Applying traditional animation principles for creating learning objects

Sameer Suhas Sahasrabudhe
IIT Bombay
s1000brains@iitb.ac.in

Sridhar Iyer
IIT Bombay
sri@iitb.ac.in

Sahana Murthy
IIT Bombay
sahanamurthy@iitb.ac.in

Abstract:

In eLearning content creation, animation is a preferred medium for explaining complex concepts. Typically, animators refer to the traditional animation principles for creating animation. These principles are for the entertainment domain. Therefore, it is important to study the feasibility of applying them to create animations for educational learning objects (LOs). In this paper, we consider the animation principles and present rationale for the inclusion and modification of principles by providing appropriate examples from educational domain. We found that while all the principles are required for LO creation process, applying them should be based on the topic of the LO.

Keywords:
Traditional cell animation principles, adaptation of animation principles, principles for creating learning objects

1 Introduction:

Visualization and interactivity aspects of animation are useful for explaining complex concepts in eLearning (Neo 2004, Fisher 2010, Chang & Ungar 1993). Selecting animation as a medium is dependent on the type content. The types of contents mentioned in research are facts, concepts, process, procedures, and strategic principles (Clark & Mayer 2007). Out of these, processes, procedures, and principles have change-over-time and complex visualization requirements. Therefore, these are suitable to be shown using animation. Multimedia eLearning animations provide the ability to add motion to these static diagrams. There are positive learning effects of animation in many areas like Physics, Microbiology, and Mathematics (Windschitl 1996). This visualization with an addition of interactivity and assessment can help in achieving the learning objectives planned by the instructor. An interactive, standalone unit with defined learning objective and assessment built into it is a popular type of content in current eLearning domain. This is termed as a 'Learning Object' (LO). There are many definitions of LOs, but the one which we are following is “the smallest independent structural experience that contains an objective, a learning activity and an assessment" (L’Allier 1997). LOs are valuable for teaching and learning mainly because of the reusability factor, not only in online scenarios but also in classroom teaching (Bratina 2002, Boyle 2003, and Wang 2008).

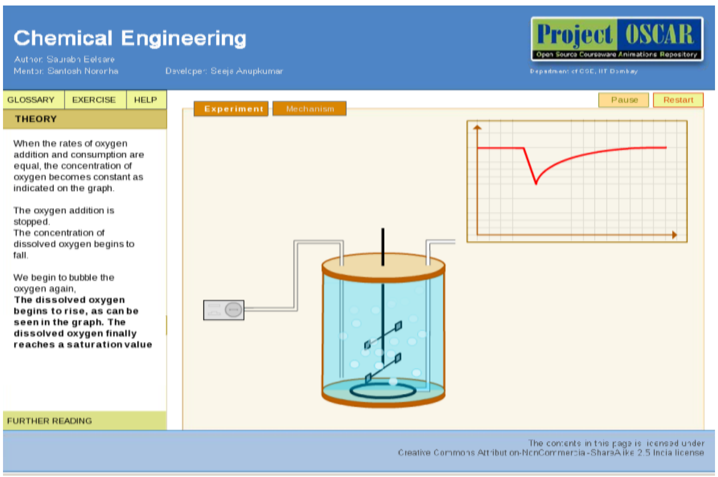


Figure 1: Screenshot of an LO

In order to create effective LOs, it is important to know about the production process of animation (being the key component of an LO). Origin of animation was in the form of cell animation, where each frame was hand drawn. This technique is straight ahead animation. The technique further developed into keyframe-inbetweening process for scalability, and is known as pose-to-pose technique (see section 3.11 for details of these techniques). This technique creates animation faster, as compared to single person drawing all the required frames alone.

Senior animators at Disney studios documented the animation principles. They presented 12 principles for cell animation process (Frank and Johnson 1981). These principles have enhanced the entertainment objective of the animation. Animators all over the world, use these principles to create animation. John Lassetter (Pixar Studios) wrote a paper about adaptation of cell animation principles for computer animation (Lassetter 1987). He concluded that principles of animation are tools to create content, and therefore ALL the principles from the traditional cell animation technique are required in computer animation. This is important because objective of both the techniques is entertainment.

On the other hand, the objective of content creation for education domain is about explaining concepts. This objective is different from the entertainment objective, and therefore it is necessary to study whether all the animation principles used in the entertainment domain are necessary for creating eLearning content like learning objects (LOs).

In this paper, we present rationale for applying the traditional cell animation principles for creating LOs. We start by listing these principles in various categories. Categorization of principles is based on their preferred usage in the entertainment domain. The categories are as follows:

1. Animation production: Principles which help in creating the motion in a systematic manner
2. Creating real life motion: Principles which help in adding the realism to the motion
3. Creating distorted motion: Principles which are useful in deciding the level and type of distortion of components

These categories are numbered in the way in which they are applied. Initially, the motion is created (using category 1), later specific significance is added to the motion (using categories 2 and/or 3). In this study, we observe that all traditional animation principles are necessary to be applied in LO creation domain. However, application of these principles can be done using a particular method, and is required in certain conditions specified in the description of the LO. Subsequent sections elaborate these methods and the conditions.

Organization of the paper is as follows: Section 2 explains the aspects considered for using animation as a medium in LO creation. It also explains the traditional animation process and LO creation process respectively. Section 3 has the details of applying traditional animation principles by giving the rationale and providing appropriate examples. Section 4 presents the summary of the study and the discussion about the future directions based on this research.

2 Animation as a preferred medium for LO creation process

Different mediums as text, images, audio, video, and animation are used in LO creation process. Every medium has certain potential, and is preferred based on the objective of the LO creation. For example, audio is necessary for a LO which focuses on pronunciation of the words in a given language. In their seminal paper on animation, the authors presented five functions that animation can address (Weiss 2002).

1. *Cosmetic function:* To make the LO look better. It may or may not be required by the subject matter the LO is created for. The designers use it just to make the LO look different as compared to other LOs. It is advisable for the designers to refrain from using animation just for cosmetic function.
2. *Attention gaining function:* To make interesting narrative. This includes options like transitions, moving symbols or characters, animated prompts and so on. Minimal usage of this function avoids distraction from the subject matter.
3. *Motivation function:* To provide feedback. Display of attractive motion in response to the appropriate actions done by the user, can motivate the user. However, ensure usage of this function to display positive feedback.
4. *Presentation function:* To explain abstract and dynamic processes. It provides context to the ideas that are not static (unlike book illustrations). It also presents the details in the form of moving visuals where text and static images leave it to the users' imagination.
5. *Clarification function:* To provide conceptual understanding to the user without giving new information. It uses the power of visualization along with other mediums to make it clear to the user.

After considering these functions the instructional designers (IDs) and the subject matter experts (SMEs) take a decision to use animation as the medium to create any given LO. Based on this decision, it is important to know the processes of animation production in entertainment as well as in LO creation domain. Subsequent subsections outline the two processes.

2.1 Animation creation processes in entertainment

The process of creating animation has evolved a lot since its inception. In the beginning, it started with a straight-ahead technique, where in the animators created the frames one after the other. There was a lack of plan, in terms of creating the entire animation. Later with staging and pose-to-pose principles, animation creation became more planned. Animators from Disney studios have documented this process of animation along with the key principles in the book titled: The illusion of life (Frank & Johnston 1981). In this process (see figure 1), the director and the scriptwriters are aware of the overall film and create detailed screenplay.

