaching medium [23]. A survey on the use of video as a teaching resource drawing upon the evidence gathered from papers published between 1985 to 2006 [36, 37, 38, 39, 40] identifies the following benefits:

- Video can help students visualise how something works.
- Video can show information and detail that is difficult to fully explain using text or static images.
- Video can grab students' attention, thus motivating them and engaging them with the subject.
- Video can provide concrete real life examples, thus demonstrating the relevance of the subject to the real world.
- Video can simulate discussion.
- Video can cater for different learning styles, specifically students who are 'visual learners'.

B. When is video an effective teaching medium?

Reviewing the previously reported uses of video reveals two areas where it is especially effective:-

Firstly to grab a student's **attention** and **motivate** them to learn [24, 25, 26, 27].

For example, showing a television news clip at the start of a lesson to simulate discussion and demonstrate the relevance of the topic to the students' own lives. Thus, the primary aim is *not* to use video to teach the material itself. Or as Oishi (2007, p. 32) puts it, *"These videos do not provide content, but they can stimulate the interest that makes the curriculum relevant or "jumpstart" lessons"*. A video-based learning resource with running time of 30 seconds up to 10 minutes (Tab. 1) can stimulate the interest that makes the curriculum relevant or "jumpstart" lessons [24].

TABLE 1
SHORT VIDEOS – LEARNING OUTCOMES AND RUNNING TIME

Learning Outcomes	Approximate Running Time (minimum - maximum)
Basic ideas i.e mathematics, industrial economics, sports sciences	30 seconds to 7 minutes
Industrial training i.e skills to Learn, Earn, and Innovate	4 minutes to 6 minutes
Language studies i.e Spanish listening comparison and language learning	2 minutes to 5 minutes
Student support	1 minute to 4 minutes
Learning Theories	10 minutes
Stimulations i.e Animation of Molecules, nanotechnology, DNA, molecular motors	33 seconds to 1 minute
Filed studies i.e Earth Sciences	35 seconds to 2 minutes
Laboratory practices i.e Medicine, Sports Sciences	30 seconds to 8 minutes
Course introductions i.e MBA	2 minutes
Round table discussions i.e where experts in a specific field discuss a narrow, yet interesting and cutting edge, issue.	10 minutes
Lecture introductions	2 minutes
Graduates: Student case studies	1 minute to 3 minutes

A video-based learning resource engage students in conversation and debate on the subject matter [26] and in some case video can highlight theoretical concepts when teaching specific subjects [27].

Secondly, to demonstrate a highly **realistic depiction of reality** [30, 29, 30, 31, 32].

This could be when it is necessary to expose students to things they would not otherwise have the opportunity to see (e.g. medical procedures), or when it is necessary to 'humanise' a topic (e.g. showing dramatisations or films when teaching about the war). This is exemplified by DeLeng, Dolmans & van de Wiel [33] who used video case studies to improve medical education.

They explained *"The video cases enabled them [the students] to create realistic mental pictures of disorders, provided integrated pictures of patients as people, which challenged them to elaborate the cases seriously and were more memorable than text-based cases."*(p. 181).

A highly realistic representation using video adds more value comparing to text-based or audio based information delivered in order to examine problem-based learning in specific subject areas like medicine, clinical procedures and laboratory safety.

C. How to design and deliver video-based learning resources?

A survey of literature carried out in section II C identified issues related to video such as:
Subject Area - How to choose the right subject, which can be effectively taught via video
Design - How to design video-based resources, which cater for different learning styles, grab students attention and enhance overall learning experience.
Running time – How to decide upon the length of video. i.e short videos versus long videos, which one could bemore effective?
Audience - How to measure effectiveness of video based learning?
Delivery: Which is the best way to deliver a video? i.e. e-learning, m-learning, location based learning.

