# EDUCATIONAL MULTIMEDIA PROFILING RECOMMENDATIONS FOR DEVICE-AWARE ADAPTIVE MOBILE LEARNING

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**ABSTRACT**

Mobile learning is seeing a fast adoption with the increasing availability and affordability of mobile devices such as smartphones and tablets. As the creation and consumption of educational multimedia content on mobile devices is also increasing fast, educators and mobile learning providers are faced with the challenge to adapt multimedia type educational content in order to suit the variety of devices that are used by mobile learners. This paper proposes a solution for multimedia profiling that groups mobile devices in classes based on their resolution in order to allow for the creation of a reduced number of multimedia clip versions. This solution would support educational multimedia visualization on a large set of mobile devices. The paper also makes recommendations for each multimedia profile in terms of audio and video encoding settings.

**KEYWORDS**

Mobile learning, multimedia profiles, educational multimedia clips.

## 1. INTRODUCTION

Mobile devices, in particular smartphones and tablets are increasingly used for conducting a multitude of online and offline activities, among which mobile learning. According to a recent market research report the global smartphone sales have crossed the 1 billion mark in 2013, overtaking feature phone sales in the process (CCS Insight, 2013). Moreover, almost 220 million tablets were sold worldwide in 2013, being estimated to overtake combined desktop and laptop PC sales by 2015 (Statista, 2014). At the same time, there has been a fast growth in multimedia content creation and consumption, with mobile video being estimated to increase 14-fold between 2013 and 2018 (Cisco, 2014).

Mobile and multimedia technologies have also changed radically the online learning landscape. The advances in mobile technologies such as improved network speeds, improved processing power, improved graphics and higher-resolution displays enable enhanced, more complex mobile learning experiences. As mobile devices are gradually becoming the primarily means for accessing the Internet (Meeker, 2013), learners are gradually shifting from traditional e-learning to mobile learning (Ambient Insight, 2013).

Thanks to the latest technologies, mobile learners can easily access educational multimedia content anywhere and anytime. Multimedia type educational content has the advantage of providing a rich display of information and can be used to further enforce the understanding of difficult concepts through computer generated animations, lecture recordings or screencasts. However, a number of challenges such as the multitude of mobile devices with different characteristics and the lack of clear multimedia encoding recommendations make difficult the adaptation of educational multimedia content based on learner's device characteristics (Moldovan & Muntean, 2011).

This paper comes to the help of all those involved in multimedia-based mobile learning being them educators, educational content creators and/or developers and administrators of mobile learning systems and applications. By looking at the current mobile devices market, the paper defines a set of multimedia profiles and provides encoding recommendations that enable optimum educational content delivery to a broad range of mobile devices.

## 2. ANALYSIS OF MOBILE DEVICE SCREEN RESOLUTIONS

One of the main challenges in the current mobile learning context, that this paper aims to address through the novel multimedia profiling solution, is posed by the multitude of mobile devices with different characteristics (e.g., screen resolution) that make difficult educational multimedia clips adaptation based on learner's device.

This multi-device screen resolution issue is illustrated in Table 1. The table presents a list of 25 smartphones and tablets with different screen resolutions that have been recently released on the market by various manufacturers and are suitable for mobile learning. Out of the 25 mobile devices, 21 devices were released in 2013, 3 devices were released in 2012, and one device (i.e., Apple iPhone 4s) was released in October 2011 but it is still on sale as of March 2014 due to its popularity. The table was generated based on information from online mobile device specification repositories such as PDAdb[1] and Phone Arena[2].

The screen size of the mobile devices listed in Table 1 ranges from 2.8 inches to 10.1 inches. There are 7 unique aspect ratios across the 26 individual display resolutions, with the most common ones being 16:9 for eight resolutions, 4:3 for 6 resolutions, and 5:3 for three resolutions. The aspect ratio represents the proportional relationship between the resolution width and the resolution height. The analysis of current mobile device screen resolutions includes only resolutions equal and higher to 320×240 pixels. This was defined as the baseline resolution for smartphone devices to be used for mobile learning in the M-learning Standard (Drinkall & Kneebone, 2012) developed as part of Australia's National VET (Vocational Education and Training) E-learning Strategy.

While Table 1 provides an idea on the variety of screen resolutions variety of screen resolutions of devices that can be used for mobile learning, it provides little indication of the actual usage or popularity of different display resolutions. Therefore, to provide a better insight, the popularity of mobile device screen resolutions was investigated based on mobile web data traffic statistics from more than 3 million websites globally provided by the StatCounter Global Stats web analytics service (StatCounter, 2013).