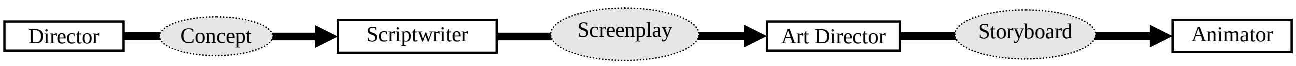


Figure 2: A generic animation creation process for entertainment domain

This benefits other personnel like animators, inbetweeners, background painters, and music directors, who execute the respective tasks in the film. Although an animator is in control of the motion in the particular shot/scene, he/she is dependent on the script and the storyboard for the overall flow of the film/concept.

2.2 Animation creation process for eLearning

Creating effective LOs (having high usability) is not simply a matter of programming. It is a collaborative process involving specialized personnel from various domains. Communication between these personnel is a combination of text, visual and face-to-face interaction (Sahasrabudhe et. al. 2012). Figure 2 shows a generic LO creation process.

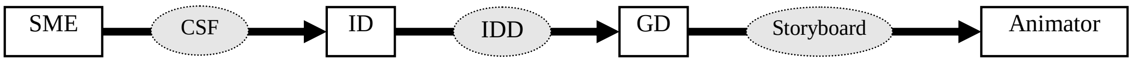


Figure 3: A generic animation creation process for education domain

The subject matter expert (SME) proposes a concept for the LO to the Instructional Designer (ID). The document used for this communication is called as concept selection form (CSF). The ID introduces suitable pedagogy principles and creates an Instructional Design Document (IDD). The IDD has specific instructions (mainly textual) for the animators about the motion to be created on screen. The graphic designer applies his expertise to create a visual design of the LO, based on the IDD. This is a storyboard. This document is a combination of text and visuals. At this stage, the animation development has to begin. The assumption is that the animator knows animation principles. However, whether to apply all the traditional cell animation principles to the LO production, is not addressed in the literature that we have surveyed.

We found literature that explains adaptation of the animation principles in various other domains like, 3D cartoon animation (Chenney 2002), robotics (Breeman 2004), or user interface (Chang & Ungar 1993). We have not found literature where a clear guideline about using traditional animation principles for LO creation process. This paper analyses the process of applying animation principles for the LO creation process. The next section has the analysis of the process.

3 Adaptation of traditional animation principles for LO creation process

As mentioned in the introduction (section 1), the traditional animation principles are classified in three categories. First category is of the principles that help in the actual process of animation production. The second category is of the principles, which are useful in achieving real life motion, in animation. The third category is of those principles, which are useful in creating distortion of the components of the animation. Table 1 summarizes the categorization.

Animation production	Realistic motion	Distortion
These principles are useful in creating motion of the components in animation in a systematic manner.	These principles are useful in providing real life motion to the animation.	These principles are useful in creating distortion of the components in the animation.
Staging	Slow-in and slow-out	Stretch and squash
Timing	Secondary action	Exaggeration
Arcs	Overlapping action	
Appeal	Follow-through	
Techniques of creating motion (Straight ahead action and pose to pose)	Anticipation	

Table 1: Categorization of animation principles

In this study, we found that this categorization is useful, in order to decide the application of the principles to LO creation process. The first category is necessary, as it helps in the animation production. The second and the third category can be used in conditions where the type of motion is specified in the requirements of the LO. The principles in the third category are about distortion of components; therefore, these principles should be used only when the corresponding scientific principle/s require distortion. If the scientific principle/s requires distortion then the details of level and the type of distortion are necessary.

In the following sub-sections, we explain the principles in detail. We first present the principles in brief. Subsequently, we also present the results of our analysis on adaptation to LO creation review carried out. Our analysis is based on specific questions regarding the adaptation in LO creation process with appropriate examples.

Principles useful in animation production:

3.1 **Staging:** From (Lassetter 1987) staging is defined as “Presenting all the stages of the action in the shot so that all the necessary aspects displayed in the shot are clear to the animator”. Use of staging, helps the animator to understand the details of the shot, like position, action, expression, motion and gestures of the character/s.

3.1.1 Consequences of using this principle: Applying this principle makes it easy to convey the details of the action in the shot. The chief animator reads the script (written by the scriptwriter) and refers the storyboard frame for a shot. Later, he/she translates the action mentioned into a series of visuals and mentions the timing. This is helpful to the animator because he/she can see the whole action (along with the timing information) on a single paper. It also helps in understanding the details of a particular frame, in case the frame has some important action.

Staging also defines the importance of a particular character in a shot. This is done using techniques like placement, proportions, lighting etc. It becomes easier, as the viewer knows where to focus on, and this avoids miscommunication.

3.1.2 Example in cell animation: As seen in the figure 4, the details of the action in a shot are

- The first and the last frame in the staging have the positions of the character. (frames 279 and 298)
- Important change over (about the gesture/action/even the dialog are marked along with the frame numbers. See the frame numbers written above the drawing. Also, look at the overall instructions written for the animator to follow. (See the rabbits frame number 296 shown explicitly to convey the gesture in it).

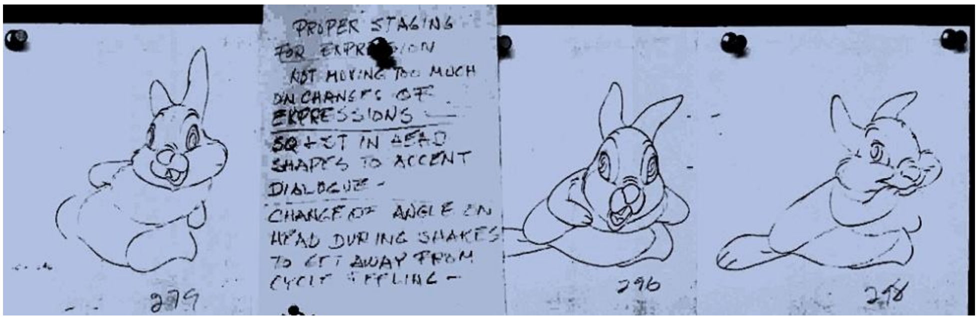


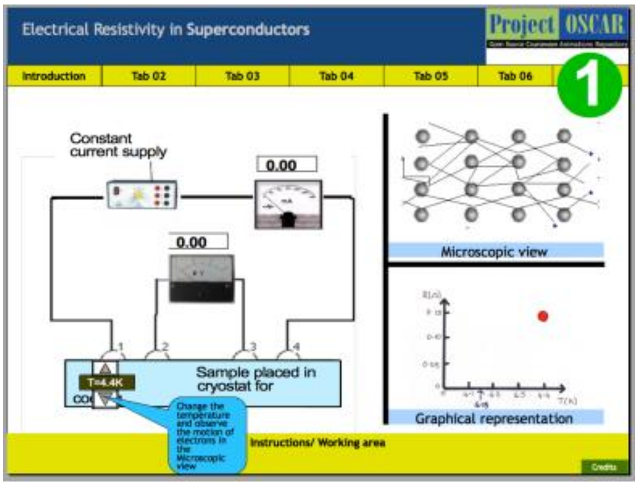
Figure 4: Example of staging principle applied in cell animation (V)

3.1.3 Does this apply to LOs? YES

3.1.4 Rationale for above claim: As compared to the traditional animation, the content in LOs is scientific in nature. In this condition, it becomes important that the animators animate exactly what the ID has written. One cannot guarantee the scientific knowledge animator has regarding the topics of LOs; therefore, it is important that information be transferred in an unmistakably clear format. Staging principle from traditional animation helps the ID and the animator to do so in LO animation.