To create video-based learning resources, it is essential to answer above mentioned issues. The following sources provide guidelines on *how* to design video-based learning resources:-

- Karppinen [34], Hakkarainen & Saarelainen [35] provides guidelines on how to design video-based resources that facilitate meaningful learning.
- Schwartz & Hartman [36] provide guidelines on how to design educational video-based resources.
- Mayer [14] & Mayer Moreno [21] provide general guidelines for creating multimedia computer-based resources.
- Asensio & Youngs' [38] three 'I's Framework (Tab. 2) highlights the specific benefits of delivering video via internet from a pedagogic perspective.

TABLE 2
ASENSIO AND YOUNGS' (2002)
THREE I'S FRAMEWORK

Value	Technology	Locus of control	Pedagogic perspective
Image	Film, television and video tapes	Teacher	Transmission model
Image + Inter-activity	Videodisks, digital desktop video, multimedia, DVD	Student	Constructivism
Image + Inter-activity + Integr a-tion	Web and streaming media	Distribute -d	Collaboration, contextualisation and community.

The above findings could form the basis for a larger study to establish whether the findings from this survey (Tab. 2) may be typical of the picture in higher education generally. However, as far as the delivery of video is concerned, it suggests that the delivery of video via internet is becoming ubiquitous due to the advantage of delivering video to a wider audience in a controlled, interactive and integrated environment.

No such design frameworks exist for designing video-based learning resources for small screen sized devices such as mobile phones. There are also no such surveys that highlight the specific benefits of delivering video on mobile devices. It is therefore essential to a carry out a pilot study to confirm the value of video for m-learning.

III. PILOT STUDY: VALUE OF VIDEO FOR MOBILE LEARNING

As discussed in section II, mobile learning may be especially useful for providing 'snippets' of information that train people to perform practical skills. The pilot study therefore focused on this aspect of learning and investigated the effect that type of media (i.e. text-based, audio-based or video-based learning resources) used by an m-learning application has on peoples' ability to learn specific practical skills.

An experiment was conducted that had the following three conditions:-

- Video-based m-learning application.
- Audio-based m-learning application.
- Text-based m-learning application.

A within-participants design was used for research question 3, thus every participant completed all three conditions.

In all three conditions, the m-learning application was presented on a T-Mobile PDA which had a screen size of 2.75 inches diagonal (Fig. 1) and a video playback resolution of 320x240 pixels. A total of 15 participants, who were all students, took part.

FIGURE 1
T-MOBILE PDA

The application aimed to teach students how to make a piece of origami (folded paper shape), specially designed to be delivered on a Compaq iPAQ H3800 PDA. To minimize the possibility of a learning effect occurring, the order in which students completed the three conditions was randomized and they made a different origami shape in each condition.

However, all three shapes required 5 paper folds, and hence they were equally complex. In each condition, the student first watched/listened to/read the instructions presented by the application. They were then given a piece of paper and asked to recreate the piece of origami. When completing this task, if they could not remember the next step, they were allowed to watch/listen to/read the instructions again.

Students' actual performance was assessed using several measures; whether they were successful at creating the piece of origami, the time to complete the task (not including the time to watch/listen to/read the instructions) and the number of times they watched/listened/read the instructions again. The students' perception of which delivery media they believed to be the most effective was also recorded.

Overall the completion rate was very high. When using the video-based and the text-based instructions, 100% of the students successfully completed the task. When using the audio-based instructions, the completion rate was only slightly lower at 96%. i.e *A video-based instruction facilitate equally effective learning compared to text-based or audio-based instruction delivered on a mobile device with a specific screen size.*

However, differences between the conditions emerge when examining the other measures.

