Adapting the twelve principles of classic animation to lectures

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Abstract

This paper borrows from the fields of classic animation and 3D animation and adapts the fundamental principles of these subjects to the lecturing context. An analogy is drawn between an animator and a lecturer due to their shared objective: to communicate in an engaging way. If the fundamental principles of animation are read under the point of view of how they communicate a message, it is not difficult to see that they summarise some of the key concepts in the fields of education and educational psychology. Once adapted the principles can be used as a guideline by novice lecturers to increase students' engagement both in traditional lectures and in e-learning environments. The principles have been applied successfully in teaching the Programming for 3D module and a number of modules at the University of Sussex obtaining good feedback from students.

Categories and Subject Descriptors (according to ACM CCS):

1. Introduction

In staff development courses it is often said that "lecturing is that mysterious process by means of which the contents of the note-book of the professor are transferred through the instrument of the (...) pen to the note-book of the student without passing through the mind of either", [Mil27] page 120.
This quote highlights an already established problem that, in the modern view of lecturing, traditional lectures are ineffective at developing critical thinking and enabling students to learn effectively. However, lectures are still effective at guiding a student though the course material and highlighting the important points that need thought.

In traditional lectures it is common to see students dozing off, talking, or being distracted by their phones. This is often due to a lack of engagement between the lecturer, student and material being taught.
Student engagement is a well studied field of research in education, see Trowler [Tro10, TT10] for a literature review on the subject. However, there is no consensus amongst researchers on a formal definition of the term. This paper follows the definition given by Kuh, who defines student engagement as "the time and effort students devote to activities that are empirically linked to desired outcomes of college *and* what institutions do to induce students to participate in these activities", [Kuh09] page 683 (emphasis in the original). According to this interpretation, engagement is both what the student does towards the acquisition of knowledge in a specific subject and what the institution does towards the stimulation of the student in acquiring the knowledge.

One of the major factors that is often linked with student engagement is *cognitive overload* [MM03,Jon09]. Cognitive overload happens when students are given too much information at the same time quickly filling up the verbal and the visual memories, which are limited. When these memories are full pieces of information stored in them are dumped before they become permanent.
An example of what may cause cognitive overloading is the use of text and audio in a presentation asynchronously. If these two communication methods are used in this way, it affects the verbal processing capabilities of the brain increasing the chance of overloading [AN12, BE81].

A number of methods have been developed to help a student develop their memory, see [Bli98, BR02], but the process of storing information in long term memory only works when a student actively pays attention to the stimuli. In order to increase the likelihood that a piece of information gets stored the lecturer has to find a way to keep the student attentive and engaged. Bligh, [Bli98], shows that a high level of attentiveness can be held for a maximum period of fifteen minutes, after that time it starts to decrease.
Modern teaching techniques [Rom13, BR02, BABHOS13,

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GDWK09, Cav11, HCTH05] take into account this attention span by introducing pauses, changes of pace and changes of activity to "reset the timer".
However, resetting the timer is not enough for the student to process and retain the lecture content.

There are many factors that influence cognitive overload such as the pace of the lecture, [CS66, Bli98, NKS13], its organisation [MV05, MM03, MHS01], its delivery format (audio, images, audio with images) [MV05, Ree83, Hob87] and extraneous material which might be involuntarily introduced by the lecturer [MM03, MHS01]. When designing a lecture these factors should be taken in account in order to reduce the chance of cognitive overloading.

Another factor that influences students' engagement during a lecture is entertainment as students disengage quickly during boring lectures. This factor spans different industries other than higher education, one of these is the animation industry. Animations are an engaging form of entertainment and they often leave the audience with something to think about. In a way they teach a message in a compelling manner. However, if the same message is moved into a traditional lecturing setting, it will most likely result in a boring lecture due to a lack of entertainment.