3.1.5 Illustrative example in LO context: Figure 5 shows the steps involved in the animation (written by the ID writer). Figure 5B shows the visual of the positions of the elements. Combined information of text and visuals are important to the animator, as he/she can read and see this and create appropriate animation.

Description of the Action / Interactivity	Audio Narration (if any)
1. Show the Animation design screen (Slide 7) 2. The temperature meter shows T= 4.4K as shown. 3. Move the electrons along the path in the 'microscopic view window. Refer to Master Layout B for details. (1 second for moving the electron from left to right) 4. A pop up will appear on the 'Click to change the temperature' – If the user clicks on 'click to go to lower temperature', go to Step 2 (Slide 8) – If the user to clicks 'click to go to higher temperature', show the feedback pop-up 'Making it more would be...so try to lower it'.	Click on these buttons to change the temperature



5A *5B*

Figure 5: Example of staging principle applied in LO creation (II)

3.2 **Timing:** Principle of timing helps the viewer to understand finer details of the character like emotions, speed of the actions being performed, physical attributes (weight, size, stiff/soft etc.), and others. More frames used for the action show slow movement and fewer frames show fast movement. It is the number of frames that are used by the animator to depict the attributes of objects and the personality of characters (2). More number of frames between the two keyframes makes an object look heavy and moving slow on screen. The objects shown with less number of frames between the keyframes would seem to be lighter and faster on screen. For example, two extremes, one of the faces on right side of the frame and the other extreme with the face on the right can be having three completely different meanings. With just one inbetween, it would mean that the face is slapped, and the reaction is shown. With five inbetweens it could be that, the character is denying the fact by shaking the head. Nevertheless, with nine inbetweens the character could be having a look at the panorama in the front of him.

3.2.1 Examples in cell animation: Numbers of inbetweens decide the weight and size of the character as shown in the two examples shown in figures 6 and 7.

- Slow movement: Elephant walks very slowly. It also has weight shift from one leg to other. More inbetweens between the key frames creates this motion. One walk cycle takes 24 frames to show slow leg movement.

Figure 6: Example of timing principle applied in cell animation (slow) (VII)

- Fast movement: Butterfly has very fast motion where the flipping of the wings happens in a fraction of a second. It weighs less, and moves faster. Less inbetweens between the key frames creates this motion. See figure below, where one flip of wings takes six frames.

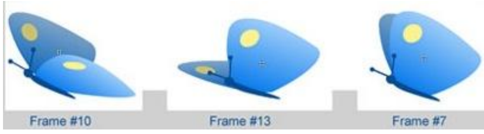


Figure 7: Example of timing principle applied in cell animation (fast) (VIII)

3.2.2 Does this apply to LOs? YES

3.2.3 Rationale for above claim: In LO creation, there could be some concepts which have to be depicted in slow speed, while others in faster speed. Animator can use this principle to decide on the number of inbetweens to create the animation.

3.2.4 Illustrative example in LO context: As shown in figure 8, the LO has a button for playing the animation in slow motion. This helps the users to see the motion clearly. Timing principle would be required for creating the slow motion of the existing animation. This would be done by adding more frames to the existing motion.

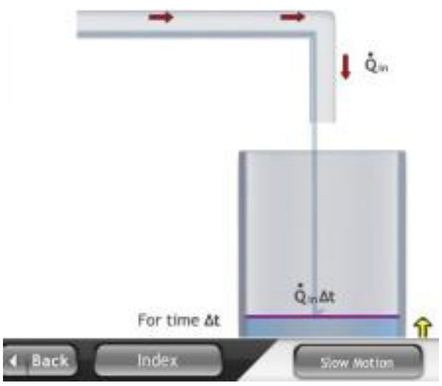


Figure 8: Example of timing principle applied in LO (II)

3.3 **Arcs:** Action happens in a gentle curve rather than a straight line (Lassetter 1987). Principle of arcs is used to create this path for the animators.

3.3.1 Consequences of applying this principle: Avoiding a straight line for animating an action makes it look more natural. Once the path (gentle curve) is created, the animators can place the positions of the action along the path.

These guidelines (arcs) help the inbetweener to make the action livelier, than the action shown along a straight line.

3.3.2 Example in cell animation: In the figure 9, the golfer is hitting the ball with the stick. The path followed by the stick (shown from the images A to F in figure 9). The player lifts the stick high up in the air, and then moves in a curve to hit the ball. It does not stop immediately after hitting the ball, and continues the curvy motion but does not take a straight path. The animator creates the inbetweens using the yellow arc.

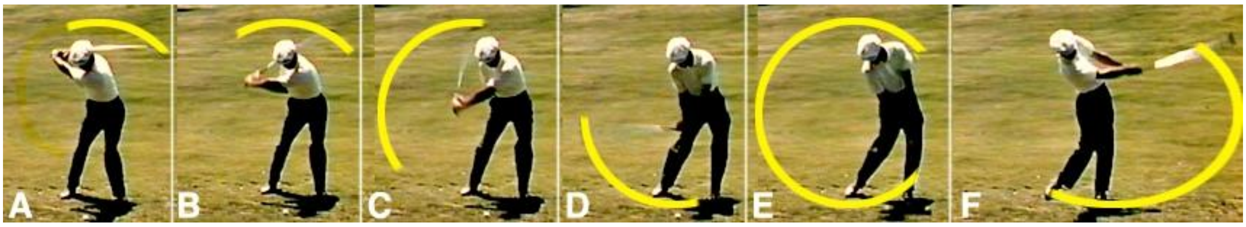


Figure 9: Example of arcs principle in cell animation (IX)

3.3.3 Does this apply to LOs? YES.

3.3.4 Rationale for above claim: In LO creation there is a motion of the objects. However, it is to be created for the respective scientific concept of the LO, which may/may not be a curve always. Depending on the actual line of action, the animators can create the paths, and create animation accordingly. Part of the principle of using the paths as a guideline, and placing the inbetweens along that can be useful for LO creation.

3.3.5 Illustrative example in LO context: As shown in the figure 10, the paths for the movement of the electrons are specified in the IDD. The animator has to use them as guidelines and create the motion. As seen here, if the motion has to be in the straight line (as per the scientific phenomenon), then animation cannot be created using arcs (curves). However, the paths (shown here using arrows) have to be used for creating the inbetweens.

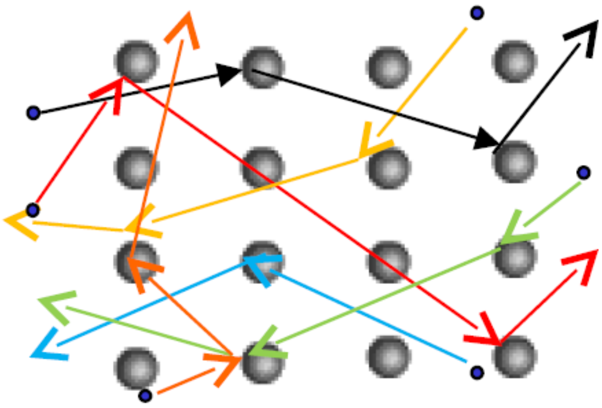


Figure 10: Example of arcs principle in LO (II)

3.4 **Appeal:** Appeal is defined as "a combination of the attributes of an object: a quality of charm, pleasing design, simplicity, communication, or magnetism" (Lassetter 1987). An action would make the maximum impact if it can communicate the desired emotion.