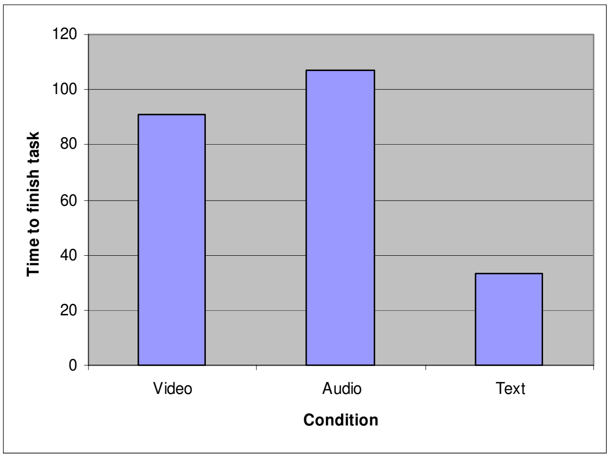

FIGURE 2
TIME TAKEN TO COMPLETE THE TASKS

The time it took students to complete the task (Fig. 2) was analyzed using a one-way within-participants ANOVA. A significant main effect was found ($F(2, 28)= 24.59$, $p<0.001$), thus pair wise comparisons were conducted to determine which type of delivery media was responsible.

The task completion time when using text-based instructions was significantly lower than the task completion time when using either audio-based instructions ($p<0.001$) or video-based instructions ($p<0.001$).

However, there was no significant difference between the task completion times when using the video-based instructions and when using the audio-based instructions ($p=0.28$).

The task completion time (Fig. 2) must be considered in conjunction with the number of times that the students referred back to the instructions (Fig. 3). When using the audio instructions, 4/15 students referred back to the instructions twice and 11/15 students referred back to them once.

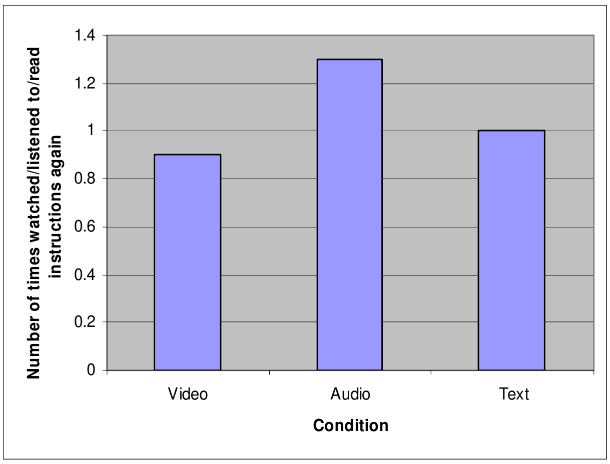

FIGURE 3
NUMBER OF TIME STUDENTS REFERED BACK TO THE INSTRUCTIONS

When using the text instructions, all of the students referred back to them once. When using the video instructions, 13/15 referred back to the instructions once and 2/15 students did not refer back to them.

Content analysis techniques were used to categorize the students' subjective perceptions. This revealed that 5/15 students said they found the audio-based instructions the most difficult to learn from, which is in agreement with the objective (i.e. actual) performance measures discussed above.

However, this also revealed that 11/15 students said that they thought the video-based instructions were the easiest to learn from.

Findings of this study are not in agreement with the 'Cone of Experience' that predicts concrete media, such as video, facilitates more effective learning than abstract media, such as text (Fig. 4). For the effect that 2.75 inches screen size has on delivery media it was found that although the text-based application was the most effective, students thought the video-based application was easier to learn from.

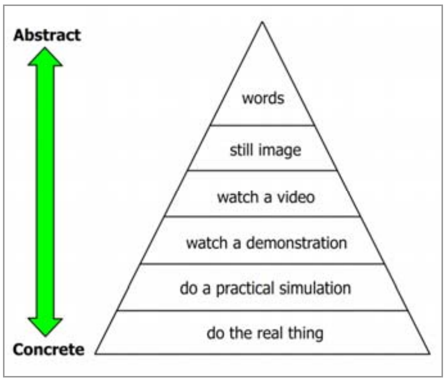

FIGURE 4
CONE OF EXPERIENCE [6, 63]

Despite the text-based instructions facilitating more effective learning on 2.75 inches screen, it may not facilitate equally effective learning on 1.65 inches screen, such as an average mobile telephone. The majority of students believed that the video-based application was the easiest to learn from.

Overall, video-based application was equally effective and preferred delivery medium in this study. An empirical investigation is therefore required to investigate the effect that different screen sizes has on video-based m-learning.

