

Design considerations for creating eLearning animations

By

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Declaration

I declare that this submission is my own work and to the best of my knowledge and belief it contains no material previously published or written by another person, nor material which has been accepted for award of another degree or diploma at a university or other institute of higher learning except where due acknowledgment is made in the text. I further declare that this research report has not been submitted by me to any other university.

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Certificate

This is to certify that the candidate, Mr. Sameer S Sahasrabudhe (PRN: SR200149), has satisfactorily conducted research under our guidance on the topic:

'Design considerations for creating eLearning animations'

This thesis is the result of the candidates own work for not less than eighteen months and is of sufficiently high standard to warrant its presentation for PhD (Subject Communication: Computer Science) degree of Yashwantrao Chavan Maharashtra Open University, Nashik-422 222, Maharashtra, India.

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Abstract

Learning object (LO) is a smallest independent structural experience that contains an objective, a learning activity and an assessment. Usability of LOs is important for creating effective eLearning content. Major stakeholders participating in a typical LO creation process are the subject matter experts (SMEs), instructional design (ID) writers and animators. Literature suggests that constant communication between these stakeholders, assisted with good documentation results in usable LOs. However, this ideal scenario is difficult to implement, owing to scarcity of experienced personnel, and limited availability of these experts. Templates are used at respective stages to achieve systematic communication in the LO creation process. One of the key problem that still persists is the miscommunication between ID writers and animators. Face-to-face interaction between ID writers and animators is a popular solution applied to address this problem. However, having unlimited face-to-face interaction as and when required, is not a scalable option.

The focus of this research is on this communication between ID writers and the animators, since this is the stage where the textual+verbal information is translated in to visuals. We start off by analyzing the feedback from the animators, which reveals lack of visual communication (VC) aspects in the ID documents received. The solution approach used in this research is to modify ID template (IDT) by operationalizing principles from VC domains (graphic design, multimedia, interaction design and animation). Design based research (DBR) is used for conducting research cycles (RCs) to modify the IDT. In the initial RCs, ID writers (n=16) and animators (n=15) validate the versions of IDTs until a version is found usable.

Multiple experiments are conducted with students (n=128) and SMEs who compare usability of two types of LOs. First type is created using IDT having VC principles and the other type is created without the VC principles. Results show that the LOs created using VC principles are more usable, as compared to the LOs created without them ($p=0.000$ and $z=0.016$). Unstructured interviews with SMEs reveal that the LOs created with the VC principles, are not only usable, but these LOs are engaging and promote learning.

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Chapter 1

Introduction

1.1 Background

In recent years, increased computer penetration has resulted in increase in the applications of electronic learning (eLearning). eLearning is defined as ‘*a means to deliver the information via electronic media*’ Pastore (2002), or as ‘*technology-based learning in which learning materials are delivered electronically to remote learners via a computer network*’ Zhang, Zhao, Zhou, and Nunamaker Jr (2004).

Government of India is focusing on the potential of eLearning technologies through various programs like ‘National Mission on Education through Information and Communication Technology’ *NMEICT, Govt. of India* (2013). eLearning is found effective to address important issues because of its advantages like, reach, re-usability, asynchronous availability and integration of multimedia.

Modern age educational techniques have adopted eLearning as a stable component because it is learner-centered, and provides a self-paced learning environment. It has the ability to integrate multiple mediums required to explain a particular concept. It is also useful in terms of scalability, where classroom teaching has limitations.

eLearning types

Figure 1.1 shows the types of eLearning content (Steen, 2008). These can be broadly categorized as static and dynamic content. Static content is mostly in the form of images, graphs and diagrams. There are few types of content which only have audio, like narrations and lecture recordings (without visuals). Motion graphics contain videos shot by camera, and computer generated imagery (animations). Some processes and concepts have complex viewing angles, viewing size or speed of motion are difficult to be seen and registered for a naked eye. In some of the cases where extremities like

temperature or sizes (from nano structures to mega ones like solar system etc) even camera videos are incapable of providing visualizations.

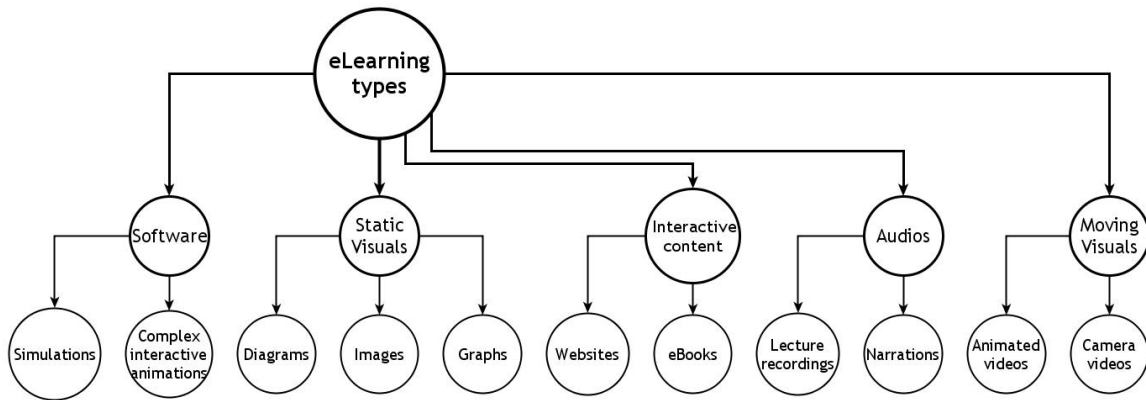


Figure 1.1: Various types of eLearning content

Animations is a preferred medium especially in these scenarios. It opens up the possibilities of adding moving visuals of any object (too big or too small), views from any angles (microscopic or otherwise) etc. One of most differentiating feature that animation provides is interactivity. Interactive eBooks and web based content are emerging trends in eLearning. Some researchers agree that these solutions are not designed to replace the instructors, but they can certainly be useful as additional aid for the students to understand the concepts (Ellis, 2004), (Mackenzie & Jansen, 1998). Hence, today animation is recognized as an important component of eLearning.

A learning object is an interactive, standalone unit which often has animation as a component. It has defined learning objective and assessment built into it. Learning objects (LOs) are small in size and also in terms of the duration (runtime). LOs can be combined to create a course. These features make LOs a popular type of eLearning content. Subsequent sections discuss the creation processes followed by various LO creators.

1.1.1 Learning objects (LOs)

Out of various types of eLearning content, one of the preferred type is Learning Objects (Bratina, Hayes, & Blumsack, 2002), (Boyle, 2003), (Wang, 2008). This section presents more details of this medium. LOs are of different types. Some are textual, while some also have visuals supporting the text. Degree of interactivity offered to the user also differs. Examples below show three variants of LOs, first with textual content (a), second having text+visuals (b) and third having interactivity options for the users (c) 1.2.

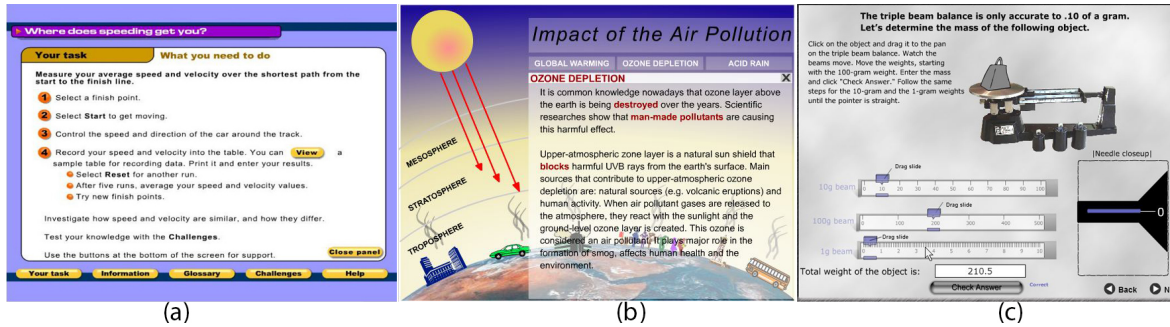


Figure 1.2: Various examples LOs

1.1.2 Different definitions of LOs

There is no one accepted definition of a LO. Various researchers have defined LOs in different manner. Here are few samples:

Harvey (Harvey, 2005) defines an LO as, ‘*a digital entity intended to further the achievement of a specific learning objective*’.

According to L’Allier (L’Allier, 1997) LO is, “*the smallest independent structural experience that contains an objective, a learning activity and an assessment*’.

South et al. (South & Monson, 2000) in their paper define LO as ‘*digital media that is designed and/or used for instructional purpose. Such objects range from maps and charts to video demonstrations and interactive simulations*’.

A working definition by The Learning Technology Standards Committee defines LO as ‘*any entity, digital or non-digital, which can be used, re-used or referenced during technology supported learning*’ (Wiley, D. A., 2012).

Out of the definitions given above, the repository chosen for this research, (Project OSCAR) (*Project OSCAR website*, 2013) follows the definition by L’Allier (L’Allier, 1997). The details of this repository are mentioned in section 1.1.5.

Following sections provide details about the stakeholders in the LO creation process and few examples of LO creation processes followed by various organizations.

1.1.3 Stakeholders in the LO creation process

Creating effective LOs having high usability is not simply a matter of programming; it is a collaborative process involving specialized personnel from various domains such as the subject matter, instructional design, visual communication and software development (Weerasinghe, Nishakumari, & Hewagamage, 2007). Communication between these personnel is a combination of text, visual and face-to-face interaction. Each organization involved in creating LOs, modifies the components of the process to suit their context. Literature regarding LO creation processes is mainly available from or-

ganizations creating the LOs (Websites: *Excelsoft* (2013), *USPatent* (2013) and *Espire* (2013)). Details of the stakeholders in a typical LO creation process are given below:

Subject Matter Expert (SME)

LO creation process starts with SME deciding a topic for the LO to be created. SME has the required academic knowledge for the chosen topic. She/he details out the concept in such a manner that the instructional design writer is able to understand it.

Instructional Designer (ID) or ID writer

ID writer is the person who writes the further details of the concept. She/He applies the instruction design principles, to convert the concept in a document that the animator is able to understand for creating animation. This document is known as ID document (IDD). ID writer may/may not have the domain knowledge. However, this person is well versed with the pedagogy, teaching/learning and other theories related to cognition.

Animator

Animator creates the final product of the concept in the form of an LO. She/he uses various applications/software to create motion, animation and interactivity for the LO. She/He is an expert in graphic design and animation, and rarely has the knowledge of the topic of the LO. Therefore, she/he is dependent on the document/s provided for creating a LO.

Users

Users are either student/teacher who uses the LO for learning/teaching. They have the necessary knowledge about the topic of the LO.

Although the core stakeholders in LO creation process are the same, the processes are customized by the individual organizations based on the context. Different LO creation organizations follow their own processes. A generic LO creation process is explained in the next section.

1.1.4 Generic LO creation process

As mentioned earlier, a generic process for LO creation involves multiple stakeholders 1.3 from diverse professional and specialized fields. They are: SME, who is the proposer of the topic for creating a LO; ID expert and visual communication expert

(VC expert), who decide the strategies for instructional design and visual communication respectively. The team also consists of IDs and the graphic designers (GDs) who implement the pedagogical and visual approaches decided by the ID expert and VC expert respectively. In the end, the animators do the programming to create the LO (Sahasrabudhe, Murthy, & Iyer, 2012).

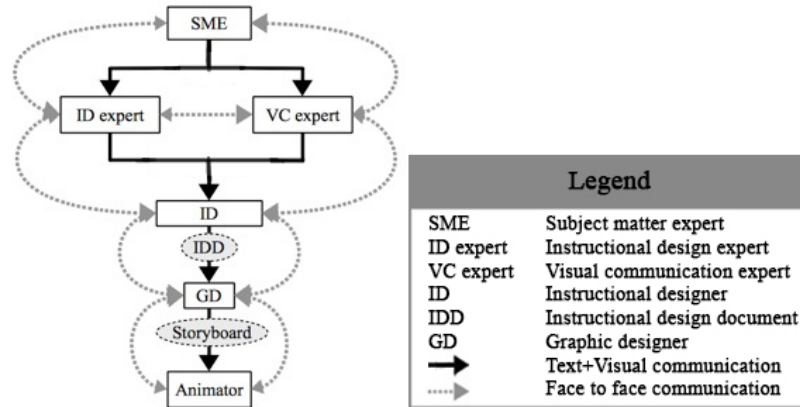


Figure 1.3: Generic process of LO creation

The SME proposes the LO topic and discusses it with the Instructional Design (ID) and the Visual Communication (VC) experts about ID and VC strategies to be incorporated in the LO.

These guidelines are communicated to the instructional designer, who creates an instructional design document (IDD), for the Graphic Designer (GD) to create a storyboard of the LO. Finally, the animator creates the LO using the storyboard and the IDD. The grey dotted lines in the figure denote the requirement of the face-to-face interaction on a certain decision.

1.1.5 Repository used for this research: Project OSCAR

Project OSCAR has over 300 LOs uploaded online. The repository covers a range of subject domains like electrical engineering, mechanical engineering, bio-science, computer science and other engineering domains *Project OSCAR website* (2013). It is a project funded by the Ministry of HRD, Government of India. The 300+ LOs in this repository are created using the definition by L'Allier.

Screenshot showing the composition of a typical LO from Project OSCAR, is shown in figure 1.4. The menu options are shown in a magnified form to show the details. Apart from the learning objectives, the LO also has the main explanation (Demo) and an assessment (Quiz) sections (shown in red circles).

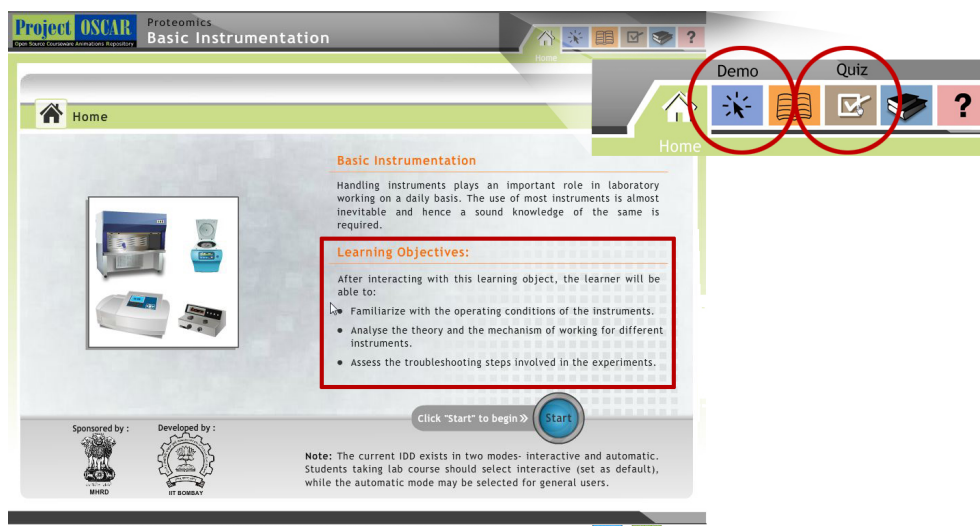


Figure 1.4: Screenshot of OSCAR LO

OSCAR LO contains the following sections:

1. Introduction: Textual introduction of the subject, topic and also the learning objective/s of the LO.
2. Actual animation: The animation is the learning activity
3. Assessment: Multiple choice questionnaire under ‘Exercises’ section for checking the understanding of the user
4. Resources: ‘Glossary’ and ‘Further reading’ links on the concept if the student is interested to explore more on the topic of LO.

The top right corner of a typical OSCAR LO has the icons for the sections explained above (see figure 1.4). These tabs enable the user to select the desired section, at any time during their interaction with the LO.

