



VIRTUAL EXPERIMENTS MANUAL

A Good Practice Guide

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Planning

Virtual Experiments (VEs) vary hugely in complexity and development time. Making an effective VE requires a lot of thought and good planning. This document is designed to help guide you through key concepts to get the best out of your VE.

LEARNING OUTCOMES

Taking a more pedagogical view, first define an ultimate learning goal, whether it be to familiarise the student with the equipment, to explore phenomena or to understand the consequences of measurement. Then examine which learning path the students will need to follow. This will provide a baseline and context throughout the VE development.

LAYOUT

This is important for both aesthetics and usability; both help the student engage with the VE. The aim is to simplify the process and make performing the experiment as obvious as possible without removing too much realism.

From a technical prospective we focus on framing the shot, what equipment will be used, where will it be positioned and how it will be used.

Students may feel irritated or confused by not knowing how something works or what it does. Good design can significantly reduce this anxiety, so we strive to make VEs as intuitive as possible.

RANGE OF VARIABLES

The range of variables ultimately defines how long the project will take to complete and its complexity. The best approach is to work backwards from the final equations and graphs you wish the students to find, and determine which variables over what ranges will be needed. It is usually good practice to use a step size far smaller and range larger than the student would realistically use, to ensure they are given a choice and have to make educated decisions.

PRIORITISING

The process of making a VE involves several independent tasks, which can normally be run in parallel to increase efficiency. Prioritising key tasks such as designing the layout or making the framework in Flash before capture stage can also save you time.

COMPLIANCE TESTING

Bug hunting and tracking is a key part of the development process; bugs can affect the user experience to the point that the VE becomes unusable. Quality tolerances should be agreed and bugs should be tracked in priority order of time to fix against benefits.

User testing is the best way of finding bugs and monitoring the usability of the VE. It can be time consuming, and its effectiveness is largely dependent on the abilities of the person leading the testing. That said, the insights available from good user testing can be remarkable.

INTERACTION

Decide on the level of interaction and virtualisation you want in your VE. Some VEs require the student to setup or calibrate the equipment, others require students to simply switch on apparatus and some only require a measurement.

Measuring devices need to be selected carefully. Digital displays can be easier to work with but do not provide visual feedback like analogue displays; other equipment such as rulers and stopwatches will all have to be modelled. Some of these can be usability disasters, as replacing two hands with a single mouse is always tricky.

The uses of learning devices such as contextual specific messages or checklists provide benefits, but are prone to “getting in the way” and spoiling the experience.

STORYBOARD

Storyboards are important frameworks which normally provide a starting point for development. Their main role is to describe the user journey and their interaction with the VE. A storyboard focuses more on the VE’s user interface elements (next buttons, changing views, etc.) rather than the experimental interactive elements (knobs and dials). The storyboard is different for every experiment, but normally features common elements depending on your institutions chosen branding and paradigms; eg title screen, selection screen and then experiment screen

Storyboards should result in clean and simple user interfaces with as few frames as possible whilst remaining intuitive.

Capture

The look and feel of a Virtual Experiment (VE) is crucial for a quality user experience. An experiment captured well not only looks professional and credible but will also help to immerse the user, which is the greatest benefit VEs have over simulations.

SETTING THE SCENE

The stage and background can help to give the VE a different look and feel. A plain solid colour background helps the user not to get distracted, and gives the impression of a tightly controlled environment. A more natural environment, for example in a lab with other equipment out, helps acclimatise the user, but can cause aesthetic issues (messy cables, unwanted reflections, and images that later require editing).

CAPTURE EQUIPMENT

A decent SLR camera should be appropriate for most experiments. It has the ability to take very high resolution photos and can capture 30 minutes of film. Choosing the correct lens can sometimes be a challenge. The lens size is given in mm and written on the lens, the larger the lens size the greater the zoom capacity.