Table 1. Common screen resolutions for smartphones or tablets, and their classification based on standard video resolution classes used by online multimedia streaming services.

| Resolution Class | Display Resolution | Aspect Ratio | Example of Mobile Device | | |
|---|---|---|---|---|---|
| | | | Device Model | Display Size | Release Date |
| 1080p | 2560×1600 | 16:10 | Samsung Google Nexus 10 | 10.1″ | Nov 2013 |
| | 2048×1536 | 4:3 | Apple iPad Air | 9.7″ | Nov 2013 |
| | 1920×1200 | 16:10 | Amazon Kindle Fire HDX | 7.0″ | Oct 2013 |
| | 1920×1080 | 16:9 | HTC One | 4.7″ | Mar 3013 |
| | 1800×1080 | 5:3 | Meizu MX3 | 5.1″ | Sep 2013 |
| 720p | 1366×768 | 16:9 | Samsung ATIV Tab 3 | 10.1″ | Aug 2013 |
| | 1280×960 | 4:3 | LG Optimus VU 3 | 5.2″ | Oct 2013 |
| | 1280×800 | 16:10 | Toshiba Encore | 8.0″ | Nov 2013 |
| | 1280×768 | 5:3 | BlackBerry Z10 | 4.2″ | Jan 2013 |
| | 1280×720 | 16:9 | Huawei Ascend P6 | 4.8″ | Jun 2013 |
| | 1136×640 | 16:9 | Apple iPhone 5s | 4.0″ | Sep 2013 |
| 480p | 1024×768 | 4:3 | Acer Iconia A1-810 | 7.9″ | May 2013 |
| | 1024×600 | 16:10 | Lenovo IdeaTab A1000 | 7.0″ | Jan 2013 |
| | 1024×480 | 32:15 | Sony Tablet P | 5.5″ | Mar 2012 |
| | 960×640 | 3:2 | Apple iPhone 4S | 3.5″ | Oct 2011 |
| | 960×540 | 16:9 | Samsung Galaxy S4 Mini | 4.3″ | Jul 2013 |
| | 854×480 | 16:9 | Motorola RAZR D3 | 4.0″ | Mar 2013 |
| | 800×480 | 5:3 | Nokia Lumia 720 | 4.3″ | Feb 2013 |
| | 720×720 | 1:1 | BlackBerry Q5 | 3.1″ | Jun 2013 |
| 360p | 640×480 | 4:3 | BlackBerry Curve 9220 | 2.4″ | Apr 2012 |
| | 640×360 | 16:9 | Nokia 808 PureView | 4.0″ | Feb 2012 |
| | 480×360 | 4:3 | BlackBerry 9720 | 2.8″ | Aug 2013 |
| 240p | 480×320 | 3:2 | Acer Liquid Z3 | 3.5″ | Aug 2013 |
| | 400×240 | 16:9 | LG Wine III | 3.0″ | Oct 2013 |
| | 320×240 | 4:3 | Nokia Asha 500 | 2.8″ | Oct 2013 |

[1] PDAdb.net - Comprehensive Database of Mobile Device Specifications, http://pdadb.net/.
[2] Phone Arena - Phone News, Reviews and Specs, http://www.phonearena.com/.

Figure 1 presents the worldwide market share of different mobile display resolutions in 2013, based on mobile data traffic statistics collected between January 2013 and October 2013. The figure shows that in terms of actual presence on the market the 480×320 resolution is the most popular accounting for 18.47% of the mobile web requests. This is followed by the 320×240 resolution with 10.61% of the global share, the 1280×720 resolution with 7.5%, the 568×320[3] resolution with 6.62%, and the 800×480 resolution with 6.39%.