3.4.1 Consequences of applying this principle: Applying the principle of appeal, helps in clarity of communication. Characters or objects presented in the appropriate size, angle, action etc., communicate the desired messages to the viewers.

3.4.2 Example in cell animation: In the figure 11, a scene at night is shown. The light is less, and therefore it is important that the viewers should be able to distinguish between the characters.

Figure 11: Example of appeal principle applied in cell animation (XVII)

The director has used the principle of appeal, and placed the characters with enough space between each other. Additionally, the poses of the characters are chosen in such a way that the action is clear (hands spread across and holding each other). These characters are seen standing in the water. The placement is done in such a way that the trees do not interfere with the characters in the frame.

3.4.3 Does this apply to LOs? YES

3.4.4 Rationale for above claim: In eLearning domain, this becomes an important principle. The viewers are drastically different. Animation films are seen for entertainment and LOs are used for education. So in order to keep the viewer interested in what is presented, and to communicate the exact concept on screen, this principle is required to be incorporated while creating LOs.

3.4.5 Illustrative example in LO context: In the example shown below (figure 12), the LO has two important components. One is the weighing balance and the other is the graph showing the variations. The design has the appeal principle; where in the screen has an enlarged view of the weighing balance. This makes the user interested in looking and understanding the concept. It also makes it very clear, as the weighing balance shows the details like the spring movement and the marker.

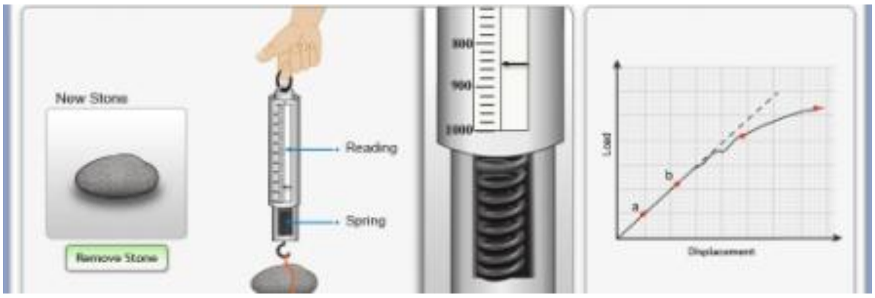


Figure 12: Example of appeal principle applied in LO (II)

3.5 **Techniques used for the animation creation:** In the process of actual creation of animation. Two important types of techniques are commonly used. They are Straight ahead and Pose-to-pose. In computer based animation processes, pose-to-pose animation technique is preferred over straight ahead animation.

3.5.1 **Straight ahead animation:** Straight ahead action is a method of animation, where the animator creates the frames (of animation) in a linear sequential manner. Frames are drawn or created on computer one after the other. This method of animation creation is suitable for hand drawn, cut out or claymation. It is difficult to create computer animation using this method (Lassetter 1987). Computer uses the pose-to-pose (key frame) method, where the inbetween frames follow the interpolation principle.

3.5.2 **Pose-to-pose animation:** In this technique the animators first create the key frames and later create the inbetweens. This planned way of creating animation is faster, as the roles of the stakeholders are clearly defined. The animator creates the key frames, and the inbetweener creates the inbetweens. It makes the overall animation process well divided and in turn more effective.

3.5.2.1 **Consequences of applying this principle:** This method of animation is a planned method. The animation can be created quickly, and also more effectively, using this method. The entire execution of creating the frames is planned in the beginning. This method helps in dividing the animation work to the animator and the inbetweener, there by speeding the process. Using this method animator has more control on size, shape and the angle of the characters, as compared to the straight ahead method of animation.

3.5.2.2 **Example in cell animation:** As seen in figure 13, the ball starts from frame 1 and hits the ground at frame 9. It rises up after hitting the ground, and frame 12 is shown to be at its highest position in air, for that particular bounce. The ball hits the ground again at frame 17. This goes on till the end. Here, the animator has carefully planned the action, keeping the gravitational force and the weight of the ball in mind.

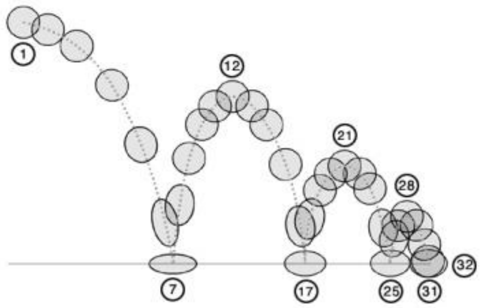


Figure 13: Example of pose-to-pose principle applied in cell animation (XVI)

The total animation has some keyframes (1, 7, 12, 17, 21, 25, 28, 31, and 32), and other inbetweens. This makes it possible to distribute the work to various contributors in the animation creation process viz. Chief animators, animators and inbetweeners. Not using this method may result in a slow process (may not be scalable), as one animator has to create the entire animation.

3.5.3 **Does this apply to LOs?** YES

3.5.4 Rationale for above claim: LO animations are created using computers. This principle is suitable for a process where the key frames are created first and then the computers create the inbetweens. It is also important to use this method for LO creation, as the scientific animations have changeovers in the actions, where the behaviour of the objects in the animation changes. It is possible to identify the keyframes using this principle, and create the inbetweens accordingly.

Principles useful in achieving realistic motion:

3.6 **Slow-in and Slow-out:** As mentioned in (Yee 2001) “Animation begins slowly, smoothly accelerates, and then decelerates at the end. Most of the movement occurs in the middle third of the time interval. This provides good visual cues to help the user anticipate the movement of nodes into their new positions”. The slow beginning is the 'slow in' animation and the deceleration at the end is the 'slow out' animation.

3.6.1 Consequences of applying this principle: As mentioned in (Chang & Ungar 1993) applying the slow in and slow out helps in giving a feeling of weight to the character and physicality to the movement. If this principle applied the viewer is able to see the effect of various forces applied on the object e.g. gravitational force. Not applying the principle makes the animation look unrealistic.

3.6.2 Example in cell animation: Pendulum is a classic example for demonstrating the principle of slow in and slow out (figure 14). The motion becomes slower from the central position (shown in grey colour) to the key pose 01 (left). At key pose 01, the pendulum stops, and then it begins to come down and stops again at the key pose 02. The time span between the centre frame and key pose 01 is the slow in and the span from the key pose 01 to the central frame is the slow out.

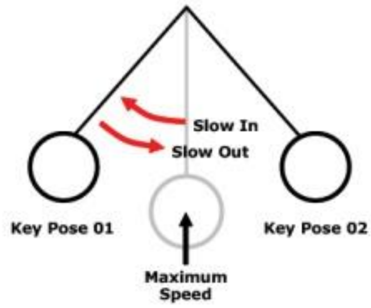


Figure 14: Example of Slow in and slow out principle used in cell animation (XIV)

3.6.3 Does this apply to LOs? YES

3.6.4 Rationale for above claim: It is important that, motion depicted in LOs is scientifically correct. In order to achieve it, the IDD would mention the details of the motion. Principle of slow in and slow out helps the animator to achieve the expected motion by the ID writer and the SME.