Terminology and abbreviations used in this research

- **eLearning** means to deliver the information via electronic media, or as technology-based learning in which learning materials are delivered electronically to remote learners via a computer network (Zhang et al., 2004).
- **Instructional design** means to describe the process involved in the systematic planning of instruction. The abbreviation used for this is **ID**.
- **IDT** is the abbreviation used for instructional design template.
- **IDD** is the abbreviation used for instructional design document.
- **VC** is the abbreviation used for visual communication domain.

- **Interaction design** is defined as:
 - ‘*a discipline dedicated to define the behavior of artifacts, environments, and systems (i.e., products)*’ (as defined by Riemann, in (Kirschner, Strijbos, Kreijns, & Beers, 2004))
 - ‘*designing interactive products to support the way people communicate and interact in their everyday and working lives*’ (as defined by (Sharp, Rogers, & Preece, 2003), page 8.)
- **eLearning animations** are educational content consisting of interactive files which have motion graphics.
- **Learning object** means a smallest independent structural experience that contains an objective, a learning activity and an assessment (LAllier, 1997). This would be abbreviated as: LO in this research, henceforth.
- **Usability OR engagement** is the feature which makes the user satisfied after using it.

1.2 Motivation

The need for large number of usable LOs mentioned in section 1.1, is the motivation for this research. In order to create these LOs, it is important to devise a methodology, which will create usable LOs, with the help of few specialized personnel available, and the limited time the available personnel have.

Goal of this research is to devise a methodology to create usable LOs without having the dependency on the face-to-face interaction between the stakeholders.

Typically, the process starts with the Subject matter experts (SMEs) selecting a concept for creating the learning object. This is communicated to the instructional designer (ID), using a concept selection form (CSF). The instructional designers use instructional design template (ID template) for creating instructional design documents (IDDs) to communicate this concept to the animators. VC expert provides face-to-face input to both the instructional designer and the animator on the visuals in the IDD.

We capture the expertise of the VC expert within the ID template by studying the decisions taken by VC experts, understanding the principles behind the decisions and operationalizing them in the form of prompts and guidelines in ID template (see figure 1.5).

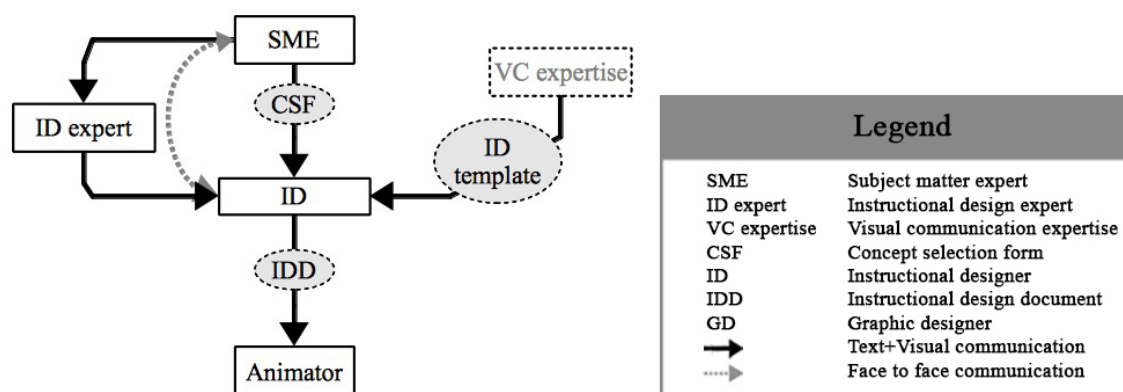


Figure 1.5: Our LO creation process, having VC principles embedded in IDT

We show that enhanced template makes the ID documents more usable for the animators. We also establish, that the LOs created using this template are found usable and engaging by the students. SMEs too find these LOs usable, and promoting learning.

1.2.1 Problems with existing LO creation processes

Various problems have been studied by researchers, like the poor interface design of eLearning systems (Zaharias & Poylymenakou, 2009) or about central role of user interface design in order to increase system intelligent behavior.

Based on the study carried out for the content creation process for Project OSCAR (Banerjee & Murthy, 2011) it was found that apart from emphasis on the user interface design of eLearning content, communication between the stakeholders SME, ID writer and animators is a point of concern. This is important, as failure or delay in this communication leads to increase in the creation time, effort and cost. This in turn obstructs the scalability of the content creation process.

- Templates help in achieving clarity in the process flow. However, the communication between instructional designer and animator is a commonly known problem (Boot, Nelson, Van Merriënboer, & Gibbons, 2007), (Boot, van Merriënboer, & Theunissen, 2008). The reason for this is that this stage of the process has the transition from textual content to visual/animated content.
- As shown in the figure 1.3, face-to-face interaction between various team members, which involve visual elements, is critical in ensuring high quality usable LOs.

However, this dependency on frequent and extensive face-to-face interaction becomes a key bottleneck when the goal is rapid creation of LOs. Given the increas-

ing demand for LOs, the traditional process limits the scaling up the creation of LOs.

- Furthermore, when LO creation in multiple domains is involved, scaling the number of team members along all domains may not be feasible.

There is a need to address these problems. The specific research problem based on the ones discussed above is given in the next section.

1.3 Research problem

What modifications to the existing ID templates can reduce the dependency on the face-to-face interaction with VC expert?

One way to address that is by ensuring that the visual information necessary for the animator is present in the ID templates. However, in order to achieve this it is crucial to know:

How to incorporate the VC principles (provided by VC expert) into the existing ID templates?

Additionally, it is important, to validate the usability of the product (LO) created using the these modified templates, with the end users: students.

1.4 Aims and objectives

Research aims to capture VC expertise, thereby reducing face-to-face interaction between the stakeholders (mainly the ID writers and the animators) and without compromising on the usability of the LOs. A positive consequence of this could be scaling up of LO creation.

1.5 Significance of the problem

- **Inclusion of visual design considerations in the LO development process:** Usability of the LOs is an important concern. It is seen that LOs with less usability have less impact on the learn ability of the users. In this research, we address the visual design considerations, which are an important component (apart from the ones mentioned below). The research also proposes creation and validation of a guidelines document for visual design, for creating animation based eLearning content.

- **Reduce the requirement of face-to-face communication between the stakeholders of the LO creation process:** The current process of creating LOs involves a substantial time of the stakeholders to be spent face-to-face. This becomes a bottle neck when more and more LOs have to be created in limited time duration. LOs created with less emphasis on face-to-face time have been found low on usability, and also having factual errors.
- **Make the LO creation process scalable:** Reduction of the face-to-face timing required by the stakeholders would make the process faster, and thereby creating more number of LOs in a given time slot would be possible. One of the options applied in this research is the usage of templates. Templates for instructional designing of LOs have been popular, and effective. However, the required duration of face-to-face interaction between the stakeholders is not reduced.

This research creates template, modifies it by applying additional principles and examines if that reduces the face-to-face interaction. This has to be achieved without compromising the usability of LO.

The purpose of this research is to create an intervention to address the research problem mentioned in the earlier section. We focus on the ID template which plays a pivotal role in the communication between the ID writer and the animator. In other words the ID template is crucial since it facilitates the conversion of textual script to animation.

1.6 Scope and limitations of the problem

The scope of this research is for the topics from computer science domains, and specifically from the first and the second year curriculum of the Mumbai University.

Primary focus of this research is the usability of the LOs, however, feedback is also gathered for the engagement of the students. Additionally, feedback is sought from the SMEs about the usefulness of the intervention for teaching the respective topics.

1.7 Assumptions

Following assumptions are made while conducting this research:

- The stakeholders in the process of LO creation are well versed with their respective subject matter and the skill sets.
- The qualifications of the major stakeholders are as follows:

- **Animators:** Graduates from any discipline, with a course on digital animation. Additionally, working experience of 1-2 years in the field of eLearning animation creation, is mandatory.
- **ID writers:** Graduates from science domain. Specialization course in instructional design (ID), OR working experience in eLearning content creation for 1-2 years is mandatory.
- **Subject matter expert:** PhD/Masters in the respective subject, and 4-6 years of teaching experience in an educational institution.
- **Visual communication expert:** Graduate in fine arts, with either post graduation in visual design/interaction design OR working experience in the respective field for 4-6 years.

1.8 Research design

The research problem mentioned in 1.3 requires a research method which facilitate iterations. Additionally, the research method should also facilitate observation of the interactions between multiple stakeholders and the iterative testing of the products.

Design based research (DBR) is one such research method, which can address multiple interacting variables and allow for iterations of the intervention until it becomes effective (Plomp, 2009). DBR is a systematic study of designing, developing and evaluating educational interventions (like programs, teaching-learning strategies and materials, products and systems) as solutions for complex problems in educational practice. It also aims at advancing our knowledge about the characteristics of these interventions and the processes of designing and developing them. Iterative development of interventions based on summative evaluations is a characteristic of DBR.

In a research study, the initial intervention may or may not have effectively solved the problem. Research methodology where the intervention can be iterated till found useful is design based research (DBR) (Plomp, 2009). Each iteration of modifying the intervention is termed as a research cycle. The important aspect of DBR is that the outcome/s of every research cycle is used as input for the next research cycle (figure 1.6). This helps in augmenting the intervention on the basis of the ‘failures’ in the earlier research cycles.

The cycles conclude after a particular version of the intervention shows desired results. In DBR, the conclusions of this process not only have the detailed log of the chronological development of the intervention but also the documentation of the problems recorded in the earlier cycles (along with the steps taken to address them).

The specific research questions addressed in this research are as follows:

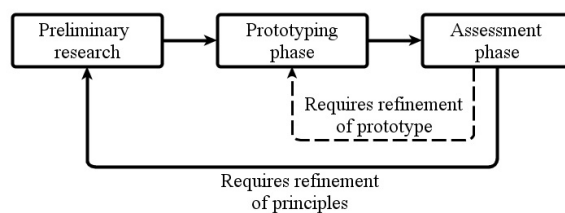


Figure 1.6: Cyclical process of DBR for creating a prototype by analyzing the results

1.8.1 Research questions

Would students find the LOs created using a template having VC principles embedded, to be more usable than the LOs created using a template without VC principles?

In order to have answer for this, it is important to have the following sub questions:

- Do ID writers find our ID templates having VC principles usable?
- Do animators find IDD's created by the above ID writers usable?
- Do students find the LOs created by the above animators usable?

1.9 Variables

Independent Principles applied in the intervention These are proven principles from visual communication domains like graphic design, multimedia, animation and interaction design.

Dependent Usability of the intervention These are proven constructs to test the usability of interactive eLearning content like: perceived usefulness, ease of use, format, accuracy and content (details in 6.5.3).

1.10 Hypotheses

H₀ No difference would be seen in the usability scores of the LOs created using ID templates having VC principles embedded in it and LOs created using ID template without VC principles embedded in it.

H₁ There would be increase in the usability scores of the LOs created using ID templates having VC principles embedded in it and LOs created using ID template without VC principles embedded in it.

1.11 DBR model used for this research

The DBR model cannot be adopted as it is and has to be modified to suit the requirements of this research. These modifications are shown in figure 1.7. The modifications to the model are based on the contextual requirements of the LO creation problem. DBR model with four stages is shown in figure 1.7.

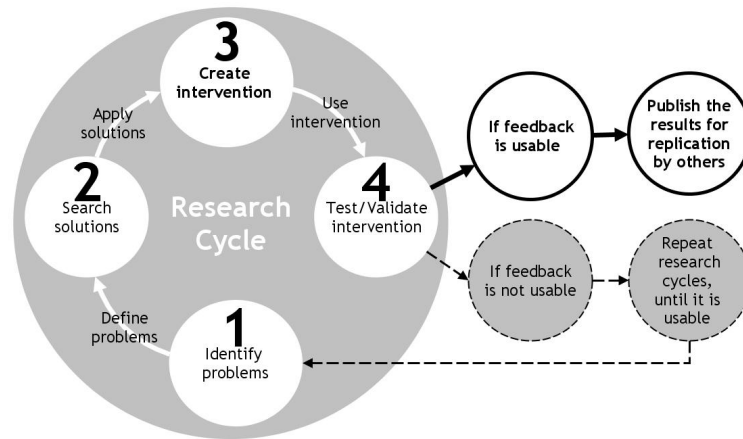


Figure 1.7: Details of a research cycle used in this research

As mentioned earlier, DBR methodology leverages iterative development of intervention. These iterations are termed as research cycles (RCs). A typical DBR model, has at least two RCs (two iterations of the intervention), however, the number of RCs can vary depending on the respective research objectives. The methodology starts with identifying problems from data/literature. The problems are defined properly and appropriate solutions are searched. An intervention is created by applying/operationalizing the solutions. This intervention is used (by the respective users) and validated to see the results. At the end of the validation tests, if the feedback is found usable (corresponding to the objectives set in the beginning), then the researcher can stop further development of the intervention. If the feedback is not usable, then the researcher has to repeat the RCs till the time feedback is found usable.

1.11.1 3 research cycles in this research

DBR methodology for this research was implemented using 3 RCs, (see figure 1.8). Every RC was designed to validate the intervention for particular stakeholder/s, and then proceed to check it for the rest. After the RC3, the intervention (IDT) was found usable by the respective stakeholders, and therefore, further modifications were stopped.

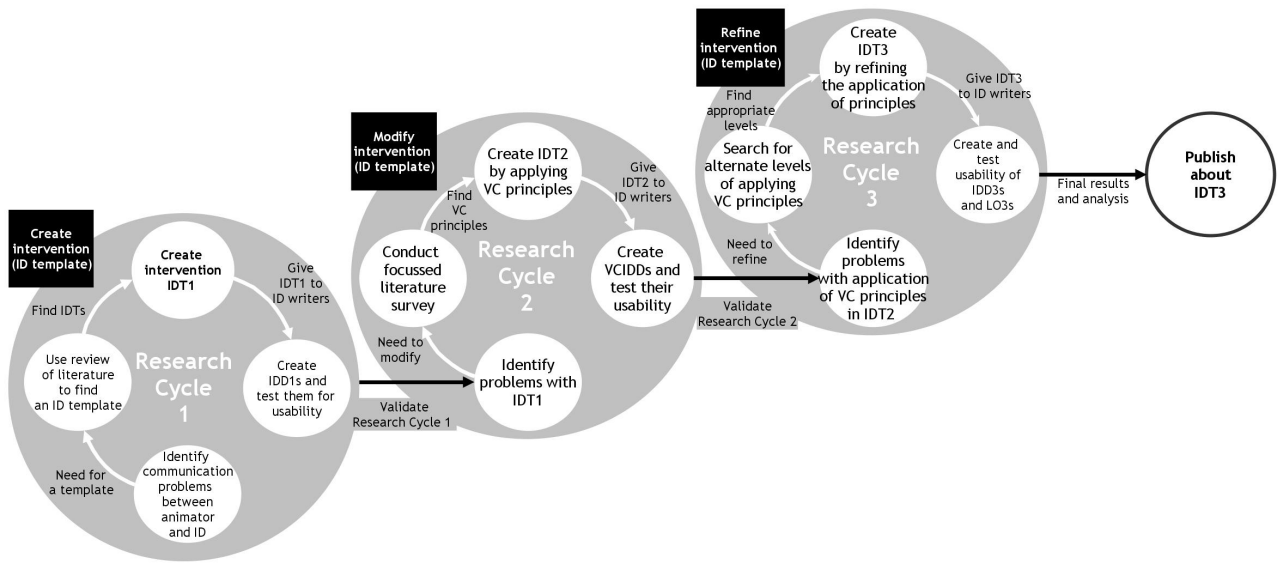


Figure 1.8: DBR model for this research having 3 RCs

RCs were conducted to create iterations of the intervention (IDT). IDT1 (based on generic IDT), was the output of RC1. It was found non-usable by the animators. Therefore, IDT1 was modified in RC2 by operationalizing VC principles to it. This was termed as IDT2. Animators found IDT2 usable, however ID writers found it non-usable because of the manner in which the VC principles were operationalized in the IDT2. Refinement of operationalizing VC principles was done in RC3, and a new IDT was created. Since it had advanced operationalization VC principles, it was named as IDT3. ID writers found IDT3 usable. Detailed adaptation of design based research is presented in chapter 5.