Prime lens (e.g. 20mm) are fixed focal length lens, they have no variable zoom. They give the best image quality but not having a zoom makes them less versatile.

Zoom lens (e.g. 17-70mm) offer the best versatility but suffer from a phenomenon known as lens barrelling, in which the image is distorted at the edges when either fully zoomed out or fully zoomed in. This effect can be corrected but its best to avoid it by not using the maximum and minimum focal distance of the lens.

FRAMING THE EQUIPMENT

Hopefully by this stage you already have a storyboard to direct what equipment needs to be in which shots. There are several things to consider when positioning the equipment:

- It is important to fill the shot with the equipment; any unfilled space will be cropped in the editing stage and the pixels thrown away
- Legibility; all the equipment needs to be in shot and readable when fully zoomed out (unless another mechanism like a magnifying glass is going to be used)
- Layout must be clear. The users cannot look around the back to see where the equipment is plugged in - aim to show every cable neatly and clearly.

CAMERA SETUP

VEs work by switching images, therefore any changes in the images will be clearly noticed. The aim is to remove as many unwanted changes as possible while controlling the conditions.

The first step in setting up the camera is to set the **white balance**. This calibrates the camera's sensor so what we see as being white it too sees as white. White balancing varies between makes and models but is normally found in the settings section labelled WB. It usually requires a source photo which you can take by placing a white piece of paper in front of the equipment and taking a photo. Once the camera's white balance has been set, you should see the colours replicated accurately on the LCD.

The next step is to set the camera's exposure. Putting the camera into full manual mode ('M' mode) allows control of the **aperture**, **shutter speed** and **ISO setting** without the camera trying to guess the correct setting. All 3 settings affect the exposure of the camera. Since conditions are never the same between experiments, there is no single solution which fits all. Every experiment will require adjustment of these 3 settings so a basic understanding of what they all do is necessary.

Aperture

defines how large the lens opens when taking the photo. A large aperture (low f-stop) means more light can enter the camera which is useful in low light conditions. A large aperture also gives a large depth of field and very tight focus, meaning the camera cannot keep everything in shot in focus.

Shutter Speed

given in 1/x seconds (e.g. a shutter speed of 40 = 1/40th of a sec). This is how long the shutter stays open for. A long shutter speed allows more light to enter the camera but makes it more prone to blurring the shot because the camera can shake.

ISO setting

given as a multiple of 100, this defines how sensitive the film is. Higher ISO settings amplify the sensor's sensitivity, increasing exposure, but any ISO over 500 can add noticeable graining and artifacting (seen as "noise") as the sensor overcompensates for the lack of light.

General good practice procedure for setting up the camera:

1. Focus the camera either manually using the lens disk or automatically by moving the focusing ring
2. Set the camera to manual focus so it does not try to refocus between shots
3. Switch the camera to manual mode
4. Set the ISO to an acceptable level; ISO 400 on a normal day, or ISO 800 if it's a dark experiment
5. Set the aperture to as large as possible checking to make sure all the equipment stays in focus
6. Set the shutter speed to a fast setting such as 100, and decrease the shutter speed (stays open longer) until the light meter indicates the correct exposure. Take some sample shots and view on computer screen
7. If shutter speed goes above 20 then increase the ISO and continue adjusting the shutter speed.

CONTROL LIGHTING

Lighting has a big effect on the aesthetics and professionalism of the final VE. Suitable lighting is very easy to set up; the main aims are to reduce hard shadows and reflections.

By placing lights either side of the subject, most of the hard shadows should disappear. Pointing a third light up to the ceiling can help 'flood' the stage with light, further reducing shadows.

Reducing reflections can be more difficult. Depending on the experiment, a black screen behind the camera can help or slightly rotating the object or moving a light to ensure it doesn't reflect into the camera. Sometimes reflections are unavoidable; for example, if working in a well-lit lab with a lot of glassware. It is good practice to check all glossy/glass items in shot via a computer screen for unwanted and avoidable reflections.