VI. EMPIRICAL INVESTIGATION

Screen size may be especially limiting for m-learning environments that rely heavily on detailed video clips. Therefore, to explore the effectiveness of using a video-based m-learning environment to teach university students, it is necessary to empirically investigate the effect that screen size has on learning. To answer the research questions, three pilot experiments where carried out.

A between-participants design was used for research question 1 and 2. Thus, each participant was randomly allocated to one of three conditions (Fig. 5); *'small screen'* (Nokia 6600 mobile telephone, screen size = 1.65 inches diagonal, video playback resolution = 128 x 96 pixels), *'medium screen'* (Motorola E1000 mobile telephone, screen size = 2.28 inches diagonal, video playback resolution = 320 x 240 pixels) and *'large screen'* (Compaq iPAQ H3800 PDA, screen size = 3.78 inches diagonal, video playback resolution = 320 x 240 pixels). These conditions were based on the three categories of mobile device screen size proposed by Weiss [40]. A total of 45 participants, who were all students, took part. Their average age was 24, which ranged from 18 to 58 years old.

FIGURE 5
MOBILE DEVICE SCREEN SIZE

Experiments were carried out in a busy café, similar to where an m-learning application may typically be used. Participants were not allowed to communicate during the study.

A. Does learner subjective opinion of learning via video differ based on the screen size?

To explore the effect that screen size has on learner' subjective opinion of m-learning, each participant watched an educational 5 minute video (about industrial economics) on their allocated device. The video clip was of equal quality (both audio and visual) and there was equivalent resolution on all three devices.

After watching the video, students completed a questionnaire. The questionnaire contained 9 questions, to which they responded to on a 5 point

Likert scale (1 = Strongly Disagree, 2 = Disagree, 3 = Uncertain, 4 = Agree, 5 = Strongly Agree).

The results were analyzed using a one-way between participants MANOVA. A MANOVA essentially conducts multiple ANOVA tests simultaneously in a single analysis whilst taking into account the number of tests, and hence minimizes the probability of a Type I error occurring [13].

TABLE 3
SUBJECTIVE OPINION RESULTS

Question	Large screen	Medium screen	Small screen
Q1. This form of communication could increase access to learning.	3.80	4.20	3.67
Q2. This form of communication could increase the quality of my learning.	3.40	3.40	3.13
Q3. I wouldn't mind carrying the mobile device	3.70	3.67	3.60
Q4. Watching the video on the mobile device was fun.	3.70	3.73	3.27
Q5. I would recommend 'mobile learning'.	3.60	3.73	3.30
Q6. The screen was bright enough.	4.80	4.73	4.26
Q7. The screen size was large enough.	4.40	3.93	3.00
Q8. The overall picture quality was good enough.	4.20	3.73	2.40
Q9. The content of the video was clearly visible.	4.00	3.66	2.60

Questions 1 to 5 (Tab. 3) focused on the students' overall opinion of mobile learning. No significant main effect was found for any of these questions; question 1 ($F(1,43)= 2.62$, $p=0.09$), question 2 ($F(1,43)= 0.55$, $p=0.58$), question 3 ($F(1,43)=0.03$, $p=0.97$), question 4 ($F(1,43)=1.59$, $p=0.22$) and question 5 ($F(1,43)=0.94$, $p=0.40$). This suggests that increasing the screen size (up to 3.78 inches diagonal) does not significantly affect a learner's subjective opinion of video-based m-learning. Interestingly, for questions 1 to 5, in all three conditions the students' responses were on average above 3 (Tab. 3). This indicates a tendency to respond favourably to the questions, and hence this indicates that overall students had a positive attitude towards m-learning.