1.12 Single group experimental studies

After IDT3 was found usable by ID writers and animators, we tested the output of the interventions (IDT2 and IDT3). An usability experiment was conducted with the students, who were the end users. Usability feedback for two LOs (one created using IDT2 having basic VC principles, and the other created using IDT3 having advanced VC principles) were compared to determine, whether the operationalization of VC principles was effective. Feedback from students about the engagement the LOs offer was also gathered in another experiment. Additionally, SMEs perception of the learning from the LOs was also gathered. Details of these experiments are given in Chapter 6.

Artifacts

Two topics from computer science domain, were selected for this study to test whether the IDTs were generalizable. Two LOs were created for each topic, using IDT2 and IDT3 respectively. In all four LOs (LO₂₁, LO₃₁ for topic 1 and LO₂₂, LO₃₂ for topic 2) were used in the experiment.

Sample

132 students gave feedback for LOs on 2 topics (topic 1: n=64 and topic 2: n=68). These were engineering students from Mumbai university, having these topics in their curriculum.

Tool

Likert scale based tool (having seven statements) was created using constructs from usability and engagement for the experiment. To establish validity of the instrument, three experts were interviewed about the content, constructs being applied and formatting of the statements in the instrument. Reliability of the questionnaire was measured by administering a test of 10 students not included in the sample. The instrument was found reliable, since Cronbach alpha for the feedback given by 10 students (for seven statements) was found greater than the accepted value of 0.6.

Process

A group of students, interacted with both the levels of the LOs (LO₂s having basic VC principles and LO₃s having advanced VC principles). After interacting with LO₂s and LO₃s for some time the students provided their feedback using the survey tool. Since the data gathered was ordinal, and same group interacted with the intervention, Wilcoxon signed rank test was performed to analyze the data.

1.13 Results and analysis

Results of this research show that all the stakeholders found the intervention usable. There are two types of results. One about the DBR cycles (RCs) and the other about the single group experimental study. Summary of both these results are given below:

1.13.1 Results of DBR cycles

For the DBR cycles (RCs), the usability feedback was collected by using ‘System Usability Scale’ (SUS) (Brooke, 1996). According to the creators of SUS, if the score is 68 and above, then the product tested is considered to be usable for the users. Scores less than 68 mean that the product is non-usable (Bangor, Kortum, & Miller, 2009).

For RC1 the animators’ usability score for IDT1 was, 34.75 (IDT1: Non-usable for animators). The usability score by animators for IDT2 created in RC2, was 68.75, (IDT2: Usable for animators). However, in RC2, the usability score for IDT2 by ID writers was 54.16 (IDT2: Non-usable for ID writers). In RC3, IDT3 was created and it’s usability score was 69.42, (IDT3: Usable for ID writers).

1.13.2 Results of usability experiments

The ordinal data gathered during this experiment was analyzed using Wilcoxon signed rank test. The results showed that for both the topics, students found the LO3s more usable as compared to LO2s (topic 1: $p=0.00$ and z value= -3.77 ; topic 2: $p=0.01$ and z value= -2.39). Results of other experiment for testing engagement, also showed that LO3 was found more engaging than LO2. The effect size for both the topics was found moderate (topic 1: $r=-0.323$, $W=9.500$, and topic 2: $r=-0.212$, $W=99.0$) Cohen, Manion, and Morrison (2011).

Unstructured interviews with SMEs revealed that LO3s promoted learning than LO2s.

1.14 Contributions

This research has resulted in tangible artifacts like the ID template (IDT3) and the IDD (image thresholding and line coding). The SMEs mentioned that, the LOs (for both the topics) can also be useful for teaching the respective topics. The research also resulted in creation of tools like the modified SUS, and the usability and engagement questionnaire.

Apart from these, the research documented various processes like:

- identifying the VC principles applicable for LO creation.
- operationalizing the VC principles in an IDT.
- refining the operationalization of VC principles so that the ID writers find it usable.

- creating feedback instrument having usability and engagement constructs and validating it.

1.15 Organization of the report

To present the work conducted for the research, the chapters are organized in the following manner:

1. Introduction chapter outlines the background of the research problem. It encapsulates the solution and the research methodology in brief.
2. Chapter 2 has discussion about the research and findings of the previous literature that are relevant to the topic of this research. The relevant findings from these studies are considered for this study.
3. Chapter 3 has the details of the communication in this research is discussed. It also presents the details of the stakeholders in this communication, and their respective roles.
4. Chapter 4 has details about the design based research (DBR) method used in this research. It also presents a comparison of various DBR models.
5. Chapter 5 has details of the DBR implementation. It also presents the details of the three research cycles conducted in this research (see sections 5.1, 5.2, 5.3).
6. Chapter 6 has the details of the research methodology used for the single group usability experiment. It has details of sample used, tool created and the process followed for the experiment.
7. Chapter 7 has the results and analysis of the final experiment conducted in 3rd research cycle.
8. Chapter 8 presents the summary and conclusions of this research. A discussion is presented about how this research addresses the research questions.

Appendices A to D have the necessary documentation of tools, processes and artifacts used in this research.

Chapter 2

Review of related literature

The literature reviewed for this research was focused on advantages of eLearning, production processes of creating LOs and principles from various VC domains which enhance the quality of LOs. The following sections will detail the publications referred for the topics. Literature for certain topics is summarized in these sections, and a detailed description of the publication/s is given in subsequent chapters, as it is more relevant there.

2.1 Background

Researchers agree that eLearning cannot replace the instructors, but can be certainly used as additional aid for the students to understand the concepts. This has been presented by various researchers, through their experiments conducted for different topics. A study shows that, boolean algebra tutorial enhanced with animations produced a significant improvement and ability to apply knowledge as compared to traditional text-based tutorial in adult students (Ellis, 2001).

Using multimedia based instruction, for teaching technical graphics is found promising as compared to traditional methods (Mackenzie & Jansen, 1998). The multimedia based instruction was found useful in capturing and maintaining students' attention. Students also mentioned the advantages of eLearning based instruction in terms of revisiting the information subsequent to the presentation of the lesson.

eLearning is also useful in simulating laboratory experiments. These simulations are not only reusable and accessible to large numbers of users, but also can be maintained, modified or upgraded with minimal resources. Simulations having sufficient interactivity and user control, can be a close approximation to performing the experiment in a real-life laboratory (Gratch, Kelly, & Bradley, 2007). Another interesting application of eLearning is to teach abilities like mental rotation (Kadam, Sahasrabudhe,

& Iyer, 2012). The authors show that after interacting with 3D animation based eLearning, the students benefit significantly, and are able solve the mental rotation test.

Researchers have also pointed out the aspects to be considered while using multiple mediums such as diagrams, graphs, animations and equations in eLearning content. It is found that, while the students learn the complex concepts using this content, if the mediums are combined appropriately (Ainsworth, 2008). The heuristics to be followed are: understand the context, use minimum representations possible, follow a sequence while introducing representations, provide support.

Web based application of eLearning content allows users to see the effects of interaction (Neo, Lin, & Gay, 2004). In this paper, a online system for teachers, to design their own simulations is explained. Authors argue how visualization and interactivity aspects of simulation are preferable over simple display of continuous animation for explaining complex concepts in eLearning. Display elements of the eLearning material along with individual cognitive abilities contribute to the effectiveness of eLearning (Austin, 2009). The experiment results show that text positioning and motion distracts learners from comprehension and also shows differences in transfer test performance.

2.2 Multimedia in education

Multimedia is a integration of various mediums like text, images, audio and video. It is possible to have any two or more mediums in a multimedia content. Instruction using multimedia, is researched by researchers and is found that to be effective. As per Mayer, multimedia instruction is defined as, ‘presenting words and pictures that are intended to foster learning’ (Mayer, 2002).

Owen and Helps use multimedia assisted learning to survey the reactions of the students. The results are satisfactory, for the teachers as well as the students. There students find presentations clearer and there is a increase in their interest levels. The instructors find multimedia based presentations beneficial for communicating the technical topics (Owen & Helps, 1996).

A comprehensive literature survey about multimedia for eLearning is published by Stemler in 1997 (Stemler, 1997). The paper examines effects of the features of multimedia like: (a) screen design, (b) navigation, (c) feedback, (d) interactivity and (e) audio-video elements on the development of the educational multimedia modules. It shows that users concentrate on the multimedia modules, when their actions on the screen match their expectations. The paper also suggests, that elements of multimedia should be used in such a way that they are intuitive for the users.

Apart from the research which establishes advantages of multimedia in eLearning, there exist literature which proposes guidelines for its usage. Researchers suggest that use of multimedia should be done in a way that it doesn't overload the memory resources of the learner (Mayer, 2005). Integration of different mediums should be used in a way that it benefits learning, and doesn't pose a threat to learning.

In the book 'Multimedia learning', Clark and Mayer (Clark & Mayer, 2011), capture the details of the studies to evaluate the effectiveness of the principles proposed earlier. Every principle is validated using multiple studies. The book presents examples used in the studies, which is useful in understanding the range of topics, different data collection and analysis methods and different examples of applying multimedia in eLearning. A detailed review of this book is given in Appendix A later in this thesis.

2.3 Use of animation in eLearning:

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, 2011). 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.

In their seminal paper on animation, the authors presented five functions that animation can address (Weiss, Knowlton, & Morrison, 2002).

- **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.
- **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.
- **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.

- **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.
- **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.

Animation has shown positive and significant effect on learning outcomes (Poohkay & Szabo, 1995). However, the effectiveness of eLearning content depends on the appropriate use of the advantages offered by animation as a medium. These advantages can easily become distractions if misused, which reflects in loss of effectiveness. Researchers have accepted that, inclusion of animation certainly improves the impact only if used in a correct manner (Tversky, Morrison, & Betrancourt, 2002).

Studies carried out by Schnotz (Schnotz, 2002) indicate that different types of functions provided by animated content can be useful in different contexts, and for various users. Enabling and facilitating functions were tested and it was found that they are helpful to the users with higher and lower prior knowledge respectively. The author concluded that facilitating function is not necessarily beneficial, because unneeded external support can hinder learners to perform relevant cognitive processes.

Use of animation is found useful in conditions where it is used for attention gaining, presentation and practice (Rieber, 1990). Another important aspect which is found useful by the researchers is 'interactivity', (Neo et al., 2004), (Tversky et al., 2002) and (Rieber, 1990). Authors mention that the advantage of interacting with the content promotes learning, as against just consuming it when presented in a non-interactive manner.

Process of LO creation has animation as the core medium. This review of how animation helps in communicating the complex topics in eLearning, is useful to apply the appropriate principles while conducting the research on LO creation.

2.4 LOs: advantages and creation methods

LO is one of the promising mediums of eLearning, as it encourages collaborative learning and teaching (Koochang, 2004). LOs contain different aspects required for explaining a particular topic like: visual description, interactivity and assessment. Because of this, the LOs are also reusable, in varied contexts and diverse intentions. Author further describes the LO creation process various personnel required. These are: content

expert, instructional designer, user interface designer, and technology experts from database, XML, and multimedia domains.

LO creation process based on film making is presented by authors (Crichton & Li, 2004). The emphasis is on the storyboarding stage since it outlines the content requirements and defines the basic structure of the sequences for the animator.

Less documentation is available for the processes of creating LOs. The process of a synchronous model with extensive face-to-face interaction between all team members is used by some organizations for creating LOs, like: MIDOA (Arturo, Jaime, Francisco, & Maria, 2009), PheT (Adams et al., 2008), and TEAL (Belcher, 2001). These models have a few common aspects like the participating team members, emphasis on face-to-face interactions between the team members and following iterative spiral model of software engineering. The processes also demand lot of time commitment from the SME and expects the entire team to be stationed in the same place. The output has been (less number of) high quality LOs for specific domains.

2.4.1 LO creation processes

It is a complex process involving stakeholders from multiple domains. Few sample processes followed by various organizations are given below.

Crichton and Li

In their paper Crichton and Li have proposed a process based on the principles of film making (Crichton & Li, 2004). The steps are:

1. problem identification: conduct needs assessment
2. planning: identify specific concept, grade level
3. idea, learning strategies and approaches
4. storyboarding: outline the content requirements, determine relevant approaches
5. pre-production: script finalization, and determining the final audio-video
6. production: actual audio-video creation
7. post production: Fine tuning and testing
8. dissemination

The paper emphasizes the importance of the storyboarding stage, since it has multiple sub stages. These are outlining the content requirements, determining relevant pedagogy approaches, working with the SME for correctness of content, and script writing of sequences after identifying appropriate media.

Generic process of content creation

Since the eLearning content creation industry is bound by confidentiality norms, publications or white papers about their processes are not published regularly. An informal representation found on a blog of an individual, working with a reputed eLearning content creation organization, shows the process followed by such type of organizations (*Sumeet Moghe, Thoughtworks, 2012*). It underlines the bottlenecks at the stages like: script writing and animation creation (see figure 2.1).

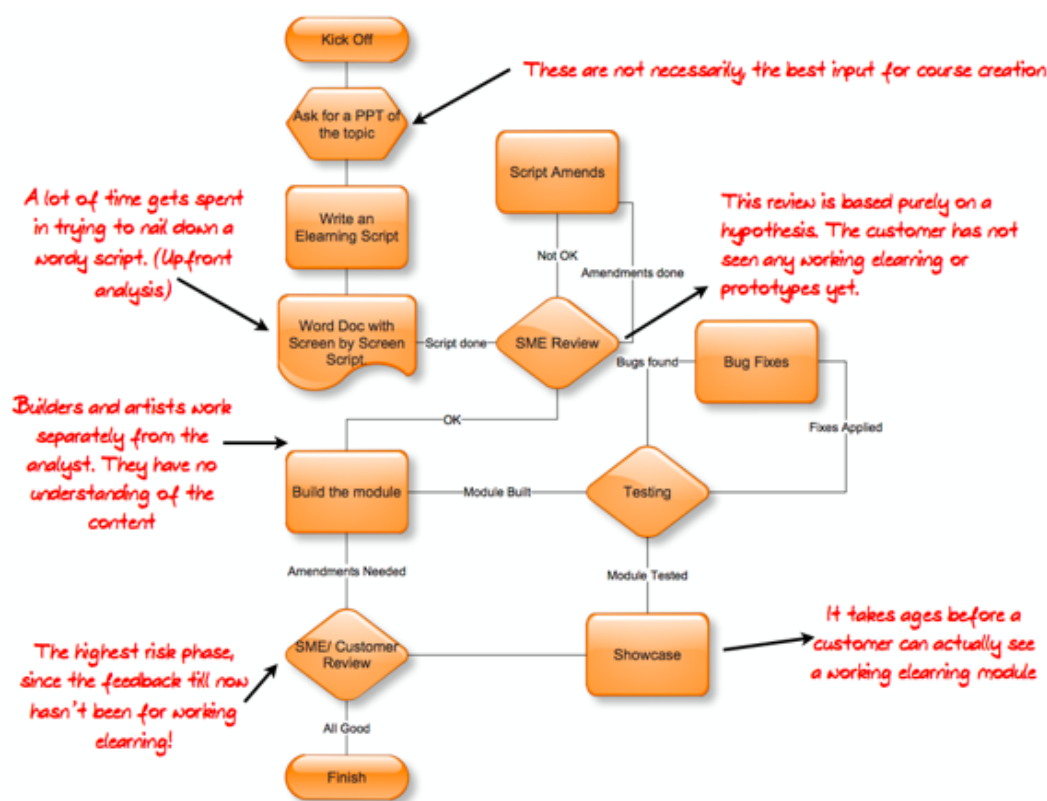


Figure 2.1: Generic LO creation process published by a professional

The process starts with getting inputs from the clients, and is modified to elearning script. The creators mention that creating a scene-by-scene script takes a lot of time. After the review of this script, the animation is built by the animators. Authors emphasize that the animators do not have the understanding of the content. Once created, the animation is tested and showcased to the client if approved internally.