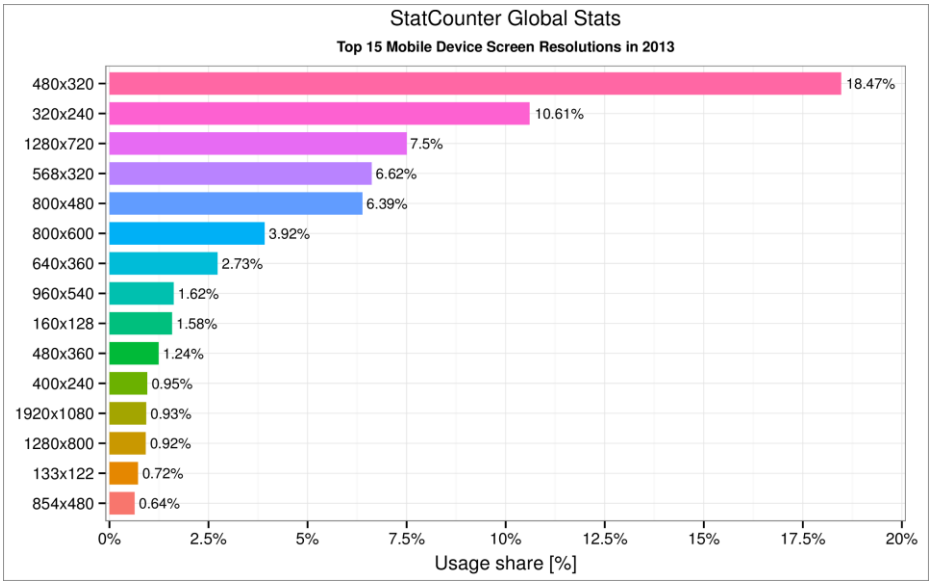



Figure 1. Percentage worldwide market share of the top 15 mobile screen resolutions based on data collected by StatCounter Global Stats between January 2013 and October 2013.

## 3. RECOMMENDATIONS FOR MULTIMEDIA PROFILING

In the context of this paper, a *multimedia profile* is defined as a set of recommended values for video and audio encoding parameters such as video resolution, video framerate, video bitrate, audio bitrate, number of audio channels, etc. The profiles specify how to create different versions of an educational multimedia clip that are suitable to different groups of mobile devices that have similar characteristics (i.e., device classes).

Ideally, for an optimum quality level each learner should receive a multimedia clip version that fits its particular device screen resolution. However, in practice this is not feasible due to the large number of versions that would need to be created and stored for each educational multimedia clip.

The overview of the current mobile landscape, presented in the previous section has revealed that while there are a multitude of mobile device screen resolutions currently in use, only a limited number stand apart as considerably more popular. Moreover, while there is a trend towards higher screen resolutions, small resolutions will continue to be used especially in lower-end devices targeting lower budgets and emerging markets. In conclusion, although a broad range of screen resolutions should be covered there is no need to cover each and every one. Therefore, the multitude of mobile devices can be grouped in classes based on their screen resolution, and a single multimedia profile associated to each class. Five classes of mobile devices are proposed in this paper one for each of the standard video resolution profiles:

- Very Small Screen Resolution Devices (VSRD) – for the 240p video resolution profile
- Small Screen Resolution Devices (SRD) – for the 360p video resolution profile;
- Medium Screen Resolution Devices (MRD) – for the 480p video resolution profile;
- Large Screen Resolution Devices (LRD) – for the 720p video resolution profile;
- Very Large Screen Resolution Devices (VLRD) – for the 1080p video resolution profile.

[3] This is actually the 1136×640 resolution of Apple iPhone 5+ smartphones, but is reported as for , but report the 480×320 resolution for background compatibility in terms of webpages rendering with older iPhone models.

## 3.1 Video Resolution Recommendations

For a given educational multimedia clip and a given mobile device, the recommended multimedia clip version (i.e., corresponding to a particular multimedia profile), should be selected by considering both the clip resolution aspect ratio and the aspect ratio of the device's screen resolution, as the two can often differ in practice. For example, a mobile device with a 640×480 resolution can accommodate the 480p profile (640×480 pixels clip resolution) for an educational clip with a 4:3 aspect ratio, but only the 360p profile (640×360 clip resolution) for an educational clip with a 16:9 aspect ratio.

However, in case of multimedia content production the wide 16:9 aspect ratio has become almost ubiquitous in recent years, with the increasing adoption of HD (High-Definition) 1280×720, Full HD 1920×1080, and more recently of Ultra HD e.g., 3840×2160 resolutions. These resolutions are used from video cameras integrated with mobile devices to professional video cameras.

Therefore, the research presented in this paper recommends the usage of the 16:9 video aspect ratio for encoding the educational multimedia content. Figure 2 illustrates the recommended video resolutions for multimedia profiles associated to the proposed mobile devices classes. As indicated in the figure, the resolution approximately doubles in size with every profile.