This paper borrows from the fields of classic animation and 3D animation and adapt the fundamental principles of these subjects to a lecturing context. The goal of this paper is to generate a framework adapting these principles to produce both engaging and entertaining lectures that limits the cognitive overload of the student. Within classic animation and 3D animation the key role of an animator is to communicate an idea or concept in an effective and engaging way. This is also the role of a good lecturer. The main difference between the two is in the way the communication happens, an animator will draw or use a computer to render a frame, while a lecturer will rely on an array of different communication tools, i.e. speech, slides, films, etc. However, their objective is the same: to communicate in an engaging way. If the principles of animation [TJ81, Las87] are read under the point of view of how they communicate a message it is not difficult to see that they summarise some of the key concepts in the fields of education and educational psychology. Once adapted the principles can be used as a guideline by novice lecturers to increase a students' engagement both in traditional lectures and in e-learning environments. It is worth observing that some of the principles are intuitively applied by experienced lecturers without noticing the link with the animation field. At the University of Sussex the principles have been applied successfully in a number of modules taught using traditional and blended teaching.

The twelve principles of animation will be linked with education research in section 2, and in section 3 some examples of how the principles have been applied to lectures at University of Sussex will be presented.

2. Applying the twelve principles to lectures

In this section the twelve principles of animation, see Thomas and Johnston [TJ81] and Lasseter [Las87] will be examined in the context of educational psychology and lecturing.

1. **Squash and stretch**: This principle should be read as: plan to use modern techniques for students' interaction during class [Cav11, GDWK09, BABHOS13]. Thomas and Johnston [TJ81] and Lasseter [Las87] defined squash and stretch as a means to show the rigidity (or flexibility) and mass of an object. In the context of a lecture the principle should be read: keep the lecture flexible. This can be achieved by using modern teaching techniques as they often suggest, amongst other things,to let students discuss a key topic during class or let them decide the amount of information treated on a specific topic or its speed. These techniques effectively squash and stretch the lecture in both time and in its content to fit the needs of the audience, allowing for flexibility during the lecture.

2. **Anticipation**: as Thomas and Johnston [TJ81] described it, this principle is about preparing the audience. In order to be able to introduce a concept or an idea, especially a complex one, the students need to be prepared with the majority of the information they need to grasp it. An idea should not be introduced straight away but it should be gradually developed and finally introduced when the students are ready for it.

3. **Staging**: this principle has two meanings. The primary meaning of the principle is strive for clarity. The clearer and more accessible the content is made the more likely students will grasp it.
The alternative understanding of this principle relates to the environment where the lecture is taking place and the means by which the lecture is being transmitted.
If it is a live lecture the lecturer should always be aware of the space where the lecture is going to take place. Modern lecture theatres are often built according to the concept that a single lecturer will talk to a large passive audience, writing on a black or white board or showing slides. This model, although widely spread, is not the best option for teaching [Bli98, BR02]. If possible it is recommended that the lecture is given in a configurable space, which you can modify according to the needs of your students, subject and teaching style. If such space is not available the lecturer should survey the space assigned to him or her before using it, especially if it is unfamiliar. They should predetermine where they are going to stand, check where the projector and the screen are, and whether they can easily see the slides from their chosen standing position. The lecturer should always be aware of their audience as this helps to reduce chatter during the lecture and keep the students attentive, especially those at the back of the room. The following

questions should be answered when preparing a lecture and associated slides: can the students in the back row see and clearly read what is on it? Can they hear you clearly? Does the projector work? Can you connect your laptop to it if necessary? Does the projector work with your laptop?
The slides and tone of voice should also be designed for the students on the back row as the students who sit there are more likely to be the ones who disrupt the lecture if not kept attentive.
If the lecture is recorded, the lecturer should think of where he or she will be on screen. Will they always be clearly visible and well lit? Will their facial expressions always be clearly readable? Will their voice be recorded properly? When the recording is played back, will their slides be easy to read on all common devices (e.g. computer screen, tablet and mobile)? The lecturer should design their slides so that he or she and the content can always be easily seen on screen at the same time.