OSCAR

Process for creating LOs at OSCAR is divided in five main stages (Banerjee & Murthy, 2011).

1. **Concept selection:** The topic or the concept on which the LO has to be created is proposed by the SME. This is done using a form called the concept proposal form. This form is created to capture the rationale behind selection of animation as a medium for explaining the particular topic.
2. **Content specification using ID template:** The concept proposal form is passed on to the ID writers who create an ID Document (IDD). OSCAR has its own template for ID writing, which is used in this stage.
3. **Instructional design** In this stage the pedagogy experts introduce the apply the ID principles in the explanation or the assessment sections of the IDD.
4. **Interface design** The graphic design experts create a design suitable for the ID principles used in the IDD.
5. **Implementation:** Animation is developed using the IDD. It is reviewed by ID writers and also by the SMEs. Upon approval from both the reviewers, it is given to the web team to be uploaded on to the website, for download. This package of the downloaded LO contains the source code of the animation as well as the respective IDD.

Reviews are conducted at every stage, from the corresponding stakeholders. The modifications are done to get it approved from the reviewers before passing it to the next stage. This is continued till the LO is created.

2.5 Principles to enhance the quality of LOs

The review includes domains like graphic design, design of multimedia for eLearning, visual communication in general as well as specific to eLearning, interaction design, pedagogy principles, and technologies used for LO creation.

All these domains address core visual communication issues, however there are attempts by researchers to apply these principles to the eLearning content creation. Holzinger and Ebner show that principles from interaction design and graphic design are essential for developing animations and simulations for eLearning (Holzinger & Ebner, 2003). The experiment shows that the eLearning animations with the principles applied are preferred by the users over those animations, which are created without the principles.

Huizingh mentions design considerations of 3 important components for the website design. These are (i) navigation, (ii) use of graphics/animation and (iii) presentation style Huizingh (2000).

2.5.1 Animation principles

Basic process of animation has been documented initially by the animators at Disney. In the book titled, ‘Illusion of life’ the senior animators described the details of the animation process, the principles used and the examples of the stages of animation. This is a main reference for the students learning animation. They presented 12 principles for cell animation process (Thomas, Johnston, & Thomas, 1995). These principles have enhanced the entertainment objective of the animation. Animators all over the world, use these principles to create animation.

John Lasseter (Pixar Studios) in his paper, has described the adaptation of cell animation principles for computer animation Lasseter (1987). He concludes that principles of animation are tools to create content, and therefore ALL the principles from the traditional cell animation are required in computer animation. 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 LOs.

Researchers have also shown how animation principle like Staging/storyboarding plays an important role in eLearning content creation. Storyboard is a document which contains instructions for the animators, programmers, voice-over artists and the text to be inserted in the content. The storyboard is developed during the instructional design phase, typically by IDs, with input SMEs and VC experts (Orrr, Golas, & Yao, 1993). In another publication, the author mentions how staging is a borrowed concept from theater by providing various examples .

2.5.2 Graphic design principles

One of the seminal research in the area of graphic design is Gestalt laws. It is found that there have been studies of applying these laws in various domains. For example: screen design, web design and eLearning content creation.

Lemon et. al, report how gestalt principles like continuity, similarity and proximity affect the accuracy and efficiency of understanding the diagrams (Lemon, Allen, Carver, & Bradshaw, 2007). In another paper (Graham, 2008), understanding gestalt principles within the framework of interactive media design is presented. It provides educators and students with a scientific structure by which they can analyze and visually improve their interactive designs. Skillful application of gestalt can result in web and multimedia designs with stronger compositions that facilitate communication.

Application of gestalt principles in the creation of IDT is mentioned in chapter 5.

2.5.3 Multimedia principles

In the area of Multimedia principles specially for eLearning, the research done by Richard Mayer, and Ruth Clark is widely accepted (Clark & Mayer, 2011). The authors have also proposed five types of content which are: fact, concept, process, procedure, and principles. This is mainly because of the fact that they have conducted a lot of data based on empirical studies done by various researchers. According to the others, there are five principles of multimedia especially for creating eLearning content. The principles and their brief details are summarized below:

1. Multimedia principle:

This principle states that words and graphics both should be used instead of text alone. Studies are conducted, to examine the performance of the students using text and graphics as against the students using text alone. It is found that the group using text and graphics perform better than their counterparts mentioned above. The overall effect size is found to be in the range of 0.55 to 1.50 which is considered between ‘moderate’ to ‘strong’ effect (see part 5, section 24 of (Cohen et al., 2011)).

2. Contiguity principle: This principle states that the the chosen graphics should be placed near the corresponding words. Various tests with the groups using integrated text and graphics as against non aligned text and graphics are performed. The results show that the students in the group accessing the content with the integrated text and graphics, performed better as compared to the students using the non aligned text and graphics. The effect size ranges between 1.0 to 1.3 (strong).

3. Modality principle: This principle states that the words should be presented as speech rather than showing them as ‘on screen text’. The tests conducted to evaluate the performance of the students show that, the groups having the content with the narration, performed better that the group having the content with printed text. The effect size ranges between 0.7 to 1.0 (moderate to strong).

4. Redundancy principle: This principle states that visuals should be explained using words, but only with the help of one of the mediums: ‘on screen text’ or audio narration. Both the mediums should not be used to convey this. The test results show that the group which used the content without redundant text performed better than the group using the content with redundant text. The effect size ranges between 0.8 to 1.0 (moderate to strong).

5. Coherence principle: This principle states that adding any other interesting (even relevant) material to the eLearning content could hurt learning. The authors document two types of the tests: (a) adding extraneous sound to the content, and (b) adding extraneous video/graphics to the content. The authors mention, the groups which received the content without the extraneous audio/video performed better as compared to the groups which received content having extraneous audio/video. The effect size ranges between 0.86 to 1.66 (moderate to strong).

This study suggests that Contiguity principle is one of the well researched principle amongst all others. The tests of this principle have been conducted for various domains. The effect size of the results of the tests are also in the range which is considered to be significantly high.

The application of these principles in the IDT is given in Chapter 5.

2.5.4 Interaction design principles

Various researchers have researched about the interaction design principles. Most of these principles are in the form of guidelines (Yee, 2002). According to Cooper (Cooper, Reimann, & Cronin, 2012), interaction design principles can be categorized in the following categories:

- Design values: Considers ethical, purposeful, pragmatic, elegant design decisions. Ethical design is about creating designs which won't harm the users in any way like interpersonal, psychological, physical etc. Purposeful design is about understanding goals and motivations of the user. The purpose of the design should be to support the design when it is weak, empower it when it is strong. Pragmatic design facilitates communication between the various groups, business, engineers, stakeholders. Elegance in design deals with gracefulness and beauty.
- Conceptual principles: Define what a product is and how it fits into the broad context of use required by its users.
- Behavioral principles: Describes how a product should behave generally as well as in specific situations.
- Interface level principles: Strategies for visual communication of behavior and information.

Out of the various publications on the topic of interaction design, the book referred in this research is ‘Interaction design: beyond human-computer interaction’ Sharp et al. (2003). This book presents a comprehensive study of the interaction design principles, with examples. Most of the principles are in a prescriptive format, suggesting the designers to provide or avoid certain things while creating the interface. They are not written in manner to specify, the creation of actual interface. They act like a scaffolding to the designers, by providing the dos and don’ts of interaction design. Referring to the principles triggers the designers to provide necessary features while designing the interface. The commonly used principles are: Visibility, Feedback, Constraints, Mapping, Affordance and Consistency.

When users interact with any interface, their first action is to see it. Visibility principle contains *‘prescriptive guidelines for offering this visual information’*. It mainly suggests to show the usable information, and hide other information, which is not required by the user for carrying out the main objectives of the interaction. Feedback is about, *‘sending back information about what action has been done and what has been accomplished, allowing the person to continue with the activity’*. There are different types of feedback that can be used to communicate to the user like: audio, verbal, textual, tactile etc. Using appropriate feedback, provides necessary visibility to the user. Constraints can be defined as, *‘determining ways of restricting the kinds of user interaction that can take place at a given moment’*. In other words the user should be not be able to click only those options which are valid at that particular point of time. User should ‘see’ other options (visibility principle), but the technology should prevent him from using them, as those options are invalid at that particular moment, are invalid at given moment. Mapping is a logical extension of visibility and constraints principles. Mapping can be defined as *‘creating pointers in the design, which enable the user to establish a relation between the elements used for input and the corresponding output’*. This principle enables the user to understand (and predict) the effects of the interconnectivity of the elements. Affordance is another important principle, which says *‘everything which does a particular function, should communicate on its own about the function it is meant for’*.

A detailed explanation of these principles and their suitability for adaptation in LO creation is given in Chapter 5.

2.5.5 Instructional design (ID) principles

LOs are created for to be used mostly without physical presence of a teacher or facilitator it is desirable to have a well-designed user interface which will help learners guide themselves through instruction. This requires the ID writer to have knowledge of

subject matter (for the topic selected), psychology and also of editorial design. In addition to these, familiarity with visual design principles is very important for creating ID documents (Lohr, 2000).

2.6 Design based research (DBR) method

There exist several models and approaches in which DBR is implemented. A DBR model typically has three phases of: preliminary research, prototyping phase and assessment phase. The models discussed in this research are by Reeves, Mafumiko (Plomp, 2009), Wademan (Wademan, 2005) and McKenney (McKenney & van den Akker, 2005). Characteristics of DBR and the details of the model by Wademan, which is chosen for adaptation in this research are given below. Additionally, since DBR is an important component of our research design, these models are discussed in detail in Chapter 4.

Characteristics of DBR

There are three phases in implementing DBR:

Preliminary research: In this phase, need and context analysis is done in the beginning. This is followed by review of the literature regarding the domain. These two sub-stages are useful in formulation of a conceptual framework for the study, leading to the choice of principles to be applied for addressing the problem.

Prototyping phase: In this phase, products/artifacts are created to address the problem. Context analysis and the focused review of literature provide the necessary scaffolding to choose appropriate principles for creating the product/artifact. Further, this product/artifact is applied to the problem.

Assessment phase: In this phase, the intervention is evaluated to see if it addresses the problems and gives the desired outcomes. This is called as Semi-Summative evaluation phase (Plomp, 2009). The results of this phase may be in the form of recommendations or guidelines for the improvement of the intervention or solution.

At the end of these phases, theories and principles (found effective) are published as a contribution to knowledge.

There exist several models and approaches in which DBR is implemented (see chapter 4). DBR methodology leverages iterative development of intervention. These iterations are termed as research cycles (RCs). Each model typically has the 2-3 RCs,

as described above. The number of RCs varies depending on the respective research objectives. Each model addresses a particular problem in educational research and has its own characteristics. Out of the various published DBR models, Wademan's model (Plomp, 2009) was chosen for this research.

The rationale for this decision is given below:

1. RCs of Wademan's model coincided with the requirement of this research. That made it easier to adapt Wademans model to our research compared to other models which did not have similar RCs (for example: Identification of tentative products and design principles RC is missing in Mafumiko and McKenney)
2. The stakeholders mentioned in Wademan's model coincided with the stakeholders of our research, but were not present in other models. For example, practitioners are not present in Mafumikos model.
3. Equal emphasis was expected on the preliminary research and prototyping RC of this research, as prescribed in Wademans model. Models by McKenney (where prototyping RC has most emphasis), or Mafumiko (where prototyping has most emphasis) have emphasis on other RCs.

Based on these arguments, Wademan's model was chosen for this research.

2.7 Usability tools

Variuos constructs are described by the researchers for testing the usability of a product Davis (1989), Abdinnour-Helm, Chaparro, and Farmer (2005) and Gould, Terrell, and Fleming (2008). The authors present in depth analysis of how a particular construct addresses the usability features of the respective product. Details of the usability constructs used in creation of the tool for this research is presented in Section 6.5.

Chapter 3

Research from communication angle

The communication in this research is about the message which is a Learning Object (LO). This communication happens between the sender: who is the Subject Matter Expert (SME) and the receiver: who could be a student/teacher.

The communication from the SME to the user, is divided in stages, and has multiple stake holders through the entire process. The details of this process are explained in the subsequent sub sections.

3.1 Primary communication

As shown in the figure 3.1 the sender is the SME who has a concept in his/her curriculum, which he/she has to communicate. The concept converted in the form of a LO is the message in this communication. The receiver is the student who uses the LO to study that particular concept. The receiver can also be a teacher who is teaching that particular concept, where in he/she can use the LO as an additional teaching aid.



Figure 3.1: Flowchart showing Primary communication flow

As shown in the figure 3.1, the sender SME sends the message, which is in the form of an LO to the receiver who are either student or teacher. This is the primary flow of communication. It is to be noted that SME does not directly create the LO. There are multiple stakeholders viz. instructional designers and animation developers

in this process. The details of the stakeholders are given below, followed by the detail of steps:

3.2 Stakeholders in the process

The stakeholders are (i) Subject matter expert (SME), (ii) Instructional designer (ID), (iii) Animator and (iv) the end user/s.

As explained in 1.1.3, of Chapter 1, SME has the required academic knowledge for the concept or the topic of the LO. The ID is trained professional to convert the concept in a form that the animator can understand it and create the LO. The animator has the knowledge for creating the LO, using various applications. The end user/s are the students learning this subject or even the teachers teaching the subject.

3.3 Detailed view of the primary communication flow

The information about the detailed instructions for creating an LO is passed through multiple stakeholders. These stakeholders contribute at different stages as shown in figure 3.2



Figure 3.2: Flowchart showing details of the communication from SME to the Users

- From SME to ID: SME finalizes a concept and passes it on to the ID for the further development. This communication (in our parlance) is done using a ‘Concept Selection Form’ (CSF). This form has short but key information about the concept, which is required for the ID to start the process. See Appendix D for a sample CSF.
- From ID to Animator: ID creates an IDD, which has all the necessary details for the animator. These are the timing, action, details about the graphics, audio narration etc. This document is used by the animators for creating a storyboard for actual (screen-by-screen) detailing of the LO. See Appendix B for an IDD which is based on the CSF shown in Appendix D.

- From Animator to User: The animator creates the LO, which is then given to the user as content. An LO is a end product of the concept proposed by the SME, and having the pedagogy strategies planned by the ID. See Appendix C for the screenshots of the final LO/s, created using the CSF in Appendix D and IDD in Appendix B.

The next chapter presents theoretical framework of DBR method used in this research.

Chapter 4

Theoretical framework: Design based research

This chapter presents an overview of the research methodology used in this research. Before the discussion on the method, an overview of the problem is discussed in the first section.

4.1 Overview of the research problem

This research focuses on the learning objects (LOs). As described in Section 1.1.3, the creation process of LOs involves multiple interacting stakeholders at various stages. The instructional design (ID) documents created by ID writers are found useful to a certain extent since they provide ID guidance to novice animators (Chapman, 2008). However, the animators are unsure of the subject matter details required in the final LOs. For this, they are dependent on the face-to-face interactions with the IDs for understanding of the content. ID templates (IDTs) also lack visual information required by the animators. This adds to the animator's dependency of face-to-face interaction with IDs to get clarifications on the subject matter, ID and the visual communication (VC) strategy planned for the LOs. The ID-animator interactions are iterative, in order to achieve perfection in content, visual design, interaction and usability. These iterations hereby slow down the LO development process. Absence or lower number of the interactions may lead to incorrect or non-usable LOs. Lack of VC details in the IDs is the main problem in the LO creation process.