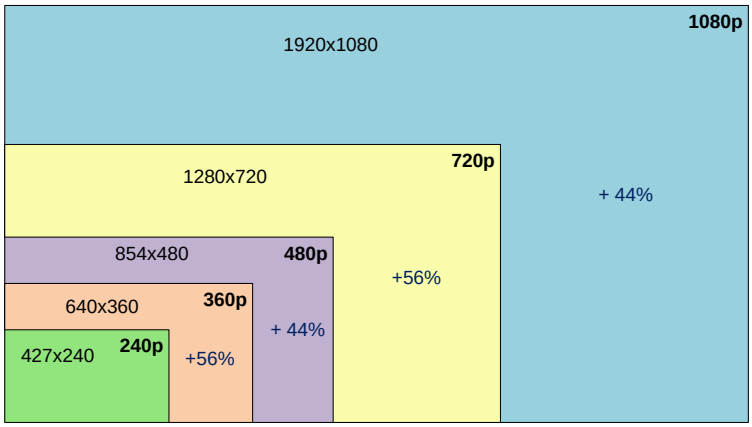



Figure 2. Video resolutions recommended for the multimedia profiles associated to the proposed mobile device classes.

## 3.2 Video Framerate Recommendations

Another important video encoding parameter is the video framerate. The video framerate usually follows some predefined standard values and is mainly determined by the equipment used for recording the educational multimedia content. However, it can be changed later on during the content editing and transcoding phases. Examples of standard framerates that are widely adopted for video recording of progressive videos, which is usually the case with Internet videos, include 24 fps, 25 fps and 30 fps.

The 30 fps value is proposed as the recommended framerate for the multimedia profiles associated to the proposed mobile device classes. This value provides excellent perceived quality for multimedia content with various dynamicity level (Ou et al., 2011). While the 30 fps framerate is the recommended one, in case of an educational multimedia clip that has a smaller framerate (e.g., 24 fps, 25 fps, etc.), the framerate of the original clip is maintained for all versions. This is because increasing the framerate to 30 fps would have little benefit in terms of user perceived quality.

## 3.3 Video Codec Recommendations

The resolution and framerate settings are independent of the video codec being used for encoding the clips. As opposed, for a particular video resolution and frame rate, the video bitrate of a compressed educational multimedia clip depends on the video codec being used (some codecs offering better compression for similar quality level such as good or excellent), as well as of particular settings specific for the video codec.

The main considerations when selecting the video codec are: supported across majority of mobile devices, cost and compression quality. Examples of video compression formats that are commonly used nowadays, include the standardised H.264/MPEG-4 AVC (Advanced Video Codec) (ITU-T, 2009), as well as its open source and royalty free alternatives Google's VP8[4] and Xiph.Org Foundation' Theora[5]. Their next generation successors, namely H.265 HEVC (High Efficient Video Coding) (Sullivan et al. 2012), VP9 (Bankoski et al., 2013) and Daala[6], promise to bring significant performance improvements but they have just been recently standardised (i.e., H.265) or are still in development (i.e., VP9 and Daala).

Although it is subject to licensing royalties, H.264 established itself as the most popular video compression format for Internet video delivery (Lawler, 2011), having also playback support on every popular mobile platform including Android[7], Apple iOS[8], Windows Phone[9] and BlackBerry[10]. Due to its widespread use and high compression quality enabled, the H.264 codec is also recommended by the Flexible Learning Advisory Group's M-learning Standard (Drinkall & Kneebone, 2012). Therefore, the research presented in this paper considers H.264 as the recommended video codec for multimedia profiling.

## 3.4 Video Bitrate Recommendations

Various aspects need to be addressed when selecting the video bitrate for encoding multimedia clips in order to enable an optimum or level of user-perceived quality (Moldovan et al., 2013). The bitrate has to be appropriate to the resolution and framerate (i.e., higher bitrate for higher resolution), and its selection should also consider among others, how the content will be distributed to the learners (e.g., download for local playback vs. streaming), the wireless networks speed, etc.

Table 2 presents the proposed video bitrate range for each multimedia profile associated to the five mobile device classes. These values correspond to a 30 fps framerate and the H.264 video codec, and can be used for encoding educational multimedia clips streamed over a wireless network.

Table 2. Video encoding recommendations for the five multimedia profiles when streaming over wireless networks

| **Device Class** | **Video Profile** | **Resolution** [pixels] | **Framerate** [fps] | **Video Codec** | **Video Bitrate** [kbps] |
|---|---|---|---|---|---|
| VLRD | 1080p | 1920×1080 | | | 2000-3000 |
| LRD | 720p | 1280×720 | | | 1500-1800 |
| MRD | 480p | 854×480 | 30 | H.264 | 600-1000 |
| SRD | 360p | 640×360 | | | 350-550 |
| VSRD | 240p | 427×240 | | | 150-300 |

The bitrate intervals are based on guidelines and recommendations provided by Apple (Apple, 2011), Adobe (Levkov, 2010) and Wowza (Good et al., 2011). These companies are big players in the adaptive multimedia area having developed commercial solutions that are widely deployed, and they also contributing to the MPEG DASH (Dynamic Adaptive Streaming over HTTP) standard.