Questions 6 to 9 focused on the students' opinion of the screen quality. No significant main effect was found for question 6 ($F(1,43)=2.63$, $p=0.08$). However, significant main effects were found for question 7 ($F(1,43)=9.27$, $p<0.001$), question 8 ($F(1,43)=20.41$, $p<0.001$), and question 9 ($F(1,43)=10.89$, $p<0.001$). Thus, to determine which device was responsible, Tukey HSD post-hoc tests were conducted. The pattern was identical for all three questions. The 'large screen' device was rated significantly higher than the 'small screen' device (question 7 - $p<0.001$, question 8 - $p<0.001$, question 9 - $p<0.001$). Similarly, the 'medium screen' device was rated significantly higher than the 'small screen' device (question 7 - $p<0.05$, question 8 - $p<0.001$, question 9 - $p<0.001$). However, the ratings of the 'large screen' and the 'medium screen' devices were not significantly different from one another (question 7 – $p=0.35$, question 8 – $p=0.26$, question 9 – $p=0.54$). Furthermore, in the 'large screen' and the 'medium screen' conditions, the students' responses tended to be positive (Tab. 3). However, the students' responses in the 'small screen' condition were not entirely positive. Specifically, students did not find the overall quality or visibility of the screen to be sufficient (questions 8 and 9). Taken together, this indicates that reducing the screen size of an m-learning environment can have a significant detrimental effect on a person's overall subjective opinion of its screen quality. If the screen size is small (around 1.65 inches diagonal), then people may not regard the device to be sufficient for learning, as a result it may affect their learning.

Physical screen size of a mobile device does influence learning i.e *learner subjective opinion of learning via video differs based on the screen size.*

B. Does larger screen size result in a significantly higher amount of information learnt via video, compared to a smaller screen size?

In contrast to section IV A, this experiment investigated the effect that screen size had on objective learning performance.

Each student watched another 5 minute video about "how to measure blood pressure" (Fig. 6) on their allocated device. It was a realistic representation of a medical procedure (section II). Again, the video clip was of equal quality (both audio and visual) and equivalent resolution on all three devices.

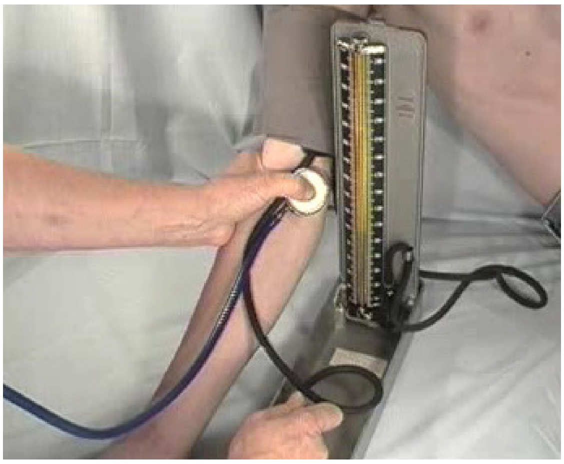

FIGURE 6
VIDEO-BASED LEARNING RESROUCE – "HOW TO MEASURE BLOOD PRESSURE"

Before watching the video, students were asked 4 questions to assess their prior knowledge of this area. Then after watching the video, they were asked the same 4 questions again to assess what they had learnt. Questions were related to visual clues [21, 22].

Conducting within-participants t-tests to compare between the 'before' and 'after' results (Tab. 5) found a significant difference for all three devices; 'small screen' (t(15)=-3.66, p<0.01), 'medium screen' (t(15)=-9.16, p<0.001) and 'large screen' (t(15)=-7.30, p<0.001). This shows that all three devices had a significant impact on learning.

TABLE 4
OBJECTIVE PERFORMANCE RESULTS
(AVERAGE NUMBER OF QUESTIONS ANSWERED CORRECTLY)

	Small screen	**Medium Screen**	**Large Screen**
Before	0.53	0.20	0.27
After	1.40	2.20	2.13
Amount learnt	0.87	2.00	1.86

However, this does not address the key issue; whether screen size affects the *amount* of information learnt. This can only be determined by conducting a one-way ANOVA on the amount learnt in the three conditions (i.e. the difference between the 'before' and 'after' results)(Tab. 4). A significant main effect was found (F(1,43)= 6.8, p<0.01). Therefore, Tukey HSD tests were conducted to determine which device was responsible. It was found that students using the 'large screen' device learnt significantly more than students using the 'small screen' device (p<0.05). Similarly, students using the 'medium screen' device learnt significantly more than students using the 'small screen' device (p<0.01). However, there was no significant difference in the amount learnt between the students using the 'large screen' device and those using the 'medium screen' device (p=0.91). Taken together, this suggests that screen sizes of approximately 2.28 inches (diagonal) and above can result in a significantly higher amount of information learnt, compared to screen sizes of around 1.65 inches (diagonal) and below.