3.6.5 Illustrative example in LO context: In the example given (figure 15), the hydrogen atoms have to be animated from the initial position and further they have to be shown moving in the open space. Using slow in slow out principle will make the motion look realistic; as no object can attain a faster speed from the point it starts moving. It has to start gradually and stop by slowly reducing the speed.

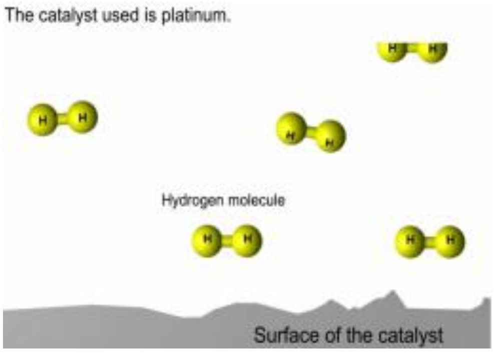


Figure 15: Example of Slow in and slow out principle used in LOs (II)

3.7 **Secondary action:** As per (Lasseter 1987) secondary action is, “a supplementary action that supports the main action”. The principle of secondary action is used for completeness in the depiction of the overall action. Every action consists of supplementary motions supporting the primary motion. Combination of these actions creates a correct and natural action.

3.7.1 Consequences of applying this principle: Even though the primary action is important aspect in the given action, the realism in the motion is dependent on the other supplementary actions. Excluding the supplementary actions and animating only the primary action would make it look unrealistic / unnatural and convey wrong information. Ex: Walk cycle without ANY movement of the hands, or head. This will not only look unnatural, but also will convey wrong information about the actual anatomical structure of the character (as the shoulder joint is not working) or the balance of the body.

3.7.2 Example in cell animation: The primary action in a walk cycle (see figure 16) is the movement of the legs and the torso, which is attached to it. The hands are attached to the upper part of the torso, and significant parts of the hands are unattached or free. This hands movement is a part of the secondary action. The hands do not move, but the movement of the torso causes this motion. One end of the hands is attached, and the other is free.

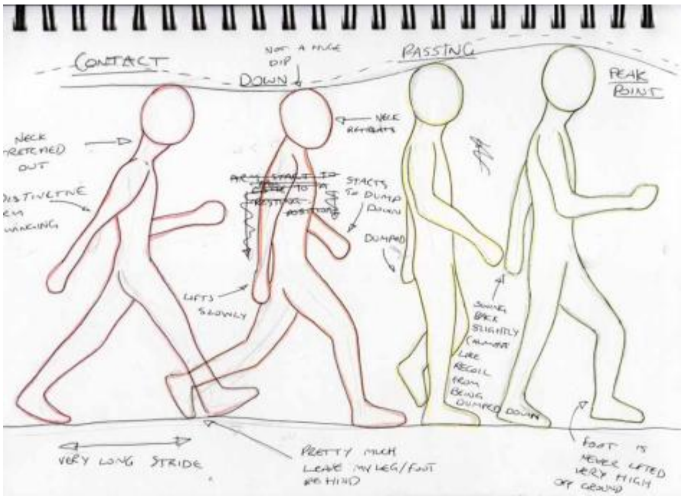


Figure 16: Example of secondary action principle applied in cell animation (XIII)

3.7.3 Does this apply to LOs? YES

3.7.4 Rationale for above claim: The objects in LOs sometimes have complex structures, where the free ends of the objects may have other motion apart from the primary motion. Principle of secondary motion will help the animator to animate other movements of these objects and create correct motion.

3.7.5 Illustrative example in LO context: In the drilling animation, the drill has a rotary motion, when it is drilling down the ground (see figure 17). The piston to which it is attached has a vertical motion to make it go up and down. There is a mechanical arm, which folds in a particular way to enable the drill to dig inside the ground at a particular point. The actions of the piston and the mechanical arm are secondary actions. These have to be defined and thought well along with the primary action of the rotary motion of the drill.

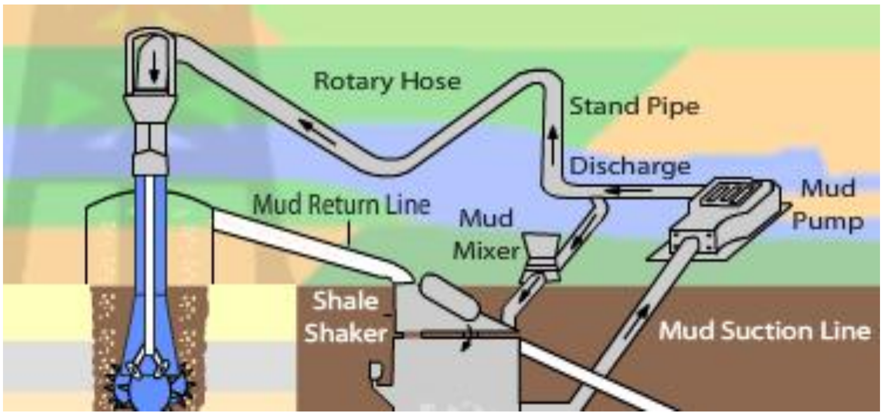


Figure 17: Example of secondary action principle applied in LO (II)

3.8 **Overlapping action:** The action that maintains the continuity between the two actions is the overlapping action. It is based on the assumption that no action will come to a complete stop before starting the second action. It acts as a transition between the followthrough (see section 3.8) of the first action and the anticipation (see section 3.2) of the second action is the overlapping action

3.8.1 Consequence of applying this principle: Overlapping principle helps in eliminating 'dead' time between actions. Dead time is the gap of time in which nothing moves on the screen. Overlapping action principle keeps the viewer interested in the actions, and presents correct information. If the overlapping principle is not used then there will not be any movement between the two actions.

3.8.2 Example in cell animation: As shown in figure 18, the character stretches on the branch, and then has to get up in joy. The frames between the keyframes 9 and 13 merge these two separate actions. These frames make sure that action 1, of stretching on the branch does not stop completely. The action 2 of dancing in joy starts towards the end of action 1. If the overlapping principle is not used, the character will stop after stretching out on the branch, and then get up to dance with joy. The dead time between these two will not be interesting for the viewers.

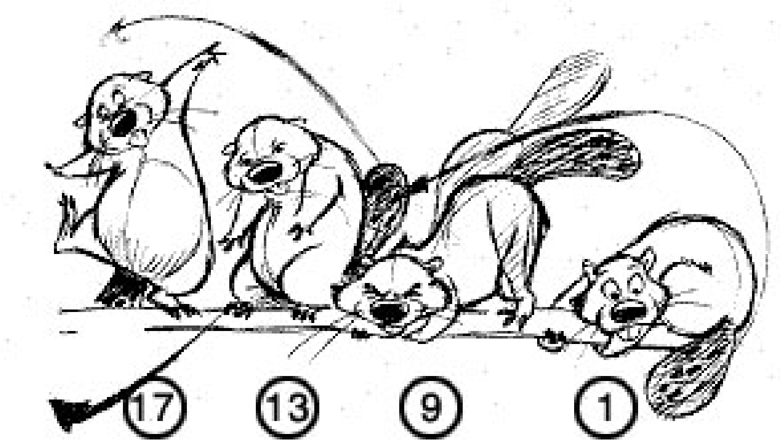


Figure 18: Example of overlapping action in cell animation (XII)

3.8.3 Does this apply to LOs? YES

3.8.4 Rationale for above claim: Motion of the objects specified in the LOs would also have situations, where the actions would be overlapped. In these conditions, principle of overlapping action would be useful. Similar to the animation for the entertainment domain, the objects/characters animated in LOs would need not stop after one action and then begin the other action.