4.1.1 Challenges in the LO creation process

Complex nature of the context: The context for this research is the process of creating learning objects on a large scale. This process involves multiple stakeholders who contribute at various stages. The communication / information flow is crucial in this process. This makes it complex, as there are multiple interactions between the stakeholders at various stages.

Iterations to create and validate interventions: This research is not based on ‘create once and use’ format. The modifications in the intervention are done based on the feedback from the relevant users, and visual communication principles are applied accordingly. This modification is validated and the feedback used as a starting point for further modifications.

Possibilities of adapting this research for creating LOs in future: This research is about content creation process. The process has to be such that it should be useful for future LO creators. In order to make it usable, it is important to use a method of ‘apply-test-record’

Multiple interacting variables: Variables in this study interact with each other and are dependent on each other. For example, change in the ‘educational background of IDs’ can change the ‘dependency of the face-to-face communication between the stakeholders’.

- Educational background of the ID writers: Graduate level education. Additionally, a postgraduate level education in ID is desirable.
- Work experience of ID writers: Work experience of 6-10 months of ID for an educational institution or in an eLearning production setup.
- Educational background of Animators: Graduate level education in design/animation. Additionally, a postgraduate level education for the animation software (1 year) is desirable.
- Work experience of animators: Work experience of 6-10 months of animation for an educational institution.
- Face to face communication between the stakeholders: Less or no face-to-face interaction between the team members producing LOs.

4.1.2 Goal of the research

The goal of this research is to address the problem of lack of VC information in the IDs, which increases the dependency of the face-to-face interactions between ID and animator. It is hypothesized that using ID templates based on VC principles would

make the IDDs (created using modified ID templates) more usable for the animators, since they will have more visual information present in the IDDs (which is necessary) (see figure 4.1). The intervention (modified ID template) should ensure higher usability of: i) the ID template for the instructional designers, ii) the IDDs created using the modified template for the animators and ii) the LOs created using the IDDs for the LO users (students or teachers). It also hypothesized that increase in the usability of the IDDs would result in reducing the dependency of the face-to-face interaction between IDs and animators. This in turn would attribute in reduction of resources like time, cost and personnel required for LO creation. In order to achieve this, the intervention which is planned to be created and tested is a modified ID template.

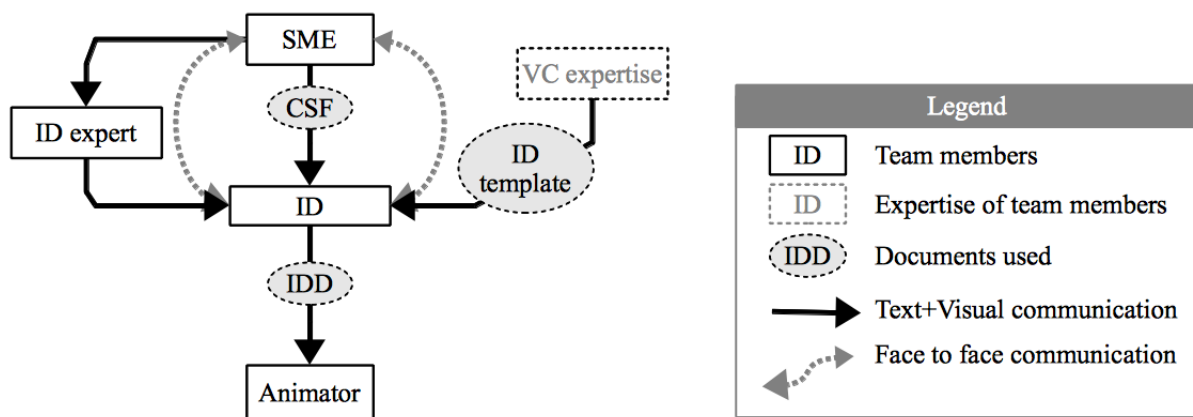


Figure 4.1: Goal of our research: Reducing the dependency on the VC expert, by adding the VC principles in ID template

4.2 Choice of appropriate research method

Educational research problems involve observing multiple interacting variables and multiple stakeholders. Educational research also involves the development of artifacts. Researchers not only develop interventions but also observe the process of developing and implementing these interventions (Johnson & Christensen, 2008). Further, they devise principles or theories related to these processes.

The topic of this research (creating eLearning animations/learning objects) is one such educational research problem. Learning objects (LOs) have become valuable teaching and learning tools in a variety of instructional contexts (Bratina et al., 2002), (Boyle, 2003) and (Wang, 2008). Creation of LOs involves multiple interactions between stakeholders from various domains such as the subject matter, instructional design, visual communication and software development. It is found that, the communication between these stakeholders is dependent on frequent face-to-face interactions

between them. These interactions are not only time consuming but also resource intensive. Templates are used to generate products such as: instructional design document, storyboard and animation design document, to facilitate the interaction between the stakeholders. However, there exists a gap in the communication between the ID writer and the animator (Weerasinghe et al., 2007).

This research addresses the gap mentioned above, by creating a template having the visual communication information required by the animator. Since, the creation process of such a template is iterative in nature, the research method should facilitate iterations. Additionally, the research method should also facilitate observation of the interactions between multiple stakeholders and the iterative testing of the products. Next subsection provides an overview of different research methods, their advantages and limitations and characteristics of educational research.

4.2.1 Types of research

Research can be defined in various ways. It could be getting new information (which one doesn't possess), or conducting systematic investigation to solve a problem, or proposing newer ways of solving an existing problem based on the observations etc.

- **Research based on purposes**

Within the research which is based on the purposes, there can be various sub categories. It can be about acquiring new knowledge, and extending it further, testing the validity of that knowledge, solving a problem and many other purposes. All these purposes are valid, as the research outcomes of these adds new knowledge about the unknown or lesser known phenomena.

Another important type of research deals about the processes and procedures used in solving a problem. It can range from solving a unsolved problem using a certain process, or solving it using a different process, and prove that the latter was efficient than the earlier one. Documentation of the methodology used for problem solving helps the knowledge base to strengthen, so that other researchers can use it for future use.

- **Research based on methods**

These two separate approaches are commonly used by researchers (Yadav, Zhou, Mayfield, Hambrusch, & Korb, 2011) and (Prince & Felder, 2006):

- **Inductive:** Observation-Pattern-Hypothesis-Theory

Inductive reasoning starts from specific observations and goes to formalizing a theory. It is a way of reasoning in which the researcher starts with

specific observations. He/She then observes and studies the patterns in these and then goes ahead to formulate temporary hypothesis based on the patterns observed. This culminates in developing some general conclusions or theories. This approach is more open ended and exploratory.

– **Deductive:** Theory-Hypothesis-Observation-Confirmation

Deductive approach starts with a theory. This could be a general theory around the topic of the research. Based on the theory the researcher constructs hypotheses, which are slightly more specific than the theory. These hypotheses are then tested by conducting the required experiments and the observations are recorded. After analysis of the observations, the researcher confirms or rejects the theory which was considered at the beginning. The deductive approach is narrow in nature as it works from more general to specific conclusions.

● **Educational research**

As defined by Gary Anderson in his book, titled ‘Fundamentals of educational research’, educational research is, “*a disciplined attempt to address questions or solve problems through the collection and analysis of primary data for the purpose of description, explanation, generalization and prediction*” (Anderson, 1998). In terms of the educational environment, the situations are ever changing. In this environment variables like educational curriculum, modes of teaching, methods which the teachers follow, teaching aids like laboratory equipment, books or classroom amenities etc. can be changed. These changes may or may not have impact on the learning of the students, but it is important for researchers to capture the changes. This data of the changes observed during the interventions have to be captured correctly so that the researchers can consolidate and recommend a plan of action for effective application of the intervention.

For educational research, it is insufficient to look only at the problem and the intervention (used to solve the problem). It is also important to observe the interactions between the intervention and other stakeholders. The interactions are important as they provide the insight of the possible options to customize the intervention in case of a specific context. It is useful to record these interactions in order to facilitate decision making based on these.

Traditional research is used for different domains, but there are some limitations which make it difficult to accommodate the requirements of educational research. Some of the prominent limitations are:

- Traditional research methods have either theory-driven or empirical data based methodologies. These fall short of understanding the complexities of educational research like why and how did a particular educational innovation worked in actual real life scenario.
- Traditional research approaches (like surveys and experiments) have more importance to description. It is observed that less importance is given to the solutions for the design and development problems in education. Theoretical claims are not sufficient to implement newer reforms in educational domain. They demand systematic and contextual research of development and implementation processes.
- One of the important functions of research is its ability to be adapted. A process published after doing research on the same has to be useful for another researcher for implementing it in a new context. Traditional research mainly does have results about an intervention working successfully in a given scenario with a sample. It is difficult to adapt the findings of this research to other scenarios with newer samples.

Based on the discussion above, there is a need for a research method which supports the complexity of educational research, helps in designing solutions for educational research problems, and is adaptable by others. One such research method is design based research (DBR). The next section describes features of DBR.

4.3 Characteristics of design based research

Design based research (DBR) method is useful in creating interventions for real world settings. The interventions are not one time creations, but created using iterative method. DBR has iterations of the products, processes or other interventions through cycles of analysis, design, development, evaluation and revision.

This type of research not only involves the users, but also involves the practitioners at various stages of the research. The focus of design based research is process oriented. Understanding and improvement of the interventions is an important aspect of this research method. The final product of the research, is evaluated (partly) based on its' utility. This is tested by the users in real contexts. Along with this, design based research is (at least partly) based on theories. The systematic evaluation of the intervention contributes to the theory of Van den Akker (McKenney & van den Akker, 2005).

In a research study, the initial intervention may or may not have effectively solved the problem. In DBR, if the intervention applied is not found to be effective; one can iterate the intervention until it becomes effective. Each iteration of modifying the intervention is termed as a research cycle. The important aspect of DBR is that the outcome/s of every research cycle is used as input for the next research cycle (see figure 1.6 in Chapter 1). This helps in augmenting the intervention on the basis of the ‘failures’ in the earlier research cycles.

4.3.1 Typical stages of DBR

The cycles conclude after a particular version of the intervention shows desired results. In DBR, the conclusions of this process not only have the detailed log of the chronological development of the intervention but also the documentation of the problems recorded in the earlier cycles (along with the steps taken to address them).

Typical implementation of DBR has the following three phases:

- **Preliminary research**

In this phase, need and context analysis is done in the beginning. This is followed by review of the literature regarding the domain. These two sub-stages are useful in formulation of a conceptual framework for the study, leading to the choice of principles to be applied for addressing the problem.

- **Prototyping phase**

In this phase, products/artifacts are created to address the problem. Context analysis and the focused review of literature provide the necessary scaffolding to choose appropriate principles for creating the product/artifact. Further, this product/artifact is applied to the problem.

- **Assessment phase**

In this phase, the intervention is evaluated to see if it addresses the problems and gives the desired outcomes. This is called as Semi-Summative evaluation phase (Plomp, 2009). The results of this phase may be in the form of recommendations or guidelines for the improvement of the intervention or solution.

At the end of these phases, theories and principles (found effective) are published as a contribution to knowledge.

There exist several models and approaches in which DBR is implemented. Each model typically has the three phases described above. Each model addresses a particular problem in educational research and has its own characteristics. In order to

choose a DBR model which can be useful to address the problem in this research (overview mentioned in Section 4.1), we review four DBR models published by various researchers, in the next section.

4.4 Comparison of DBR models

In this section, four different models of DBR implementation are studied in order to design a suitable model to address the research problem mentioned earlier. This comparison enables the understanding of various approaches and elements used by researchers for different educational research problems solved using DBR. The subsections below provide details of each DBR model, the context of applicability, and the research problem they address. Each model is analyzed in terms of what is done in each phase of research (preliminary, prototyping and assessment phases), and the corresponding outputs. Elements in the model, suitable for this research are discussed. At the end of this section, the DBR models are compared and the one which has most of the necessary elements to address the research problem is chosen.

4.4.1 Reeves' model

The generic approach of DBR presented by Reeves is shown in figure 4.2. Unlike other models (for example, models described in sub sections 4.4.2, 4.4.3 and 4.4.4), Reeves' model is not intended to solve a specific design problem at hand. Instead, Reeves' approach captures the main features of a typical DBR process and presents a generic approach of implementing various stages of DBR (Reeves, 2006). This approach can be considered as an overview to understand specific DBR models.

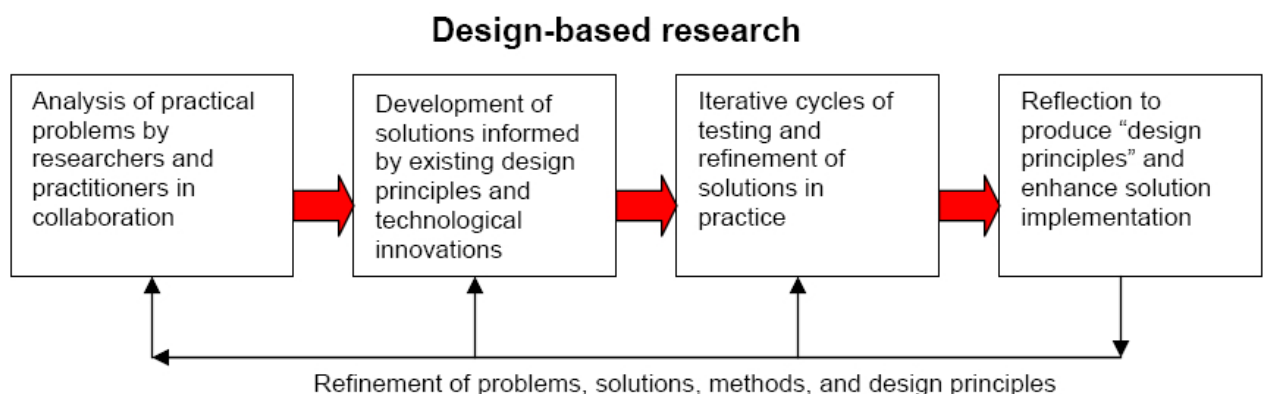


Figure 4.2: Generic model of design based research presented by Reeves

This approach has four stages 4.2, which are common in other DBR models. The

feedback from every stage is shown using thin arrows. The features and stages of this model are outlined below.

- **Analysis stage**

Practical problems are analyzed by researchers and practitioners in collaboration. Unique feature of DBR is the first stage of this approach. It provides necessary context to the researchers in development of solution for the given problem.

- **Development of solutions**

Existing principles and theories are referred to create a solution for the problem documented in the analysis phase. The ongoing innovations in the technical field are also considered while designing the solution.

- **Iterative cycles of testing**

Cycles of testing are carried out for refinement of solutions in practice. Data collection and analysis (corresponding to the research questions of the study) is carried out. Based on the analysis of the data collected, the intervention is refined, and tested again. There could be multiple such cycles before the feedback shows that the intervention is found useful.

- **Reflection of the feedback from users**

The refined intervention is tested by the users and the feedback is collected. The principles applied in creating the final version of intervention, are then documented to produce ‘design principles’. These principles can be used by researchers in future to enhance the implementation of the solution.

The aspects of Reeves’ approach that are useful for solving our problem are: refinement of problems, solutions and methods at every stage of DBR. However, Reeves’ approach does not provide the details of the process of conducting the research cycles. For example, it does not comment about the elements such as number of samples or expected timeline for the process. It is therefore necessary to study other DBR models and see if those models provide information about the missing elements.

4.4.2 Wademans’ model

Wademans’ DBR model addresses the development of interventions to help decision makers on whether and how to utilize the People Capability Maturity Model (People CMM) (Plomp, 2009). It is an approach to attract, motivate and retain talented human resource, amidst the increasing competency in the business sector. The goal of

this approach is to analyze the problem, and provide insights to the decision makers regarding adoption of People CMM. Wademan's model addresses this problem, and aims to advance the knowledge base and theory in People CMM.