Physical screen size of a mobile device does influence learning i.e *larger screen size result in a significantly higher amount of information learnt via video, compared to a smaller screen size.*

V. DISCUSSION AND CONCLUSION

Findings are in agreement with Clark [15]. Learning is affected by the way in which the media is used; in this case learning delivered on small screen sized devices.

Regardless of the screen size of a mobile device, students tended to have a positive overall opinion of m-learning (Section IV A – questions 1 to 5) and watching the video significantly increased their knowledge of the subject area. However, some important differences were noted.

Compared to students who used 3.78 and 2.28 inches screen, students who used 1.65 inches device had a significantly lower subjective opinion of the screen quality (Section IV A – questions 7 to 9) and learnt a significantly lower amount (Section IV B). This may be because people tend to pay more attention when viewing a larger screen display [41]. However, the results of the students who used the 3.78 and 2.28 inches screen were not significantly different from each other.

Taken together, these findings indicate that if an m-learning environment that relies heavily on video-based material is displayed on a device with a 1.65 inches screen, such as an average mobile telephone, then the effectiveness of the learning experience may be inhibited.

The importance of this finding is clear when one considers that a mobile telephone is the one handheld device that the majority of students own and relatively fewer students own large-screen handheld devices, such as a PDA. Furthermore, a recent user study found that there are practical reasons, such as portability, why students may actually prefer to use a small device for m-learning [42].

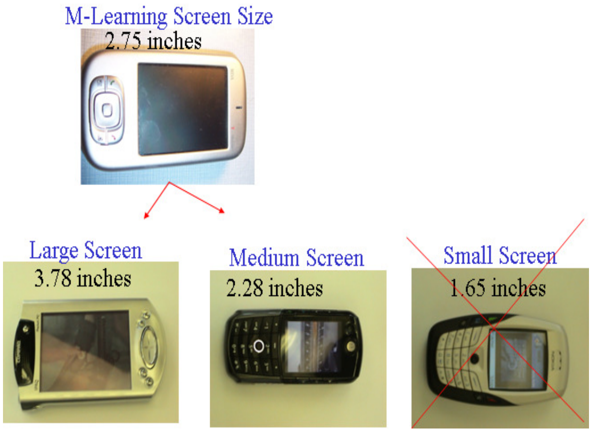

FIGURE 7
M-LEARNING SCREEN SIZE

Given that the acceptance of m-learning ultimately depends on whether people believe it to be useful, it can be argued that the effort to develop video-based applications is justifiable.

However, there are two reasons why it is unwise to draw this conclusion.

Despite the text-based instructions facilitating more effective learning on 2.75 inches screen, the majority of participants believed that the video-based application was the easiest to learn from. This suggests a disassociation between the perceived and the actual effectiveness of m-learning applications. This disassociation is in agreement with previous work that studied e-learning applications displayed on standard PC and monitor based systems [17,18]. Given that a learner's decision to use a m-learning application, or in fact any learning resource, is based on whether they perceive it to be useful, this suggests that purely text-based applications may obstruct the acceptance of m-learning.

VI. FUTURE WORK

Whilst the study reported in this paper found an interesting and coherent pattern of results, further work is needed to explore if the findings are generalised. This can be done by investigating whether the same pattern occurs if a more complex or longer task is used.