EXPERIMENT CAPTURE

A key point to note when photographing the experiment are to be careful not to move the camera and to make sure the photographer or his reflection is not in the shot. Both can be avoided by using a remote switch or extension so the photographer does not need to physically touch the camera between shots.

It is usually beneficial to plug the camera into a laptop or computer and run the Canon remote control software. This gives you a live feed of what the camera is seeing and allows the photographer to change all the camera settings, change the focus and even take the photos without the need of a remote switch or extension. The program can also be set up to save the photos to the computer's hard disk or a network share, cutting out a step of processing.

Development

The Development stage of a Virtual Experiment (VE) is the longest and most varied. Every VE is different and there is no process which works for them all. Here is some good practice and things to consider.

VIDEO ENCODING

This process is complex and very important to get right. If it's done badly it can result in poor quality videos and/or very large files; both detract from the experience and the appeal of the VE, either visually or by degrading its performance.

There are several different techniques and procedures to produce the videos ready for embedding in Flash. They all give the same final output so it's best to use what you're comfortable with.

The HE STEM team has written a guide using Adobe After Effects, which is part of the Adobe CS package. The guide can be found in the last chapter of this manual.

ACTIONSCRIPT METHODOLOGY

ActionScript 3 (AS3) is an interrupt driven scripting language based on JavaScript. It has a very simple and clear syntax. Programming listeners for Mouse, Timer and Movie events are examples of events used to control the code.

OBJECT ORIENTED PROGRAMMING

Everything in Flash is organised into separate objects. Objects can have properties (colour, size etc.) which can be read or changed, and methods (play, stop) which invoke the object to 'do' something. Objects can be nested to create new objects too. Each object has a 'type' which defines its properties and methods (MovieClip, Buttons and graphics).

USING MOVIECLIPS

Movieclips are the most versatile objects; most user interface objects are of the movieclip type. They can be moved around, have their opacity changed and even dynamically add and remove objects from inside the movieclip. Movieclips are accessed by their 'name'; anything inside a MovieClip is accessed with the parent name, followed by a dot then the inner object, eg parent.object

IMPORTING MEDIA

Flash can handle most media given to it (movies, pictures, vectors) without any problems. To import a movie correctly, it must be embedded into the timeline as opposed to hotlinked, allowing full control of the movie via Actionscript. Importing into a MovieClip also makes the video a standalone object, which is a far easier to control than placing on the timeline.

SWITCHING VIDEOS

Once all the videos are imported, changing which video to show can be problematic. The recommended method is to make a place holder MovieClip and dynamically add the MovieClip containing the correct video as a child using ActionScript. This can cause problems in referencing the added MovieClip, as they will all need unique names.

PRELOADER

Some experiments contain more media than others. For larger VEs a preloader is essential. Flash by default will display an empty blank stage until the SWF is fully loaded. This blank state gives no feedback to the user to wait and they will always assume it's 'broken'. Adding a preloader removes this problem by showing a loading progress bar, and gives you the opportunity to display some branding. The preloader code can be fairly complicated but examples will be given.

As a rule of thumb it's best to make sure each VE is less than 30mb; this keeps the VE accessible, ensuring it can be downloaded in an acceptable time. The total size of the VE is normally defined by the size and thus quality of the videos.

LIBRARIES AND CLASSES

As everything is made up of objects in Flash, these objects can be packaged up into external classes. These classes are separate files and allow the code to be reused in different VEs. The classes are completely independent and modular; this has huge benefits as there are usually common components in a lot of VEs. Writing them out into classes means there is no need to re-write the code, saving time. As they are separate independent files, all VEs using the class can benefit from any improvement or development.

The VE team has a range of useful classes it has been developing. Some examples include:

- An extensive dial (knob) class
- Rulers and protractors
- Simple skin and styled buttons
- Stopwatches
- Tooltip system
- Messaging system
- Counter
- Dialogue system

Any object can be made into a separate class. Once a code base of classes has been written and tested, the VE's development time drops significantly as each subsequent one will require fewer lines of code.