4. **Straight Ahead and Pose to Pose**: Thomas and Johnston [TJ81] describe Straight Ahead as the following: "[The animator] simply takes off, [...] getting new ideas as he goes along, until he reaches the end. [...] has little plan of how it will all be done at the time he starts", [TJ81] page 56. Replacing the word animator with the word lecturer, Straight Ahead describes those lectures where the lecturer has a rough plan of what he or she wants to talk about and which concepts they should discuss, but their plan is not accurate and they do not know in detail how the concepts in the lecture will be explained. Although this can on occasion yield good results, it is more likely that the lecturer will go astray and talk about concepts they did not really want to discuss in the first place or talk about anecdotes which are of little interest for the purpose of the lecture. These are the kind of lectures Bligh [Bli98] refers to as not well prepared.
The contrasting approach to this is Pose to Pose. In Thomas and Johnston words "the animator plans the action [...] relating [the drawings] to each other in size and action and gives the scene to his assistant to draw the in-betweens. Such a scene is always easy to follow and works well because the relationships have been carefully considered before the animator gets too far into the drawings", [TJ81] page 56. Using again the analogy between animator and lecturer, in Pose to Pose the lecturer knows exactly what he or she wants to do in the class, which ideas and concepts they will talk about, how they will be linking them, what they will be doing and what they will be saying. The lecture, the slides, and the presentation delivery are carefully planned and rehearsed. Space for the students to interact in the class is planned as well as which activities will be done during the interaction. The assistant Thomas and Johnston talk about can be identified as the teaching assistant (TA) or the lecturer themselves during labs, seminars or discussion classes, where the concepts the lecturer has introduced in the lecture are examined in detail and put in practice. This implies that the lecturer should work at close contact with the TAs, talk to them and specify what has been done in the lectures and which "in-betweens" the TAs need to draw to fill in the details that not been covered during the lecture. The Pose to Pose approach should be a must for video lectures. Every aspect of the lecture should be considered, from the visual appearance of the slides and of the presenter on screen, to what the lecturer will say and how they will say it.

5. **Follow trough and Overlapping**: as an action in an animation should not stop abruptly but carry on until its end and overlap with the following action linking them together, so different concepts should be linked in class and flow from one to another seamlessly. Ideas and concepts should not be left unlinked as there is little chance that all but the brightest students will make connections between them by themselves. In fact, Moreno and Valdez [MV05] proved that letting students organise and link the material by themselves hurts the learning process. Connecting the concepts together can be achieved by making "the bigger picture" clear to the students, for example during one or more of the initial lectures of the course an overview of the module can be given and all the key concepts can be briefly explained and related to one another.

6. **Slow In and Slow Out**: if a complex concept is presented simultaneously with all the concepts from which it derives it will be confusing and hard to understand, especially if no thinking time has been left for the students or they have no previous knowledge of the concepts. New concepts should be introduced one at the time and pauses should be left to let ideas settle, giving students sufficient thinking time. The importance of pausing during lectures is recognised in education psychology [DS79], especially when the pace of the lecture is fast [Bli98]. One or two second pauses should be left between key phrases to let the students absorb what has just been said. A fast pace for the lecture does not contrast with this principle. Introducing concepts slowly has nothing to do on how fast the lecturer speaks or how fast the lecture progresses. This principle relates to the way concepts are presented. The lecturer should make sure that the audience always follows what is being said.

7. **Arcs**: in the context of lectures creating arcs means conclude and link. At the end of the lecture some time should be spent linking the topics discussed in the lecture to one another, showing clearly what has been done during the lecture and what the student should take away

and think about.

8. **Secondary Action**: if one considers the ideas taught during a lecture as the primary action of the animation, the secondary action principle applies to the examples and tools that can be used to make the ideas clear and concrete, i.e. the keynote presentation, the software used, the props brought in class to show applications of a concept, etc.
   Using the words of Thomas and Johnston the secondary action should "always [be] kept subordinate to the primary action. If it conflicts or becomes more interesting or dominating in any way it is either the wrong choice or is incorrectly staged.", [TJ81] page 64. This can be paraphrased as: the right examples and tools should be chosen to enhance an idea and make it more concrete and clear. If the example or tool draws the attention away from the idea it is probably not the right one.