3.8.5 Illustrative example in LO context: In an interactive demo of an experiment (see figure 19), there are buttons for changing the input parameters. A graph is animated dynamically, based on the inputs selected by the users. The parameters have a defined range, and the user is free to select a value at any time. If the animation is displayed with the parameters set at a particular point, and the user changes it. In this case, the animation should change the direction, speed and the colour of the graph being created to match the changes in the parameters. This change over from one setting to the other has to be displayed in a seamless manner, so that the user can see it.

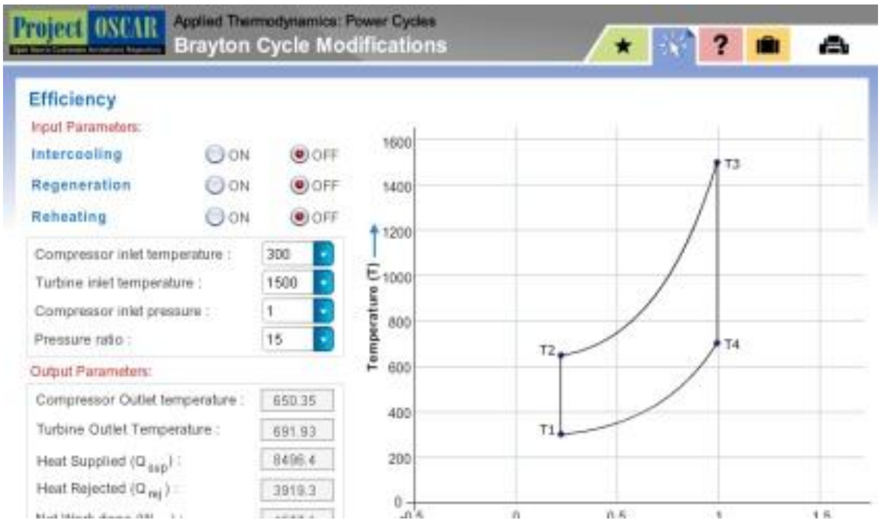


Figure 19: Example of overlapping action in LO (II)

3.9 **Anticipation:** From (Breeman 2004) anticipation is “preceding action to the main action”, or as mentioned in (Lassetter 1987, Kim 2006) “action which is done as a preparation for the main action” or (Yee 2001) “action which gives the audience a cue about the main action to follow”. It is based on the contraction and expansion phenomenon, where contraction would happen before expansion.

3.9.1 Consequences of applying this principle: Anticipation is used to show the preparation, which in turn enhances or highlights the main action and the aftermath of the action. Anticipation is used to communicate the intentions of a character to, the audience. It makes action more convincing and expressive. It increases viewer's expectation about the intensity of the action to follow (Kim 2006).

3.9.2 Example in cell animation: In the example shown in figure 20, the action which the character has to perform is 'going to the right side'. It has to be a fast action as this is start of a chase. So the actual animation would require less number of frames (Section 3.5: Timing). In the example the character lifts his foot to the left, slowly enough for the audience to see it (frame 2). Once this preparation is shown, the audience is well prepared to witness the actual action. The character (after broadcasting that he is going to go offstage soon) goes out (frames 3 and 4). This action of the character is enjoyed by the viewers on the basis of frame 2 (anticipation) along with the actual action frames 3 and 4.

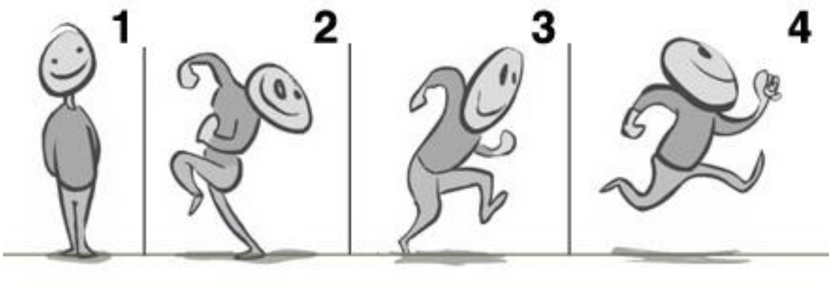


Figure 20: Example of anticipation principle applied in cell animation (III)

3.9.3 Does this apply to LOs? YES

3.9.4 Rationale for above claim: Using anticipation in LO creation would be required to make the actions in the LO animations look natural and correct. On the other hand, it is important avoid the exaggeration of anticipation, as used in the traditional animation. This exaggeration may result in incorrect depiction of the scientific concepts in LOs (see section 3.4)

3.9.5 Illustrative example in LO context: Example given below is to substantiate the decision of considering the principle of anticipation for the LO creation process. Example: Cannon ball fired in the air (figure 21): It will look natural with some amount of anticipation shown when the cannon is fired. Animation of the cannon firing, without anticipation or recoil (followthrough principle) may not look convincing regarding the distance the ball travels.

Figure 21: Example where anticipation principle could be applied in LO (IV)

3.10 **Followthrough:** Every action is split in three parts, first is the preparation (section 3.9: anticipation), the second is the actual action and the third part is of coming to rest (after completing the main action). Followthrough principle is applied in part two and three. It gives correctness and appropriate termination to the action.

3.10.1 Consequences of applying this principle: There are few objects which are single units, so when they stop, we can see them static, almost immediately. Some objects are made up of parts which are attached to the main part. In these objects, if the main part moves these open ends also move. This movement is completely based on the main parts of the object. Therefore, the movement of the other (open ends) 'follows' the movement of the main part. For example: Cape worn by Superman follows the direction of the moving body.

Secondly, if the main part stops suddenly, the other connected parts continue to be in motion little later as compared to the main part (owing to gravity, weight of the hanging part etc). Applying the follow-through principle results in animating these parts, and this achieves correctness in the overall animation. Continuing the same example of superman, the cape has to fall down, after he lands on the ground. If it doesn't then it may look, as if the cape is made up of a stiff material, which would be incorrect. If this principle is not used, the motion of the objects may come to a sudden stop, and would look unnatural.

3.10.2 Example in cell animation: As shown in figure 22, a ringmaster in the circus is having a whip tied to the top of the stick. As the ringmaster moves the stick, the whip follows the movement of the stick. The whip does not stop at the point where the stick stops; but continues to be in the motion (direction of the action) before it loses the force applied by the ringmaster. The motion of the whip with respect to the motion of the stick, is the followthrough of the whip. It continues further, even after the stick stops, and comes to resting position, after some time. This motion is based on the motion of the stick (until it came to a stop), so it is termed as follow-through (of the stick).