Compared to students who used 3.78 and 2.28 inches screen with 320 x 240 pixels video playback resolution, students who used 1.65 inches device with 128 x 96 pixels video playback resolution had a significantly lower subjective opinion of the screen quality and learnt a significantly lower amount, while 3.78 and 2.28 inches screen with 320 x 240 pixels video playback resolution were not significantly different from each other. Hence further investigation is essential to identify the effect that screen resolution has on the physical screen size of a mobile device for video-based learning.

Additionally, it is necessary to consider how the characteristics of the learner, such as their preferred learning style (e.g. visual or verbal)[2] or cognitive traits (e.g. dyslexia), may influence the pattern of results. It is therefore important to consider how this issue could be avoided.

One option is to use animation instead of video clips. As Ferwerda notes, a 'functional' representation, such as a line drawing or animation, provide a more direct way of conveying the fundamental aspects of an object or process, in comparison to using a photograph or a video [43]. Indeed, previous work has shown that students can learn effectively from animations presented in an m-learning environment [44].

An alternative option may be to employ 'perceptually adaptive' graphics techniques. For example, a video could be adapted based on a model of the characteristics of objects that humans have a natural tendency to focus on, such as peoples' faces [4].

Therefore in order to investigate the suitability of mobile phones for video based learning, more research in the areas discussed in this paper needs to be carried out.

VII. ACKNOWLEDGMENT

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Nipan J Maniar was born in Gujarat, INDIA 1977. He graduated from Gujarat University (BSc Mathematics) in 1998 and received his MSc (Multimedia Information Systems) from University of Portsmouth in 2002 followed by PgC in Learning and Teaching in 2005. He is currently a part-time Principle Lecturer in eLearning and part-time Senior Lecturer in streaming media technologies at University of Portsmouth. As the inventor of C-Shock, a gaming concept and the co-founder of www.sourcelearn.com a pay per view educational video website his research interests include the development of mobile games to overcome culture shocks and developing technical and pedagogical approaches to implement Digital Media Management and Delivery System. He has published over 20 peer reviewed papers and his projects have contributed towards UK Research Assessment Exercise. Nipan was awarded the Learning and Teaching Fellowship award by University of Portsmouth in 2007 based on his excellence in teaching and learning.

Dr Steve Hand is Head of Department in the Dept. of Creative Technologies, University of Portsmouth. He holds a BSc in Zoology, PhD in Applied Entomology and a PgD (Distinction) in Information Systems. His main research interests are on the application of new and emerging technologies in areas including healthcare, law and education. Current research is centred on virtual reality for healthcare training & rehabilitation and on the development of eLearning systems. Steve is the founder of the Dept. of Creative Technologies which was established to focus on cross-disciplinary, innovative teaching and research on the applications of creative technologies. He has previously been Head of Department in the Dept. of Information Systems, University of Portsmouth.

Dr George Allan obtained his BSc in 1967, MSc in IT in 1980, MA(Ed) in 1997 and PhD in Information Systems Configuration Management in 2003. He studied Grounded Theory under Dr Barney Glaser and has led research seminars on Grounded Theory at the University of Portsmouth, University Putra Malaysia, Trinity College Dublin, Lincoln University, Tampa University USA, George Washington University USA, and Auckland University New Zealand. His current research focus is on the ontological and epistemic grounds of IT/IS Project Management and he has lectured on this topic at The University of the Witwatersrand, Johannesburg South Africa, Syracuse University USA, Jilin University in China and UNITEC New Zealand. This led him to develop and introduce a range of student-centred methods in his teaching that have generated a lot of interest nationally in the UK and internationally, as evidenced by his publication record, his success in securing funding and invitations to give presentations and lead work -shops. He was awarded The Teaching and Learning Fellowship by the University of Portsmouth in 2006-2007 for his engagement of students through his innovative approach to teaching and learning.

Dr Emily Bennett is currently an Online Course developer for the University of Portsmouth. Recently, she has also worked as an Educational Technologist and a Research Associate. Emily obtained her degree in Computer Science in 2002 and her PhD in Human Computer Interaction (specialising in Augmented Reality) in 2006. Her research interests are in virtual reality, augmented reality, mobile computing and e-learning.