9. **Timing**: although this principle is one of the most important it is often ignored during lectures. Timing refers both to the pace of the lecture and to the length of pauses while speaking [CS66]. It also refers to the total length of the lecture.
   The tone of the voice and the speed at which the lecturer talks influence the way the pace of the lecture is perceived [CS66]. If the lecture is too slow in progressing it will be boring, if it is too fast it will be difficult to follow. A balance should be found between these two extremes. This balance depends mainly on the audience and time should be spent trying to know the audience first in order to adapt the pace to them. In general, slides should be kept flowing, presenting one concept per slide and no more. Stopping too long on a slide will make the audience loose interest in it. A lecture should be considered like a movie. It would be a boring movie if twenty minutes were spent on the same scene following a single point of the plot. A more engaging movie would be if scenes follow one another at a quick pace with a plot that flows and develops. However, the pace should not be too quick. Bligh [Bli98] points out that when going at a rapid pace pauses should be maintained after important points and lecturing times should be short.
   As pointed out in section 1 the attention span for a student is on average 15 minutes [Bli98]. Breaking down a lecture into short sections followed by activities or pauses increases the students' attention and engagement, positively affecting their learning. This model works even better when the lecture is recorded. Students today are used to the transfer of information at a fast pace, especially in video format thanks to YouTube and other video content distribution platforms. If videos are too long there is little chance that they will be watched to the end. Video lectures should be broken down into short videos of five minutes or less, well within the attention span limits. More importantly the break down of the lecture forces the lecturer to make one point at the time keeping the lecture focused.

10. **Exaggeration**: as Thomas and Johnston explain [TJ81] this principle can easily be confusing. Exaggeration does not mean that the idea of concept should be distorted and made unbelievable. Rather, in the context of lectures it means that the heart of a concept should be brought to light by developing its essence, removing all the extra information that is not strictly needed to understand it. How to do so depends mainly on the subject taught. However, independently of the subject, it requires accurate planning.

11. **Solid Drawing**: lectures should have weight, depth and balance, meaning that what is said during a lecture should be pedagogically sound, focused on how the student will receive the content while at the same time being entertaining.

12. **Appeal**: this applies to the presentation as well as to the lecturer. Both should be interesting to watch and pleasing to the eye. Moreover, the presentation should be simple. As pointed out in section 1 using audio and text together generates problems with concurrency in the use of memory resources. These problems are negated with use of audio with images [BE81] and therefore few [AN12] or no words should appear written on the slides. Images and diagrams with a commentary from the lecturer provide a better method of communication than a slide crowded with text. In this instance the lecturer is providing the main channel of communication while the slides are being used to stress and highlight the point the lecturer is making synchronously with the speech [PS13].
   For the presentation to look visually appealing diagrams should be re-created using the presentation software and images should always be at the highest resolution and cover the whole slide if there is nothing else on it. The reason for re-creating the diagrams is that often book scans are poor in resolution and they can not be animated. Re-creating a diagram with the presentation software offers guarantees that the diagram will be always be at maximum resolution and that it will be possible to animate its components, ensuring that the presentation is pleasing to the eye. Moreover, the proper use of animations in a teaching context has been reported to have positive effects on learning by many researchers [RF00, Syr00, NKS13, PS13]. However, in practice it is rare to see them used properly. Animations should be used when they have a purpose, for example making a word change its size or appear when synchronously speaking that word or making a bullet point list reorganise itself in groups when the lecturer is doing the same out-loud stresses visually what the lecturer is saying orally. On the other hand making bullet points walk their way into the slide is not a good use of an animation