Higher bitrates could be used if the educational clips are intended for download and local playback. However, these bitrate recommendations are more suitable for educational content delivery over the existing wireless networks. A recent study based on real-world usage statistics from 78 mobile providers located in 52 countries indicated that the average mobile connection speed across these operators was 2.71 Mbps (Akamai, 2013). Moreover, a number of research studies (e.g., Kennedy et al., 2010; Moldovan et al., 2011) that investigated the adaptation of the video bitrate in order to support high quality multimedia clips delivered over wireless networks to mobile devices have used bitrate values in the range of the recommended intervals presented in Table 2.

[4] The WebM Project — WebM VP8 Codec SDK, http://www.webmproject.org/docs/vp8-sdk/.
[5] Theora, video for everyone, http://www.theora.org/.
[6] Xiph.org :: daala video, http://xiph.org/daala/.
[7] Android Supported Media Formats, http://developer.android.com/guide/appendix/media-formats.html.
[8] iOS Media Layer Overview, http://developer.apple.com/library/ios/documentation/miscellaneous/conceptual/ip honeostechoverview/MediaLayer/MediaLayer.html.
[9] Supported codecs for Windows Phone, http://msdn.microsoft.com/en-us/library/windowsphone/develop/ff462087.
[10] BlackBerry media support, http://developer.blackberry.com/devzone/develop/supported_media/.

## 3.5 Audio Encoding Recommendations

The audio stream usually represents the smaller fraction of the overall multimedia clip. However, this is of high importance especially in case of educational clips that provide additional verbal explanations to the material presented in the video.

Since users are more sensitive to changes in the audio quality, as opposed to changes in the video quality (Ozer, 2013), this research recommends the audio to be encoded using the same settings for all multimedia profiles. The audio sampling frequency is the most important encoding parameter to be maintained constant in order to avoid audible pops when switching between the different versions of the clip (Ozer, 2013). A typical value for the audio sampling rate is 44.1 KHz.

The H.264 video codec is often used together with the standardised AAC (Advanced Audio Coding) (ISO/IEC, 2006) audio codec. For this particular codec, an audio bitrate of 128 kbps is recommended for all multimedia profiles. This value was recommended based on results from subjective listening tests that have shown that the AAC codec provides good to excellent user-perceived audio quality levels at bitrates as low as 64 Kbps (Jiang et al., 2012).

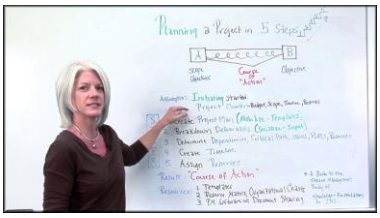
# 4. EXPERIMENTAL CASE STUDY

A subjective study was conducted in order to analyse if the proposed recommendations for multimedia profiling provide an excellent user-perceived quality level. To address the variability of the educational multimedia content, six educational clips were used in the evaluation case study. The clips are representative for the broad spectrum of educational multimedia clips, and correspond to six different categories of educational clips that are common nowadays: *animations*, *demos*, *documentaries*, *presentations*, *screencasts* and *slideshows*. These were selected from a large number of educational multimedia clips that are available on the Internet through iTunes U[11] and YouTube Education[12] multimedia services. Figure 3 presents representative frames for the six educational multimedia clips used in the study. More details about the clips can be found (Moldovan et al., 2014).


a) Animation clip ‘AtomSize’

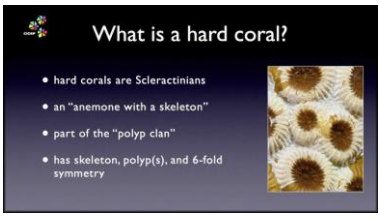
b) Demo clip ‘NitrogenIceCream’

c) Documentary clip ‘ArtOfBook’



d) Presentation clip ‘ProjectPlanning’

e) Screencast clip ‘PhotoEditing’




f) Slideshow clip ‘CoralsIntro’

Figure 3. Representative frames for the six educational multimedia clips used in the subjective case study.