PUBLISHING

Publishing the project involves making the SWF and HTML files. This should not be confused with deployment which involves uploading the compiled SWF and HTML files to the web or a VLE. Flash does most of the work when publishing, but it is important to make sure the HTML file has 'with fullscreen support', otherwise the else that feature will not work.

Encoding Procedure

This is the encoding procedure the HE STEM team use to make the RAW files suitable for Flash. The technique has been developed to be as efficient as possible in terms of time taken to edit, getting the best image quality and smallest file size.

VIDEO OR PICTURES

Processing pictures into a movie requires a few extra steps. The procedure will focus on using pictures; if your RAW media is already a video, then most of the steps still apply.

PROCEDURE

1. Load up Adobe After Effects

First, make sure the import settings are correct before we import

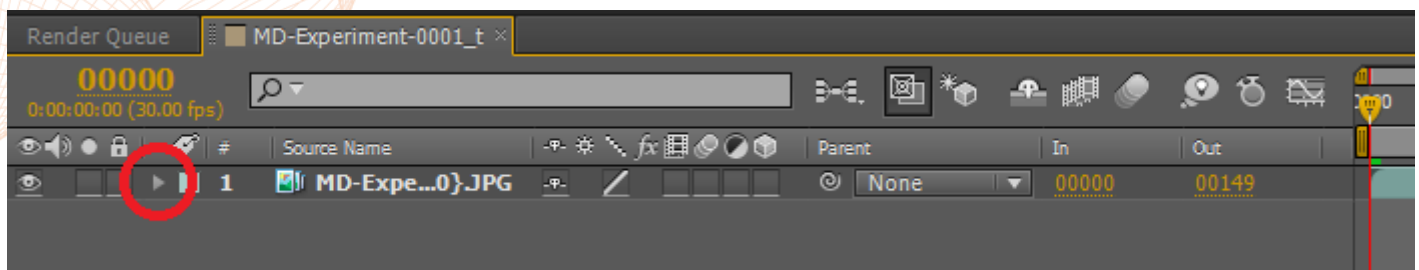
2. Edit -> Preferences -> Import
3. Change Sequence Footage option to 30 frames per second
 - This is important as the movie will need to match the frame rate of Flash

Next, Import the files

4. File -> Import
 - Make sure to select all the files (click first one, hold shift key and then select last one)
5. If you are importing a collection of pictures make sure 'JPEG Sequence' check box is ticked
6. Click Open
7. Drag the newly made item in the 'Project' tab on the left into the middle of the screen which is the composition tab; this will make a new composition.
8. Right click the newly made composition -> 'Composition Settings'
9. Change the width and height of the composition to match your required final output
 - We recommend encoding the video at twice the dimensions you wish to use in Flash. This ensures the video still looks good when in fullscreen mode