Wademan's model defines the stakeholders at various stages, their respective roles and the interaction between them. The stages of the model are explained below. Summary of this can be seen in figure 4.3.

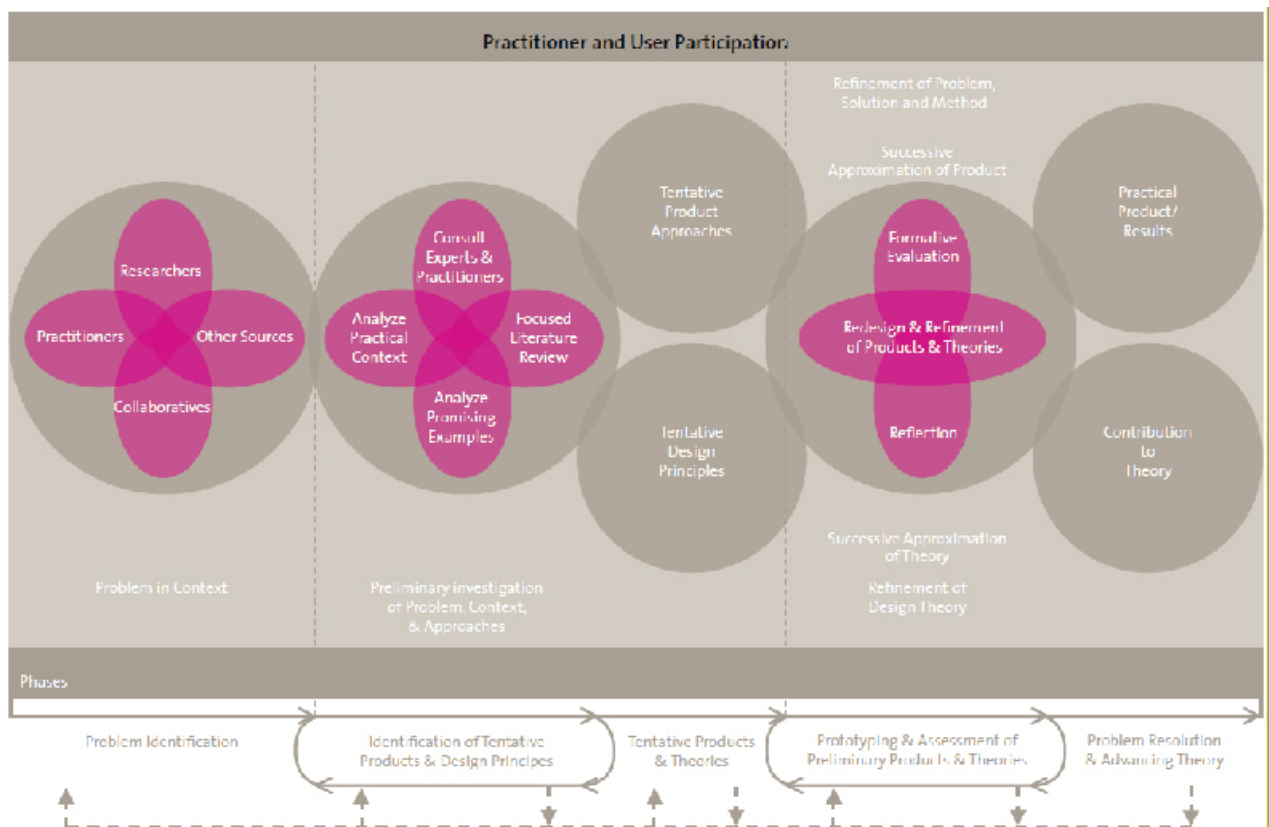


Figure 4.3: Generic model of Design based research presented by Wademan

- **Problem Identification**

In this phase, the context is studied to identify the problem. Companies experience lack of accessibility, and other relevant information about People CMM. This restricts the usage and hampers its utilization for workforce enhancement. The stakeholders interact with each other and determine the gaps.

- **Identification of Tentative Products and Design Principles**

After the problem is identified, preliminary investigation of problem, context, and approaches is done in consultation with the experts and the practitioners. This is supported by conducting focused literature review, and analyzing practical context. Promising examples, which represent the problem, are analyzed. This

process helps in identifying tentative list of products and design principles to be applied in the study.

- **Applying tentative products and theories**

Tentative products are created using the tentative list of design principles. These are introduced to the users and the results are captured.

- **Prototyping and Assessment of Preliminary Products and Theories**

Redesign and refinement of the problem, solutions (created in stage 3) and method is done based on the feedback received in stage 3. Formative evaluation is used along with the reflection of the feedback, to do the redesign and refinement. This is an iterative stage where, the refinement is done for achieving successive approximation of theory, and refinement of design theory.

- **Problem Resolution and Advancing Theory**

Practical products are created, after the iterations conducted in stage 4. These products have certain aspects, which contribute to the existing theory.

The model has loops at some stages (for example: Identification of principles and prototyping stages), which are used for refining the intervention. Unlike Reeves' model, refinement is not done using a feedback loop, but is done in a separate stage. The detail of the stakeholders at every stage is an important aspect of Wademans' model. This is useful for the research problem of LO creation, as there are various stakeholders in this process, at respective stages.

4.4.3 McKennys' model

McKenneys' model is used to explore the potential of computers for development of curriculum material (McKenney & van den Akker, 2005). This study is the context of secondary level science and mathematics education in southern Africa. DBR is used to create an intervention, titled CASCADE (Computer Assisted Curriculum Analysis, Design and Evaluation). The research design 4.4 consists of three main stages given below:

- **Needs/context analysis**

Exhaustive literature review helps in the development of the tool. The review is about curriculum development, professional development of the teachers, existing exemplary materials and support structures including computer-based support. The themes of the literature review provide the necessary insights to shape the structure of the study as well as the CASCADE program itself.

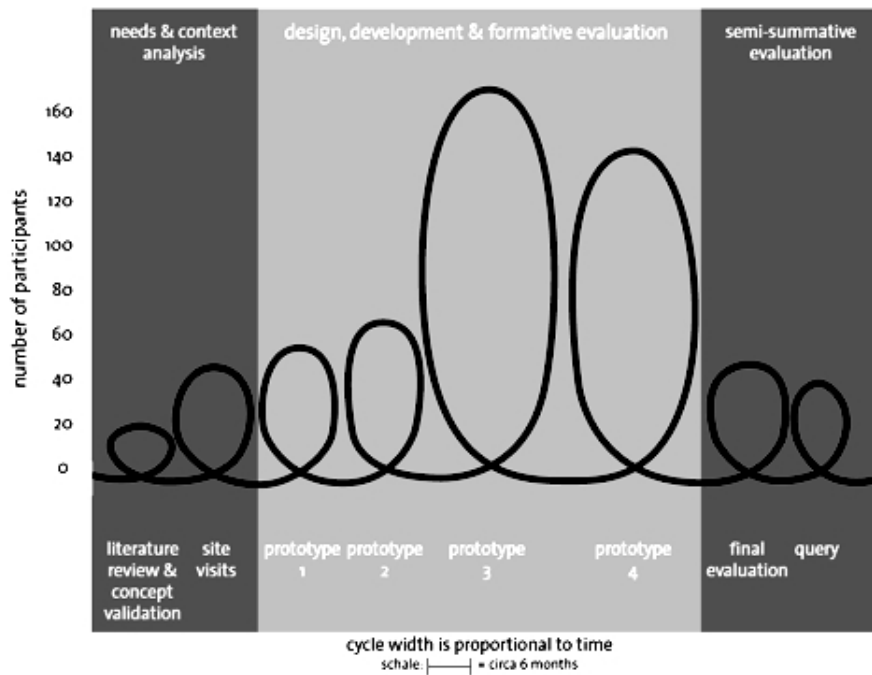


Figure 4.4: Design based research model presented by McKenny

- **Design/formative evaluation of prototype tools**

This stage has creation and testing of prototypes, with the users. Four prototypes (using the feedback of the participants) are formatively evaluated during this stage. It can be seen that the number of participants are less initially, and grow at later iterations.

- **Summative assessment of the final product**

This stage involves the final evaluation of the prototype. It also involves the reflection to produce design principles, which enhance implementation of the solution in practice and in future.

The result suggests that CASCADE system assists users in producing curriculum materials. These materials are found to be more effective than other materials created without CASCADE. The research also contributes to the articulation of design principles and related development research methods applied in creating CASCADE.

The unique features of McKenneys' model are specifications of time line as well as the number of participants. As seen in the model, the number of participants increases gradually till the penultimate prototype is created. The number slowly reduces after the test for the final prototype and final evaluation is conducted. The availability of these details is important from the point of view of the research problem of LO

creation. However, McKenneys' model does not mention details about the stakeholders in various stages like that of Wademans' model (section 4.4.2).

4.4.4 Mafumikos' model

Mafumiko in his dissertation has focused on usefulness of Micro-scale chemistry experiments (MSCE) (Plomp, 2009). This is a unique way to explain chemistry as the experiments are on a reduced scale, and use small quantities of chemicals and simple equipment. The aim of his study is to design and evaluate an intervention (MSCE) to support curriculum material, and contribute to the improvement of teaching learning of chemistry. The research design used is based on DBR 4.5, and has three stages:

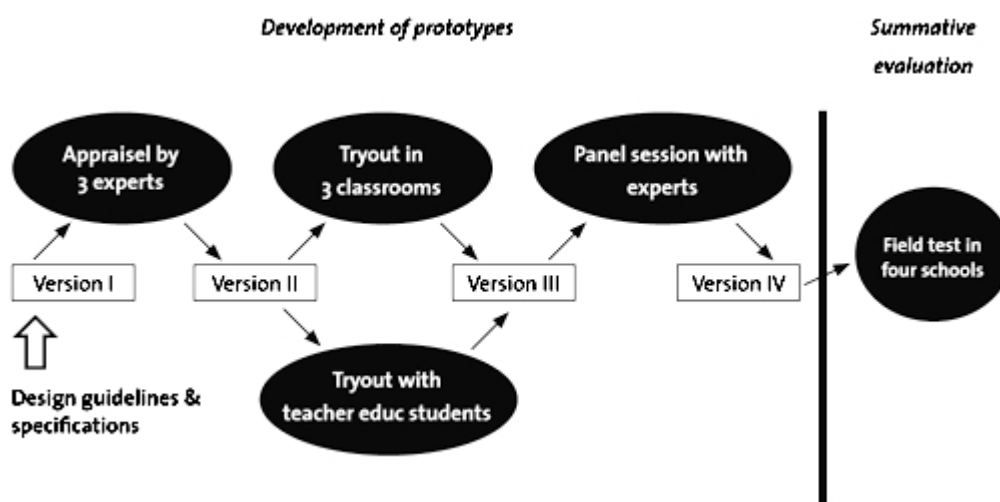


Figure 4.5: Mafumiko's DBR model with an emphasis on prototyping phase

- **Front-end analysis**

This involves the literature review and the context analysis of the chemistry education in Tanzania. Literature review focuses on improving practical component of science education in various countries. Context analysis studies the models of teaching practical chemistry within Tanzania. Experts in the similar field of MSCE are consulted in this phase, which adds value to the front-end analysis. Initial design specifications are ready at the end of this stage.

- **Cyclic approach of design and formative evaluation**

This approach used for creating the intervention is iterative. The evaluation provides empirical evidence of the practicality of the intervention. Successive versions of the materials evolve in to the final intervention. The model has

stakeholders, who inform their feedback through the formative evaluation. These stakeholders are experts, students and teachers. This feedback is useful to modify the intervention.

- **Summative evaluation of intervention (MSCE)**

This is carried out by conducting a field test of the final intervention. This stage demonstrates actual practicality and the effectiveness of the intervention.

The unique feature of Mafumikos' model is the process followed in the prototype development stage. The iterations are performed by collecting feedback from experts and users alternatively. One can also see that the number of respondents is small (for example, three experts for appraisal of version 1). However, the researcher does collect feedback during four such versions (iterations), thereby managing a critical mass required for validity of the feedback. It is also seen that the final evaluation is done using a larger sample (for example, field test in four schools).

Mafumikos' model shows the various stakeholders and their roles at respective stages. This feature can be adapted for the LO creation research problem, where there are multiple levels of users. For example instructional design (ID) writers use the ID template (IDT) created, and create ID Documents, which are then used by animators. However, the model does not elaborate about the first stage of formulating design guidelines to be adapted for creating the first prototype, like the way it is shown in Wademans' (sub section 4.4.4) and McKenneys' model (sub section 4.4.3).

4.4.5 Discussion

Sections 4.4.1 to 4.4.4 describe the features of different models of applying DBR. Stages of research and the outputs in each model are analyzed and a summary of the features of these models is shown in table 4.1 (given at the end of this chapter).

- The models created by various researchers have some common features, as well as a few differences. The differences in the features help in understanding the suitability of a model in solving a particular educational research problem. All models demonstrate the parallel creation process of prototyping of interventions and finalization of design principles.
- Almost all models have three phases: Preliminary research, Prototyping and Assessment. However due to different terminologies used by the researchers, some phases are titled differently. For example, 'Problem Resolution and Advancing Theory' in Wademan's model resembles 'Reflection of the feedback from users' of Reeves. In a typical DBR model, there exist atleast two phases of creation

and modification. These phases are termed as ‘research cycles’. Depending on the final objective decided by the researcher, more number of research cycles are added to the model.

Reeves	Wademan	McKenny	Mafumiko
Analysis by researchers and practitioners	1. Preliminary investigation 2. Practitioner participation	1. Need/context analysis 2. Literature survey	1. Literature survey 2. Context analysis 3. Consultation with experts
Practical problems are analyzed by practitioners and researchers	Context analysis by researcher, experts and other sources	Exhaustive literature survey to provide insights for designing the intervention	Focused literature review, detailed context analysis and expert opinions provide rich inputs for the development stage
Development of prototypes	Successive approximation	Design and formative evaluation	Design and formative evaluation
Developed Intervention	Developed Intervention	Developed Intervention	Developed Intervention
Iterative cycles of testing	Reflection	Summative evaluation	Summative evaluation
Final prototype emerging out of the iterative cycles of creation, test, and modify	Final prototype after design and refinement based on the users feedback	Final prototype based on multiple cycles of feedback from the users	Final prototype with feedback from stakeholders and empirical evidence of its practicality
Reflection of feedback from users	Theoretical contribution	Articulation of design principles	–
Design principles which can enhance the implementation of intervention	Insights and models relating to the areas People CMM, design theory and practice, and development research	Theories articulating design principles and development research methods related to it.	Not mentioned

Table 4.1: Comparison of stages in various DBR models

- All models address educational research problems, but the emphasis on the research cycles (RCs) varies in some models. For example, in Wademan’s model, preliminary RC has equal importance as compared to the prototyping RC. However, in McKenney’s model it can be seen that the emphasis for the prototyping RC is almost double that of preliminary RC. This variation in the emphasis can

be attributed to the goals of the research.

- Some models start directly with the prototyping RC, and combine the problem identification with that. For example: In Wademan’s model there is a well-defined RC for ‘problem identification’, however, Mafumiko’s model starts with a prototype RC based on the ‘design guidelines and specifications’.
- All models have similar types of stakeholders such as, experts, teachers, students and practitioners as categories of stakeholders in their respective stages. The goal of comparing these models is not to conclude whether a particular model is better than other one. On the other hand, it is to compare the features of the models to help in applying a particular model or adapting features of multiple models to address the research problem. Table 4.2 (given at the end of this chapter) compares the outputs of each DBR model. The next section describes the adaptation of the appropriate DBR model.