[11] Apple iTunes U, http://www.apple.com/education/ipad/itunes-u.
[12] Education - YouTube, http://www.youtube.com/education.

The evaluation study consisted in a number of 60 participants viewing the six educational multimedia clips on a mobile device and rating their video quality on a 0-100 continuous scale with the following levels: Bad (0-19), Poor (20-39), Fair (40-59), Good (60-79) and Excellent (80-100). A Google Nexus 7 tablet device running on Android operating system was used for displaying the multimedia clips used for testing. The device has a 7″ LED-backlit IPS LCD capacitive touchscreen with a resolution of 1280×800 pixels, a Nvidia Tegra 3 1.2 GHz CPU and 1 GB of RAM. The clip playback, quality rating and data recording, was done through a purpose build Android app. Standard procedures for multimedia quality assessment as recommended by International Telecommunications Union were followed (ITU-T, 2008).

The educational multimedia clips were encoded for the multimedia profile 720p that is suitable to the screen resolution of this tablet device (i.e., H.264 video codec, 1280×720 pixels resolution, 30 fps, 128 kbps). Two versions of each multimedia clip were assessed, one at the minimum recommended streaming bitrate of 1500 kbps and one at the maximum recommended streaming bitrate of 1800 kbps.

The video quality evaluation results are presented in Figure 4. The results show that both the 1500 kbps and the 1800 kbps video bitrate values offer an excellent level of user perceived quality. The average video quality as indicated by the Mean Opinion Score (MOS), across the six educational multimedia clips was 97.82 for the 1800 kbps bitrate and 95.06 for the 1500 kbps. The standard deviations of the subjective MOS scores, indicate that for the 1500 kbps bitrate there is a higher variability between the quality ratings of individual participants.

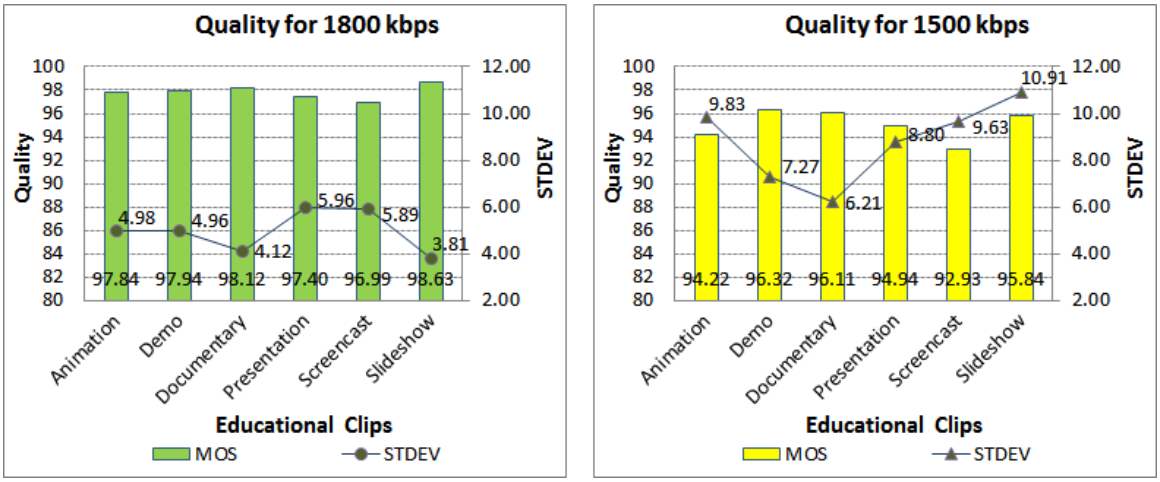



Figure 4. Video quality evaluation results

## 5. CONCLUSION

This paper has proposed a solution for multimedia profiling to address the difficulties in creating educational multimedia content for the multitude of mobile devices that can be used for mobile learning. The mobile devices are grouped in five different classes based on their screen resolution and a multimedia profile is associated to each device class. Based on the features of the latest mobile devices released on the market and the multimedia encoding technologies currently available, the paper also proposed encoding setting recommendations in terms of video resolution, video framerate, video codec, video bitrate and audio encoding. These recommendations can be used by educators, content creators or developers of mobile learning applications and services. As these recommendations cover multimedia profiles up to the 1920×1080p video resolution, they will remain applicable in the future even as more devices with high resolution displays will be released. An experimental case study involving 60 participants rating the quality of six types of educational multimedia clips on a table device, has confirmed the excellent level of user-perceive video quality provided by these recommendations.

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