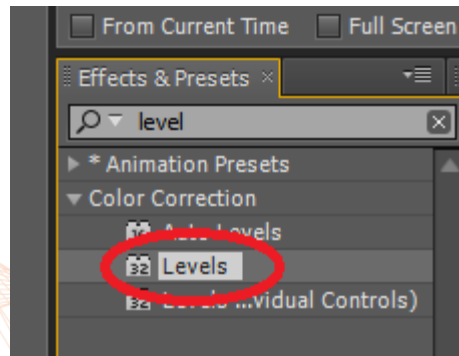
Next adjust the image

10. Open up the properties of the object inside the composition by clicking the small grey arrow:

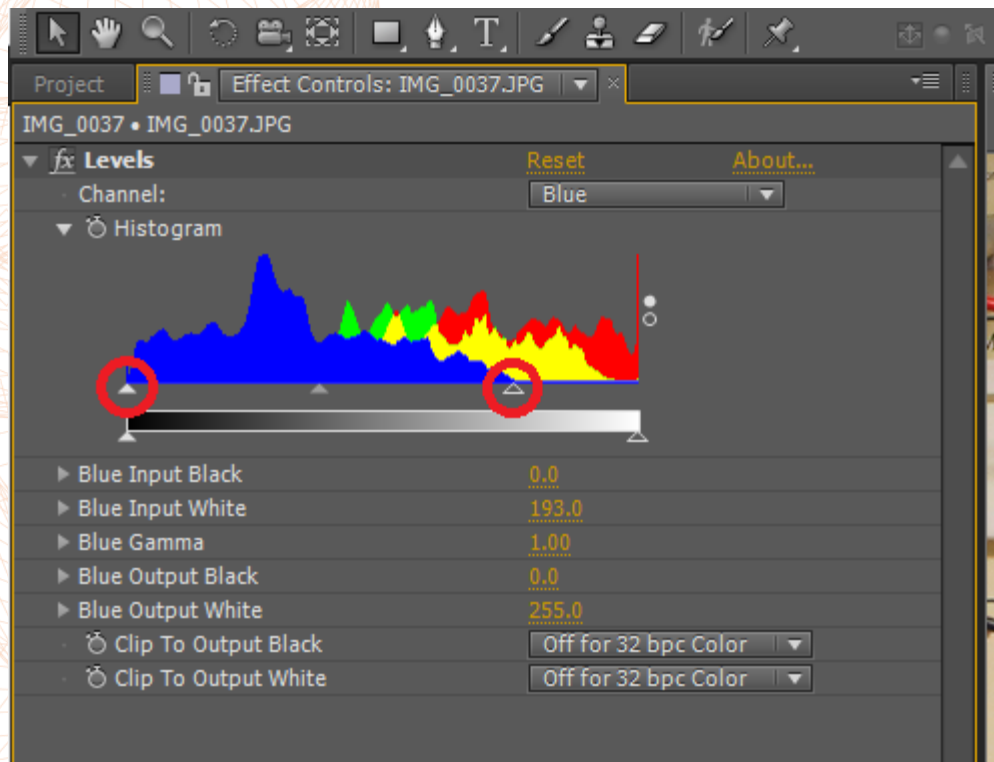


11. Rotate the image if required (use view -> Show Grid to help)

12. Position the image with the Position X and Y values
13. Change the scale to fill the composition with the subject and ensure there are no black areas
14. Drag the 'levels' effect on to the composition in the middle of the screen



15. Adjust the sliders in the effects tab for each colour channel so the sliders fill the entire histogram. This should help white-balance the image:



16. Use the middle slider to change the gamma of the channel, allowing you to fine tune the colours
17. Apply other effects such as 'Hue and saturation', 'Highlight and Shadow' and 'Brightness and Contrast' to help bring out colours and subjects.

Now we must Set up the encoder

18. With the composition selected, click 'Composition' -> 'Add to Render Queue'
19. Click the 'Output Module' name to modify the profile
20. Change 'Format' to 'FLV'
 - this is the only format with which we can embed the video into Flash
21. Tick the 'Audio Output' box if audio is needed
22. Click "Format Options..."
23. Set the bitrate from 200 kbps to 5,000 kbps depending on the purpose:
 - if you only have fewer than 10 images in the video then use 5,000 kbps
 - Larger sets of images need to be encoded at 200 kbps to keep file size down
 - The bitrate defines the quality of the final product; the lower the bitrate, the worse the image quality. Some experimenting will be required, as the visual quality depends on the subject of the video.
24. Set the undershoot to 100% if using images which the user will pause on; if not, then set to 90%
25. Click the 'Output To:' name, set the file name and saved file destination
26. Click Render.
27. The render time varies from a few seconds to hours depending on number of frames and bitrate.
28. Once the render is complete the video will be ready for Flash.