Reeves	Wademan	McKenny	Mafumiko
Problem analysis	Contextual analysis	Exhaustive literature survey	Focused literature review
Empirically tested intervention	Empirically tested intervention	Empirically tested intervention	Detailed context analysis
Design guidelines	Models	Insights on design principles and development research methods	Final intervention with empirical data
–	Insights related to the subjects	–	–

Table 4.2: Overall outputs in various DBR models

4.5 Solution approach

In order to achieve the goal mentioned in section 4.1.2, DBR process was used to refine the IDT (see section 4.6). The focus was on the IDT since this was the document used to convert textual data to visual form.

In each iteration, the problem with the current IDT was identified by obtaining feedback from the relevant users during that iteration. Later, an intervention was devised, which was a modified version of the template based on the application of visual communication principles. Further, the modified template was evaluated and this process was iterated. The iterations were continued until the evaluation results

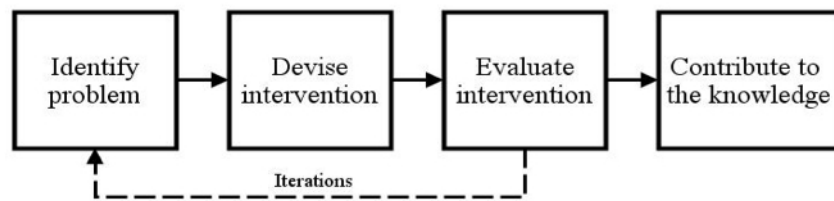


Figure 4.6: Solution approach for the ID template creation process

showed that the ID template was usable by all users - ID writers and animators. After the intervention (the modified IDT) established high usability, guidelines of selecting the visual communication principles and the procedure of applying them to IDTs were published.

Out of the four models mentioned in the section 4.4 (DBR models), the model chosen for this research was the one by Wademan (Plomp, 2009).

4.5.1 Rationale for selecting Wademans' model

The rationale for this decision was:

1. RCs of Wademans' model coincided with the requirement of this research. Other models did not have similar RCs (for example: Identification of tentative products and design principles RC were missing in Mafumikos' and McKenneys' models).
2. The stakeholders mentioned in Wademans' model coincided with the stakeholders of our research. They were not present in other models. For example, practitioners are not present in Mafumikos' model.
3. Wademans' model had equal emphasis on the preliminary research and prototyping phases. Models by McKenney (where prototyping RC had emphasis), or Mafumiko (where prototyping had emphasis) have emphasis on other RCs.

Based on these arguments, Wademan's model was chosen for this research. However, the model could not be adopted as it was and had to be modified to suit the requirements of this research. These modifications are shown in figure 4.7.

4.6 Adaptation of Wademans' model

4.6.1 Stages of a research cycle (RC)

As mentioned earlier, DBR methodology leverages iterative development of intervention. These iterations are termed as research cycles (RCs). For the research problem

of creating LOs, Wademans' model was adapted. The modifications to the model were based on the contextual requirements of the LO creation problem. DBR model with four stages is shown in figure 4.7.

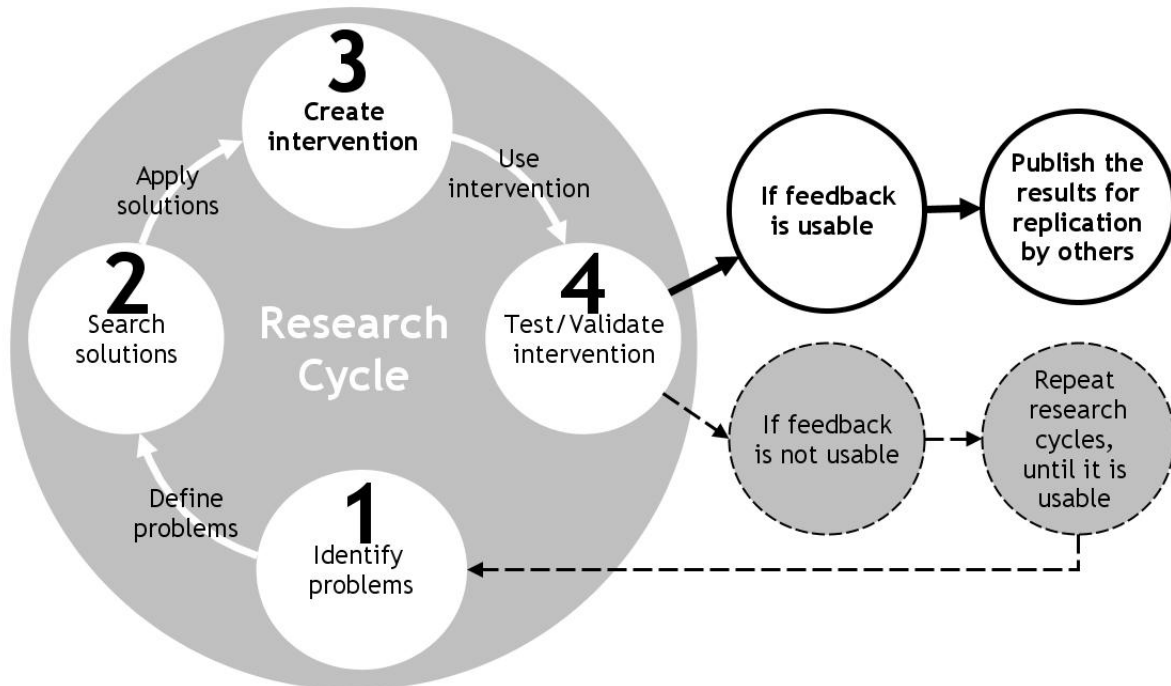


Figure 4.7: DBR model for LO creation problem

As mentioned earlier, each research cycle (RC) had four identical stages. The fifth stage (as per the DBR methodology) was added after feedback about the intervention was found satisfactory, by ALL the stakeholders. DBR methodology prescribes repeating the first four stages of the RCs until the desired feedback is received.

The four stages of a RC are presented in an anti clockwise manner. This is done deliberately, to establish the connection between the last stage of an earlier RC to the first stage of the next RC. The stages of a typical RC are shown in the figure 4.7:

1. Identifying problem

Analyzing feedback gathered (from various sources) in order to identify the problem emerging out of it.

2. Identifying tentative products

Once the problem were defined in stage 1, a tentative product/artifact/intervention was identified which can address the problem. Consultation with experts or focused literature review were conducted to identify a tentative product.

3. Prototyping tentative products

Once the tentative intervention was selected, a prototype was created to be tested. This prototype was contextual and was specifically designed for the problems identified earlier.

4. Testing the product

In this stage, the intervention was tested with its respective users and the data was collected. This data was useful for identifying problem stage in the next research cycle.

The methodology started with identifying problems (stage 1) from data/literature. The problems are defined properly and appropriate solutions were searched (stage 2). An intervention was created (stage 3) by applying certain principles. This intervention was used (by the respective users) and validated (stage 4) to see the results. At the end of the validation tests, if the feedback was found usable (corresponding to the objectives set in the beginning), then the researcher stopped further development of the intervention. If the feedback was not usable, then the researcher repeated the RCs till the time feedback was found usable. As seen in other DBR models (section 4.4) this has been repeated for 3-6 times.

The next subsection presents the overview of the implementation of this DBR model to the LO creation problem.

4.6.2 Implementation methodology

For the problem of LO creation, the intervention developed was an ID template, (IDT), to address the communication issues between the ID writer and the animators. A typical DBR model, has at least two RCs (two iterations of the intervention), first RC for the implementation and the second RC for the improvement (Herrington, McKenney, Reeves, & Oliver, 2007). However, the number of RCs vary depending on the respective research objectives. For this research problem, the DBR methodology was implemented by using 3 RCs, for the same, see figure 4.8 shown at the end of the chapter.

Every RC was designed to validate the intervention for particular stakeholder/s, and then proceed to check it for the rest. After the third RC, the intervention IDT is found usable by all the stakeholders, and therefore, further modifications are stopped.

4.6.3 Features of the adapted DBR model

In the LO creation process, it was not only the intervention IDTs which were created and tested, but also the products (IDDs and LOs) which are created using the intervention. The adaptation of Wademans' model included the following characteristics:

- The flow mentioned by Wademan had loops at the 'identification of tentative products' and 'prototyping' stages. We applied Wademans' model to our research problem with 3 loops or research cycles. First two research cycles were the loops of stages 1-4 (only, and not the fifth one about contributing to the theory) as mentioned by Wademan. However, the third research cycle had the 5th stage mentioned of contributing to the knowledge since the usability feedback about the intervention (IDTs) was found satisfactory.
- In our LO creation process, it was not only the intervention (IDT) which was created and tested, but also the products (IDDs) which were created using the intervention.

The details of the implementation of the three RCs is given in the next chapter.

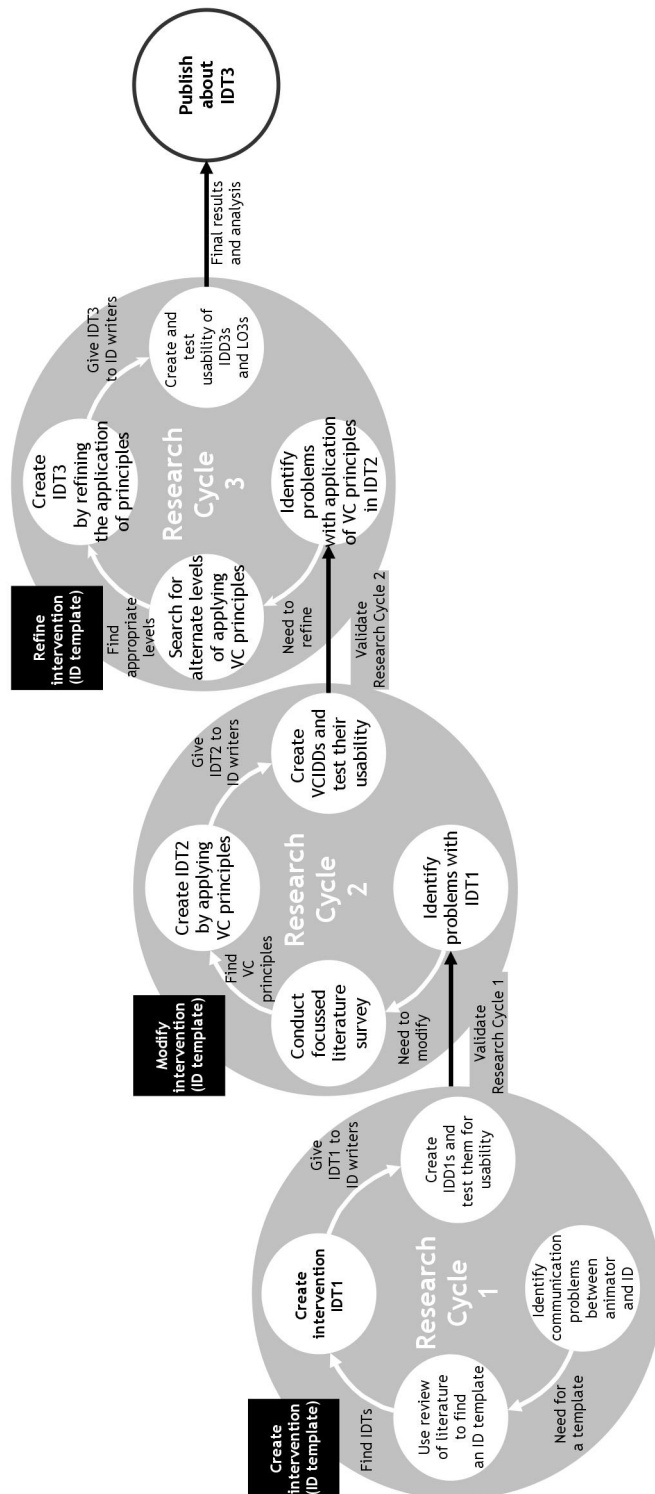


Figure 4.8: Implementation of DBR model for LO creation having three RCs

Chapter 5

Implementation of DBR cycles

The design based research (DBR) method, is an iterative process. In the implementation of DBR, an intervention is envisaged, based on the solution approach decided to address the research problem/s. The intervention is created, tested and modified (based on the feedback of the test), and retested. The stakeholders in the process, validate the intervention and provide the feedback for the modification. These steps are repeated until all the stakeholders find the intervention useful. These repetitions are called as research cycles (RCs). Typically, 2-3 RCs are required to achieve the desired objectives .

This chapter describes the RCs conducted in our research. The intervention to be created was the instructional design (ID) template (IDT), and the initial stakeholders were the animators and ID writers. Three RCs were conducted which focused on creation, modification and refinement of the IDT. The stakeholders (animators and the ID writers) provided the feedback during the iteration. Table 5.1 shows the three RCs and the respective stakeholders who validated the IDT.

	Template	Stakeholders	Artefacts	Results	Modifications
RC1	IDT1	Animators	10 IDD1s	IDD1s not usable	Modify IDT1 by adding VC principles
RC2	IDT2	Animators	12 IDD2s	IDD2s are usable	-
	IDT2	ID writers	12 IDD2s	IDT2 is not usable	Refine adding of VC principles in IDT2
RC3	IDT3	ID writers	14 IDD3s	IDT3 is usable	

Table 5.1: Overview of the 3 research cycles

Since the animators were the users of the ID documents (IDDs) created using the IDTs, the implementation was started by creating a basic version of IDT (IDT1). Feedback for IDT1 was gathered from animators, during the RC1. The animators did not find IDT1 usable. Therefore, in RC2, their feedback was used to create the modified version (IDT2). Animators found IDT2 usable. After animators found IDT2 usable, it was tested with the ID writers. However, they did not find IDT2 usable. RC3 was conducted to refine IDT2, based on the feedback of the ID writers and an advanced version (IDT3) was created. After ID writers found IDT3 usable further iterations were stopped, since both the stakeholders found the intervention (IDT) usable.

The subsequent sections present the details of the three RCs and their respective stages. As mentioned earlier project OSCAR (*Project OSCAR website*, 2013) was the repository used for this research.

5.1 Research Cycle 1 (RC1)

Primary objective of RC1 was to create an intervention (IDT). The stakeholders who use the intervention are animators, therefore in RC1, the intervention is tested with animators. The stages of RC1 are shown in figure 5.1, and the details are explained below.

In RC1 the starting point was identifying the communication gaps between the ID writer and the animator. After analyzing this gap, a generic ID template (IDT1) was created. IDT1 was validated by the users and feedback was gathered. This feedback became a starting point for RC2.