Figure 22: Example of followthrough principle in cell animation (X)

3.10.3 Does this apply to LOs? YES

3.10.4 Rationale for above claim: Certain objects shown in LOs may also have free ends. Therefore, the motion of these free ends can be created based on the principle of follow through. If the motion is not shown, it may create a miscommunication. See the example below for more clarification of the rationale:

3.10.5 Illustrative example in LO context: A microorganism has tentacles (made up of soft material). When the organism moves ahead, the tentacles move along with the body. It would be incorrect to show the tentacles without movement. The viewers will get a message that the tentacles are made up of stiff material, and therefore they are not moving. In such conditions, principle of followthrough is useful in creating the motion of the tentacles having soft or lightweight material (see figure 23).

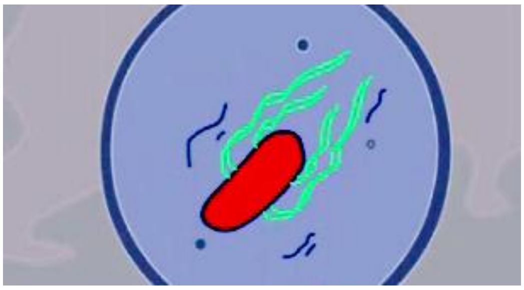


Figure 23: Example of followthrough principle in LO (XI)

Principles useful in creating distortion

3.11 Stretch and Squash: From (Frank & Johnston 1981) stretch is defined as “The distortion of an object to depict the speed at which it is moving”. Stretch is also used to show the distortion while an object is expanding, lengthening or widening. Squash is defined as “The distortion caused by the contact, impact or collision with another object” (Frank & Johnston 1981). Every object (made up of any material) changes its shape when it collides with other object. This phenomenon is not visible to the naked eye for hard materials like metals and wood. It can be seen in cases of objects like balloon, rubber ball, and soap bubbles etc. Based on (Geng 2010) “Stretch anticipates the collision, and the squash exaggerates its effects”. This principle is used extensively for exaggerating the depiction of the material of the object and the force/s acting on it. This creates a comic relief as the distortion is beyond the extremes of natural shapes and positions.

3.11.1 Consequences of applying this principle: This principle helps animators to amplify attributes of the object/s. It becomes easy for the viewers to understand or believe about the aspects like:

- Material that is used to make the object like soft v/s hard objects.
- Some additional information about the material of the objects interacting with the main object. Ex: Whether the ground shown in figure 24 is made up of concrete, not of rubber/sand.
- Various forces affecting movement of the object. Ex: Ball has been dropped from a height of 3 feet or 35 feet, whether it is dropped or thrown forcefully.

If the principle of stretch and squash is not used, then the viewer may have trouble about understanding the material used for the object. If the ball is made up of rubber, and the motion shown onscreen is without stretch and squash; this may lead to a conclusion that the ball is made up of harder material like wood/plastic which would be incorrect.

3.11.2 Example in cell animation: A ball bounces animation of a rubber ball. See figure 24: The ball A is shown with uniform shape in all the positions (frames) of the ball. This displays uniform shape animation of the ball. So, even though the ball is moving at different speeds, or hits the ground, the shape of the ball is unchanged. This makes it difficult to believe that this is a rubber ball; it actually feels like a metal/wood ball (which would not distort while in motion or at the point of impact). Ball B is shown elongated (stretched) at the positions where it is coming down. At the position of impact, the ball is shown distorted owing to the collision with a hard surface. So, a combination of stretch and squash makes the viewer get the rubbery feeling of the ball.

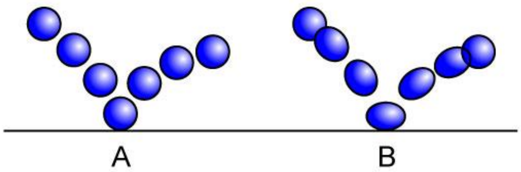


Figure 24: Example of ball bounce motion without (A) and with (B) stretch and squash principle (I)

3.11.3 Does this apply to LOs? Partly, with adaptation, and in specific conditions mentioned in the IDD. The principle can be applied if at all any material properties are to be shown with distortion, where the distortion should be based on the corresponding scientific principle. The decision should not be left to the animator's imagination.

3.11.4 Rationale for above claim: In the entertainment domain, squash and stretch are used in exaggerated manner which is not the case in LO animation. The objects in the LOs are planned for a specific purpose of depicting scientifically/technically correct information. Distorting (stretching/squashing) of the imagery is not useful in LOs, as it would present the scientific facts in a distorted manner.

3.11.5 Illustrative example in LO context: Drilling operation LO: As shown in the figure 25, the drill hits the various layers of the earth and creates a tunnel. If the drill squashes at the time of impact, then the it would be difficult for the viewers to believe that the drilling machine is made up of a harder metal as compared to the earth crusts, and therefore it is distorting.

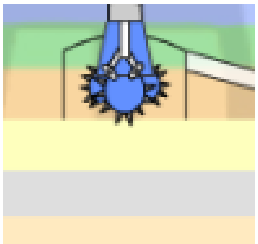


Figure 25: Example of an LO animation where stretch and squash principle cannot be applied (II)

3.12 Exaggeration: As per (Chang and Ungar, 1993) exaggeration is, "increasing the prominence of features deemed significant by the animator, whether these features are physical characteristics, qualities of action, or extremities of situation". As mentioned by (Breeman, 2004) exaggeration is used to "accent actions, personalities and expressions in order to make them more convincing."

3.12.1 Consequences of applying this principle: Applying this principle, helps the animator in achieving the goal of making the animation more interesting. Further, it is also used to achieve two important goals:

- Capturing attention of the viewer: The extra prominence added to the features of the character captures the attention of the viewer. This is possible, as this particular motion is different from others. Ex: A character is flattened like a paper when a car goes over him.
- Staying in memory of the viewer: This prominent motion then is easy to be retained in the memory of the viewer, as it is unusual as compared to the regular motion of the other characters. Ex: A character causes a cut out of his shape when running through a wall and goes through it.

3.12.2 Example in cell animation: Eyes popping out (figure 26): The script mentions that the character was so surprised, that his eyes popped out. When the shot comes for the scene planning stage, the animator takes a decision of making the 'eye popping' action 'louder'/more effective by exaggerating it. The animator first tries to increase the impact of the action by creating a bulge for the eyes, and thereby making the eyes look elongated than the real/normal shape. This is medium exaggeration. Further, he/she increases the impact by showing the eyeballs springing out of the sockets of the eyes, and hanging out. In this example, as per the definition above, animator has presented the information in a wilder/extreme form.

Figure 26: Example of exaggeration principle applied in cell animation (VI)

3.12.3 Does this apply to LOs? Yes, but in specific conditions if mentioned in the IDD.

3.12.4 Rationale for above claim: In the LO animations convey scientific concepts. Given this condition, the principle of exaggeration, which has a strong base of distorting the imagery, is to be used only when it is the demand of the concept. Secondly, the level of usage also should be defined in the concept, and not by the animator. This will help in maintaining the accuracy of scientific content.