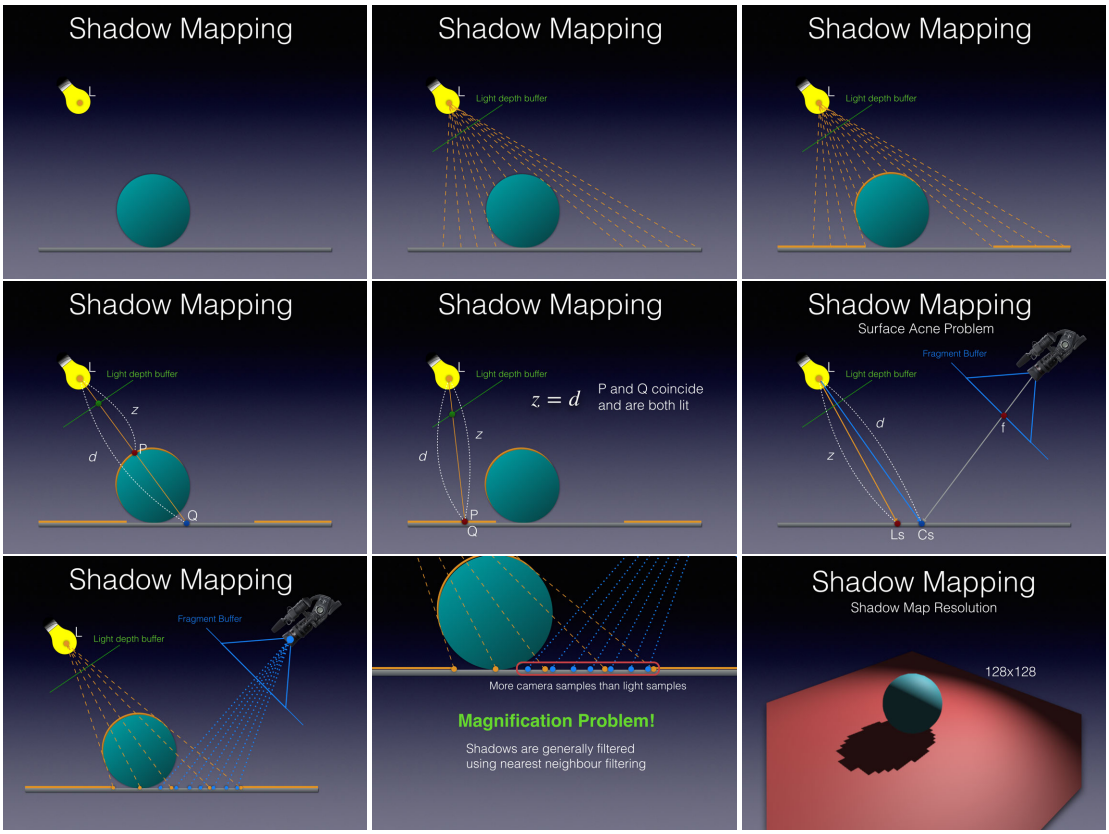

Figure 1: *(Left to right, top to bottom) An extract from the slides from the Programming for 3D lecture "Advanced Illumination and Texturing" showing how shadow maps are formed and what problems arise from the technique.*

as the animation has no purpose and distracts from what the lecturer is saying.

Although these principles provide a useful guide for the planning and preparing of the lectures it is important not to focus too much on the entertainment content of the lecture and not enough on the learning. The content should not be sacrificed for the sake of entertainment nor the entertainment should be sacrificed for the sake of the content. A successful example of how to achieve this are the lectures in Classical Mechanics delivered in 1999 by Prof. Lewin [Lew99] for the MIT Open Courses.

3. Examples

The principles have been applied to numerous modules taught at the University of Sussex including Programming for 3D (P3D), Visual Effects and Compositing (VFX), Multimedia Design and Applications (MDA), 3D Modelling and Rendering (3DMR) and others. Every lecture in these modules was designed as a mini show, with a welcome message, a short title sequence, and a thanking message at its end. This section will focus on the last lecture from the P3D module. It will be used as an example to show how the principles outlined above can be applied.

The Programming for 3D module is a second year module aimed to introduce the students to computer graphics programming. The module covers the graphics pipeline, how data are transformed into images by it and some advanced topics such as lighting, shadows, ambient occlusion etc.

The last lecture of the P3D module is a forty minute lecture titled "Advanced Illumination and Texturing" and covers shadowing techniques, ambient occlusion and, briefly, environment mapping.
The lecture, like every lecture in the module, was planned and rehearsed multiple times before being delivered (*Pose to Pose*).
The lecture has good amount of content (*Solid Drawing*) and it stays on topic (*Exaggeration*).
After the usual welcoming message and short title videoclip, the lecture starts giving an overview of the main points presented in it (*Anticipation*) and how they link together (*Follow Through and Overlapping*). Then two short clips of a dancing character are presented, initially without shadows