3.12.5 Illustrative example in LO context: As shown in figure 27, the reactor is getting a supply of a gas, and the reaction is going on. If the motion of any of the components is exaggerated, for example: the bubbles burst out forcefully, the tube deforms, as the gas passes through it, or the lid shakes and breaks because of he reaction inside etc these will communicate wrong concepts to the viewers. In LO creation, motion of the objects cannot be exaggerated for comic relief (as it is done in entertainment domain). On the contrary, every motion has to be created on the basis of the details mentioned by the ID. The distortion of the shapes and motion also has to be within the permissible limits mentioned in the IDD.

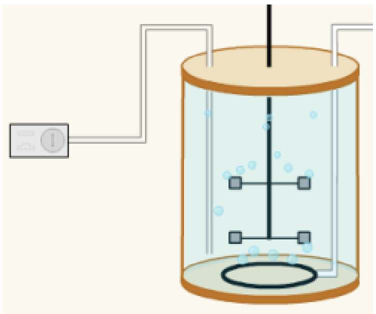


Figure 27: Example where exaggeration principle should not be applied in LO (II)

4 Summary and future directions

Based on the rationale presented in section 3, we find that all the principles of traditional cell animation are necessary for the LO creation process. In case of some principles (category 2 and 3) their application has to be done only is the concept of the LO demands it. Further, the amount/intensity of application of these principles should be determined by the concept of the LO.

In comparison with the traditional animation production, the LO creation has an important objective of education. The concept presented in LO should be presented in its accurate form, in order to achieve proper knowledge transfer. We believe that the examples and the guidelines presented in this paper, would be helpful for the animators to use the principles accordingly in the LO creation process.

Further, similar analysis is required for graphic design, multimedia design and interaction design which are necessary for LO creation. We are in process of creating a document (with cumulative guidelines from all the four domains) that would be useful for the animators, in the LO creation process.

References:

1. Chang, B. W., and Ungar, D., (1993). 'Animation: from cartoons to the user interface', *Proceedings of the 6th annual ACM symposium on User interface software and technology*, p.45-55, December 1993, Atlanta, Georgia, United States (doi>10.1145/168642.168647)
2. Chenney, S., Pingel, M., Iverson, R., and Szymanski, M. (2002). 'Simulating cartoon style animation'. *Proceedings of the second international symposium on Non-photorealistic animation and rendering* - NPAR '02, 1, 133. New York, New York, USA: ACM Press. doi:10.1145/508551.508553
3. Clark, R., and Mayer, R. (2007). 'E-learning and the science of instruction: Proven guidelines for consumers', *John Wiley & Sons*, 28-Sep-2007 - 476 pages.
4. Fisher, D. (2010). 'Animation for visualization: Opportunities and drawbacks', Chapter 19, in Steele and Iliinsky (editors), *Beautiful visualization*, Cambridge: O'Reilly, 2010, pp. 329-352
5. Kim, J., Choi, J., Shin, H. J., & Lee, I., (2006). 'Anticipation Effect Generation for Character Animation', pp. 639-646.
6. Lasseter, J., (1987). 'Principles of traditional animation applied to 3D computer animation'. In *Proceedings of the 14th annual conference on Computer graphics and interactive techniques* (SIGGRAPH 1987), Maureen C. Stone (Ed.). ACM, New York, NY, USA, pp. 35-44. http://doi.acm.org/10.1145/37401.37407
7. Neo, K. S., Lin, Q., & Gay, R. K. L., (2004). 'A Web-based System for Interactive Visualization of Scientific Concepts', Short Paper Symposium *A Quarterly Journal in Modern Foreign Literatures*, 1(212), 155-158.
8. Sahasrabudhe, S., Iyer, S. & Murthy, S., (2012) (In print), 'Embedding visual communication principles in Instructional Design phase of Learning Object (LO) creation process', *EdMedia 2012*, Denver USA,
9. Thomas, F., and Johnston, O. (1981). 'Disney Animation: The Illusion of Life'. New York, Titan Press, pp. 42-49.
10. Breemen, V., (2004). 'Bringing robots to life: applying principles of animation to robots'. *CHI2004 workshop Shaping Human–Robot Interaction*, Vienna.
11. Geng, W.,(2010). 'The algorithms and principles of non-photorealistic graphics : artistic rendering and cartoon

animation', *Jointly published with Zhejiang University Press*, 1st Edition., 2010, 360 p. 310 illus. in color. ISBN 978-3-642-04890-6

12. Weiss, R., Knowlton D S., Morrison G R., (2002). 'Principles for using animation in computer-based instruction: theoretical heuristics for effective design', *Computers in Human Behavior*, Volume 18, Issue 4, July 2002, Pages 465-477, ISSN 0747-5632, (http://www.sciencedirect.com/science/article/pii/S0747563201000498)
13. Yee, K.P., Fisher, E, Dhamija, R., and Hearst M., (2001). 'Animated Exploration of Dynamic Graphs with Radial Layout. *InfoVis'01.* pp. 43-50.
14. Windschitl, M., (1996). 'Instructional animations: The in-house production of biology software', *Journal of Computing in Higher Education*, Springer Boston, Pages 78-94, Volume 7, Number 2 / March, 1996
15. Bratina, T., Hayes D., & Blumsack S., (2002). 'Preparing Teachers To Use Learning Objects', *The Technology Source*, November/December 2002. Available online at http://ts.mivu.org/default.asp?show=article&id=961.
16. Boyle, T., (2003). 'Design principles for authoring dynamic, reusable learning objects', *Australian Journal of Educational Technology,* 2003, 19(1), 46-58
17. Wang, S., (2008). 'Ontology of Learning Objects Repository for Pedagogical Knowledge Sharing', *Interdisciplinary Journal of E-Learning and Learning Objects,* Volume 4, 2008

Images used in the examples are taken from the following websites:

I. Stretch and squash: http://charlesthompson2.wordpress.com/2012/02/03/squash-and-stretch-presentation/
II. Various LOs taken from this website: http://oscar.iitb.ac.in
III. Anticipation: http://www.freeopenbook.com/flash8-bible/BBL0093.html
IV. Anticipation: http://phet.colorado.edu/en/simulation/projectile-motion
V. Staging: Illusion of Life book, (1)
VI. Exaggeration: http://jus4tday.blogspot.com/
VII. Timing: http://nickchristian2d.blogspot.com/
VIII. Timing: http://nickchristian2d.blogspot.com/
IX. Arcs: http://perfectgolfswingreview.net/downswing.htm
X. Followthrough: http://www.toynk.com/product/FRM-66999-P/Circus-Ring-Master-Tailcoat-Adult-Costume.htm
XI. Followthrough: www.dil.iitb.ac.in
XII. Overlapping action: http://www.keremcaliskan.com/a-tutorial-on-computer-animation-1/
XIII. Secondary action: http://www.royzy.co.uk/2008/12/holy-briefs-batman-another-walk-cycle.html
XIV. Slow in and slow out: http://lmu-ac-uk.campuspack.eu/Groups/201011_-_0483/Play_wiki/Anticipation-SlowInSlowOut/slowinpendulum.jpg!351x275
XV. Straight ahead: http://webollywood.com/indian-bollywood-actors/aamir-khan/the-making-of-tare-zameen-par-clay-animation
XVI. Pose-to-pose: http://ticktockcrocodile.blogspot.com/2010/12/slow-in-and-slow-out.html
XVII. Appeal: http://en.wikipedia.org/wiki/File:Achmed1.jpg