and then with shadows (*Secondary Action* and *Appeal*). Students are then invited to discuss the difference between the two clips and are given as much time as needed to discuss (*Squash and Stretch*). Students in general answer in a short time that shadows make the character look more realistic. The lecture then moves on showing a photo of a ball projecting shadows on the floor (*Secondary Action* and *Appeal*), again, students are invited to discuss what they see about the shadow (*Squash and Stretch*). They quickly realise that the shadows form a gradient and the areas of the shadow are then classified by the lecturer as umbra and penumbra. An animated diagram is the presented (*Appeal*) that shows (1) how light is projected on the virtual scene, (2) how a depth buffer is used to store the distance between the object and the light source, and (3) how this buffer can be used to compute shadows (shadow mapping). Some of the frames of the animation are shown in figure 1. When the diagram is shown areas of umbra and penumbra are pointed out (*Follow Through and Overlapping*). The similarity between the way the shadow map is filled (*Follow Through and Overlapping*) and how the camera samples the scene to fill the frame-buffer is highlighted. The problems that the camera from the camera and sampling from the light causes when used at the same time (magnification, surface acne, self shadowing and bump mapping, the terminator problem) are shown and discussed using examples from games (*Secondary Action*). This concludes the first part of the lecture.

The pace used during the lecture is fast (*Timing*) but pauses are left after the key points (*Slow In and Slow Out*), moreover the lecture is divided into four parts Shadows, Ambient Occlusion, Environment mapping and Module Overview giving short pauses after each part (*Timing* and *Slow In and Slow Out*), which is never longer than fifteen minutes. At the end of the lecture a summary is given on how these parts fit together to produce a realistic environment (*Arcs*). Moreover, this being the last lecture of the term a module overview is presented summarising what has been discussed throughout the module and highlighting how the concepts fit together (*Arcs*). The overview is given showing images from each lecture (*Appeal*) instead of listing them using text. What has not been covered during the module is also highlighted, inviting students to further study the subject in their own time. The lecture (and the module) concludes thanking the students for their attention, showing a short clip as an example of non photo-realistic rendering in games and a title sequence.

All modules in which the principles have been applied received good feedback from the students. For Programming for 3D, students commented for the second year in a row that the lectures were the best they have attended. Moreover, students were very keen in completing the coursework for those modules.

4. Conclusions

In this paper the concept of cognitive overload has been reviewed together with some of the key points in educational psychology that aim to reduce the chance of it happening. These key points involve the pace of the lecture, the organisation, the delivery format, and the extraneous material introduced involuntarily by the lecturer.
An analogy between a lecturer and animator has been drawn including the fact that they are both communicating an idea or a concept. Working with this analogy the twelve principles of animation have been adapted to give to the lecturer a guideline for designing engaging lectures. They also nicely summarise a large part of the educational psychology literature on the subject.

Applying the principles mean: plan for interactive teaching techniques (*Squash and Stretch*), prepare the audience for the key points of the lecture (*Anticipation*), think about the clarity of the exposition and the means of communication (*Staging*), avoid too much improvisation and plan for what happens in the lecture and rehearse it (*Straing Ahead and Pose to Pose*), connect the ideas touched during the lecture (*Follow through and Overlapping*), present one concept at the time making sure the audience follows, leaving time to think between key concepts (*Slow In and Slow Out*), conclude the lecture summarising and linking its main points (*Arcs*), choose the appropriate example or tool and use it at the right time (*Secondary Action*), be mindful of the pace of the lecture and break it down into short sessions (*Timing*), remove all extra information that is not needed to understanding a concept (*Exaggeration*), make the content sound and entertaining (*Solid Drawing*) and, finally, prefer the use of images to the use of large amounts text, and use text and images synchronously with the commentary (*Appeal*).

All these principles rely on the fact that the lecturer knows the audience and what the audience knows about the subject. This final observation should probably be added as the zero principle: *know your audience and what your audience knows*.

The analogy has been drawn to provide lecturers' with a practical guideline that they can follow to produce interesting and engaging lectures. The application of these principles to a number of modules at the University of Sussex led to good results, improving the engagement of the students in the module and increasing their willingness to put extra effort into completing their coursework.

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