5.1.1 Stage 1: Identify problem

Communication gap between the animator and the ID writer

Communication between the stakeholders (like SMEs, ID writers and animators) in the process of learning object (LO) creation, is a combination of text, visual and face-to-face interaction (Sahasrabudhe et al., 2012). This communication problem was supported in relevant literature. Additionally, unstructured interviews with ID writers working with various eLearning content creation organizations were conducted. These interviews provided important insights in understanding the problem, and defining it. Following subsections explain the details of these steps:

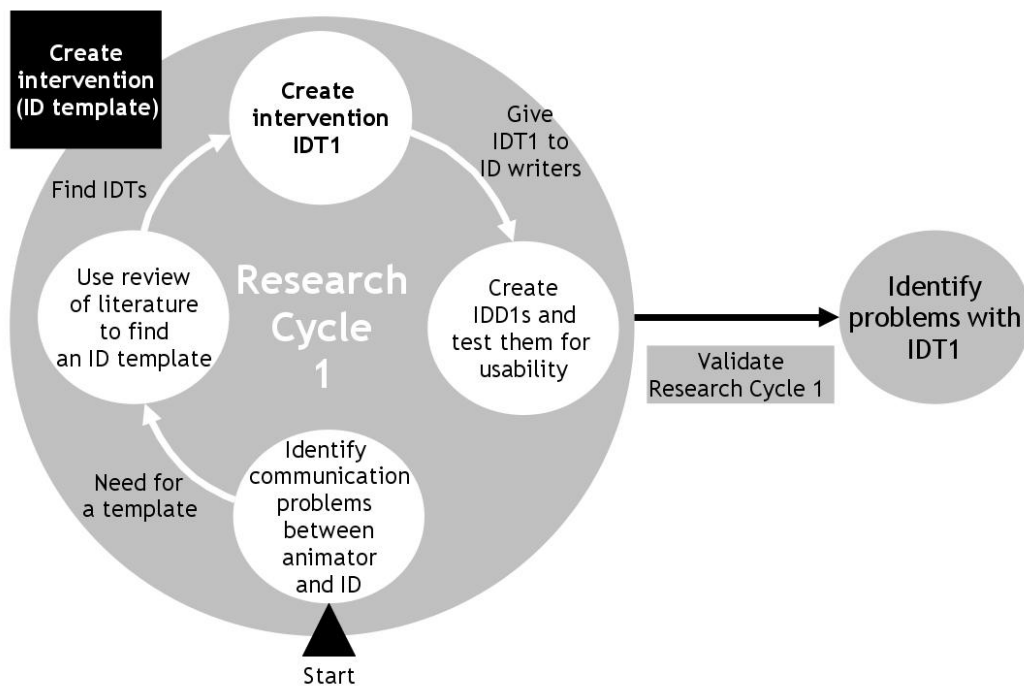


Figure 5.1: Research cycle 1: Create the intervention

Review of literature

It was observed that each organization involved in creating LOs, modifies the process to suit their context. The literature indicates that, the phase from the writing of ID documents to the actual development of LO takes the maximum time. One reason could be the lack of exact visual information leads to confusion, and therefore they need to meet face-to-face for clarification and getting the required information.

Literature has examples where this gap is established. Researchers found that ID writers mostly write documents which are textual in nature. Therefore, visual designers find it difficult to translate these in to an animation. In most cases their animation is found faulty/insufficient by the ID writers (Boot et al., 2007).

The documents used for the communication (ID documents and storyboards) are created by the stakeholders (ID writers and animators) using words from their respective domains. This results in miscommunication, since the language of communication is different. This is addressed by having more face-to-face communication.

While frequent face-to-face communication enables creation of effective LOs in terms of content, pedagogy and usability, it limits the number of LOs that can be created in a given time, especially since the availability of experts is limited. Hence the dependency on face-to-face interaction is a key bottleneck for the rapid creation of effective LOs (Banerjee & Murthy, 2011).

Based on this it can be concluded that there is a need for a new/modified ID template, which can address the communication gap in the process of LO creation. This will help the rapid creation of LOs. To confirm the existence of the miscommunication between the ID writers and the animators, we interviewed ID writers from the eLearning content creation organizations. Next subsection presents the details of these informal interviews, where the ID writers also explain the LO creation processes followed and popular IDTs in their respective organizations.

Interviews of the ID writers

5 ID writers from the eLearning content creation industry were contacted for unstructured and informal interviews. The focus of the interviews was to understand the storyboarding phase in the LO creation process, followed in their respective organizations. The ID writers explained the documents used in their organizations, however could not share them because of the confidentiality norms.

All ID writers mentioned that although the components of a template are the same, each organization does customize it to suit their production lifecycle.

One such customization is a function specifications document (FSD) used in few organizations. FSD has the details required by an ID writer in order to create the IDD. This document is created in consultation with the client and the senior ID writers. Customized template is created for a specific module (having few LOs) and is followed by the ID writers for the same. Modifications are done to the template, when a module changes. However, the ID writer confirmed that this document does not reduce the requirement of face-to-face communication. The ID writer has to meet the animator, in order to explain the details of the animation.

Few ID writers mentioned that they use proprietary tool like Adobe Captivate to create the storyboards. This tool has templates, which are used, to create the ID documents. However, the face-to-face meeting is necessary to explain the precise visual details.

Literature review and the interviews of the ID writers confirms that there exists a visual communication gap between the ID writers and the animators. It is important to asses the available templates and create an intervention to address this gap.

5.1.2 Stage 2: Identify tentative products

Since the findings of stage 1 confirmed that IDTs lack of visual informaion required by animators, a tentative product to be created, was identified in this stage. This was done by reviewing popular IDTs used by professional ID writers.

Review of literature for ID templates

Review of the available literature done in Stage 1, revealed that organizations use customized versions of IDTs. These customized templates were not available, owing to confidentiality and copyright issues. Therefore, three copyright free IDTs available on the web, were considered for creating the intervention (Websites: (*Excelsoft*, 2013), (*USPatent*, 2013) and (*Espire*, 2013)). These IDTs were suggested by the ID writers, during the interviews. The IDTs had text and visual components, and some documentation for the usage.

Observations

Popular ID templates had provision for the ID writers to provide required information in various formats like text, images and functional details. However, literature review and the informal interviews with the ID writers suggested that this information was insufficient for the animators. Common observations about the IDTs were as follows:

- The IDTs were customized by the LO creation organizations.
- Following sections were common in most of the IDTs:
 - Meta data information like: domain, topic, author, academic level.
 - Learning objectives: These are learning goals for the content to be created, which are explicitly mentioned in the beginning. These help both the creators (as a guideline to orient the content creation) as well as the users (to understand the scope of the content before interacting with it). The learning objectives are typically written using action verbs like ‘*perform, distinguish, explain*’ and more. Ex: ‘After interacting with this content, the user would be able to distinguish between various types of line coding schemes’.
 - Animation details: This is a section having information about the action to be animated. This is typically explained using reference images. Interactivity required in the LO is also mentioned mostly in this section. Additionally, this section provides the details of text which should appear on screen (on screen text), and audio explanation/instructions provided during the animation (voice over script).
 - Assessment section: having a multiple choice questionnaire (MCQ).
- Guidelines about pedagogy or interaction design were not found in such templates. ID writers mentioned that this was often solved by having face-to-face interactions.

These observations were important to be incorporated in the new IDT which was to be created. The new IDT, for this research was created in the next stage.

5.1.3 Stage 3: Create tentative products and theories

The process of creating learning objects (LOs) starts with the ID writer using an ID template (IDT) to create an ID document (IDD). Finally the animators use the IDD to create the LOs. As the starting point of the research, the first intervention (a product created to improve a situation), was the IDT.

The focus of this research was about the communication between the ID writers and the animators, therefore the first product to be created in this research (intervention) was the IDT.

This intervention was created based on the basic IDTs, and therefore was named as IDT1. The file format used for creating IDT1 was a slide presentation (.ppt file). The file can be accessed using proprietary tools like Powerpoint (*Microsoft, 2013*), as well as open source tools like Impress available in (*OpenOffice, 2013*) or (*Libreoffice, 2013*).

Creation of new ID template: IDT1

IDT1 had 5 sections for getting various relevant information about the concept from the ID writer. These sections were linear. Figure 5.2 shows the section about interactivity details. The details of all the sections of IDT1 are given below:

1. Information: Basic information about the domain area, course name, definitions of keywords, Aim/Learning objectives: What is the aim of creating this LO, OR what will the users be able to do by using this LO.
2. Concept details: This has a table to insert detailed and stepwise explanation of the animation in the LO.
3. Interactivity and boundary limits: Details of how users can interact with the LO.
4. Assessment questions: MCQ questionnaire to test whether the users have understood the concept.
5. Further reading: References of books, publications and webpages.

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Open Source Courseware Animations Repository

Interactivity and Boundary limits expected in the animation

- In this section provide, interactivity options for all the parameters/components of the concept.

For example:

- Numerical values to change the state of the component: By providing input boxes
- Drag and drop of components: To test the comprehension of the users
- Movement of objects: To explain the action of the components

Interactivity option number	Details of interactivity	Image / Diagram	Text to be displayed	Boundary limit
1	The user can move the 'balloon' of gas in the resonator		When the balloon is placed in high pressure region, it would shrink and its temperature will rise (it will become red). When moved to low pressure region, it expands becoming cold (blue)

Figure 5.2: Screenshot of Interactivity section from IDT1

5.1.4 Prototyping and assessment

Collecting feedback about IDD1s created using IDT1

The goal of RC1 was to understand the communication problems between the ID writer and the animator, especially, when they use the generic IDTs. Therefore, IDT1 was given to the ID writers to create IDD1s. They created IDD1s for fourteen topics using the IDT1. These IDD1s were created in consultation with the respective SMEs, and were labeled as IDD1₁ to IDD1₁₄. The topics were selected from different domains in under graduate engineering.

For the validation of the usability of the intervention IDT1, ten IDD1s were chosen from the available pool of fourteen IDD1s created using IDT1. Care is taken to choose IDD1s from different subjects deliberately, to get a feedback for various subject domains.

Sample

Six animators satisfying the following sampling characteristics were chosen using convenient sampling. These animators were working for Project OSCAR. The sampling characteristics required the animators to have more than one year experience of working on LO creation. Additionally, they should also have basic education in one or more animation software, like Adobe Flash, Autodesk Maya or Blender.

Tool

The tool used for the study was System Usability Survey (SUS) form (Brooke, 1996). SUS is used widely by researchers for testing usability for various advantages it has over other data collection tools (Bangor et al., 2009). SUS has ten statements, with equal

number of positive and negative statements (five of each). Important distinguishing factors are:

- Technology independent: SUS can be used online as well as offline.
- Easy to modify: Original SUS form contains 10 statements, in a specific format. It also allows modification of statements, based on the context in which it is being used. This modification is fairly easy in SUS. The modification done for this study is presented below.
- It is relatively quick and easy to use by both study participants and administrators: SUS has 10 questions in it. Five-point Likert scale ranging from Strongly Disagree (1) to Strongly Agree (5) is used for the options to be filled by the participants. Calculating the score also becomes easy for the administrators.
- SUS provides a single score on a scale: This feature helps in easy creation of the graphs to present the results.
- It is non-proprietary: It is free to use.

Interpreting SUS scores:

According to the creators of SUS, if the product tested for its usability, gathers a score of 68 and above, then the product is considered as usable. If it scores less than 68, then the product is considered non-usable (Bangor et al., 2009).

Based on these factors, SUS was selected as the tool for data collection. The modification of the statements, to the original (like replacing the product name) was done based on the guidelines specified by the creators of SUS. The Likert scale was unchanged. Table 5.2 shows the original and modified statements.

Process

Ten IDD1s selected for this study were given to the six animators. Some animators were requested to evaluate two or more IDD1s randomly, since the availability of animators was less than the number of IDD1s to be tested ($6 < 10$). The IDD1s were assigned randomly to the animators in order to evaluate the robustness of the template. They studied each IDD1 approximately for 30 minutes. Later they were given a survey instrument to gather their feedback about the IDD1 allotted to them. Apart from indicating their choice on the Likert scale, they were requested to write a one line reason for their choice.

	Original statement in SUS	Modified statement for this study
1	I think that I would like to use this system frequently	I think that I am able to use this IDD to animate.
2	I found the system unnecessarily complex	I found this IDD unnecessarily complex
3	I thought the system was easy to use	I thought this IDD was easy to use
4	I think that I would need the support of a technical person to be able to use this system	I think that I would need to support of a technical person to be able to use this IDD
5	I found the various functions in this system were well integrated	I found the various functions in this IDD well integrated
6	I thought there was too much inconsistency in this system	I thought there was too much inconsistency in this IDD
7	I would imagine that most people would learn to use this system very quickly	I would imagine that most animators would be able to understand this IDD very quickly
8	I found the system very cumbersome to use	I found this IDD very cumbersome to use
9	I felt very confident using the system	I felt very confident using this IDD
10	I needed to learn a lot of things before I could get going with this system	I needed to learn a lot of things before I could get going with this IDD

Table 5.2: Modification in the statements of the SUS for this study

Results

The results show that the mean SUS score for these 10 IDD1s was 36.75. The SUS scores of the animators are shown in Table 5.3. The score of **36.75** is lesser than the recommended good score of SUS which is 68. Therefore, this score can be translated as: **IDT1 is non-usable for the animators.**

Findings of RC1

At the end of the stage 4, RC1 is complete. Figure 5.3 shows the completion of RC1 (grayed out). In RC1, the problem was identified, and need for the intervention was established. First version of the intervention, IDT1 was created, and its' usability was tested for the animators. The results showed that IDT1 was non-usable for the animators in its' current form. In the next research cycle (RC2), IDT1 would be modified based on the analysis of the usability feedback gathered in RC1.

Q	1	2	3	4	5	6	7	8	9	10	Score	SUS score
1	3	3	3	3	1	3	3	3	3	0	25	62.50
2	1	2	2	1	3	3	2	1	1	3	19	47.50
3	1	2	1	1	1	1	1	1	1	3	13	32.50
4	3	1	1	1	2	1	1	1	2	1	14	35.00
5	1	1	0	0	0	0	2	0	0	0	4	10.00
6	2	2	1	0	2	3	1	2	1	0	14	35.00
7	3	3	3	1	2	3	3	3	2	2	25	62.50
8	2	1	1	0	1	3	0	1	1	1	11	27.50
9	2	1	0	0	1	1	1	1	1	2	10	25.00
10	1	1	1	1	1	2	0	1	1	3	12	30.00
Mean	1.8	1.6	1.2	.7	1.3	1.8	1.3	1.4	1.2	1.5	14.7	36.75

Table 5.3: Collated SUS scores of the feedback collected from animators for IDT1

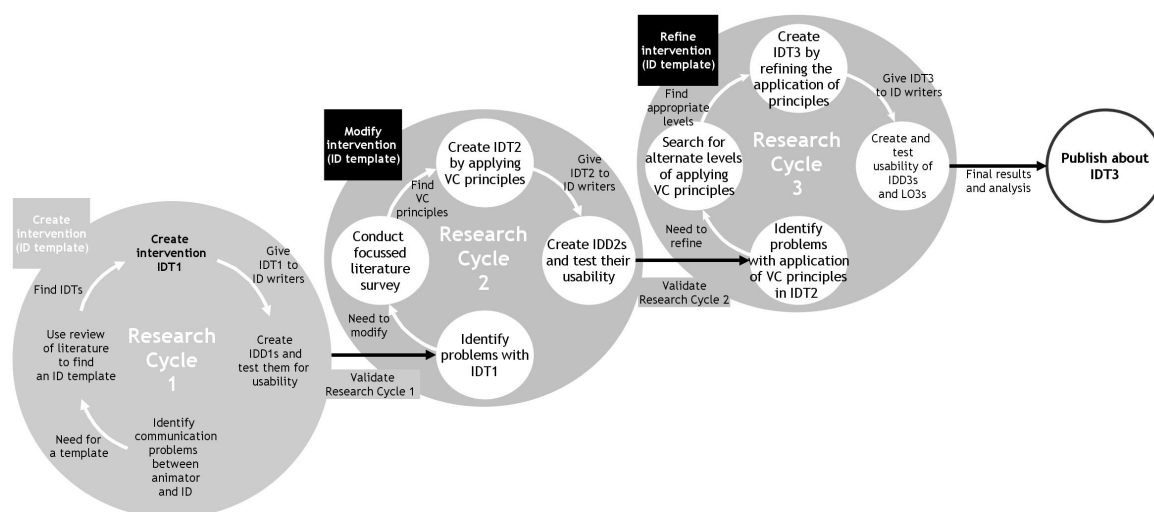


Figure 5.3: RC1 completed, with results as an input for RC2

5.2 Research Cycle 2 (RC2)

Primary objective of this research cycle (RC) was to analyze the problems with IDT1 and modify it to make it usable. This modification was validated by animators. Additionally, the modified IDT (IDT2) was also tested by ID writers for its' usability. Figure 5.4 shows the stages in this cycle:

5.2.1 Stage 1: Identify problem

In the final stage of RC1, the feedback collected from the users of IDT1, was in two formats (refer section 5.1.4). It consisted of SUS scores, and the (short) rationale for the choice made. In the first stage of RC2, the problem was identified by analyzing the

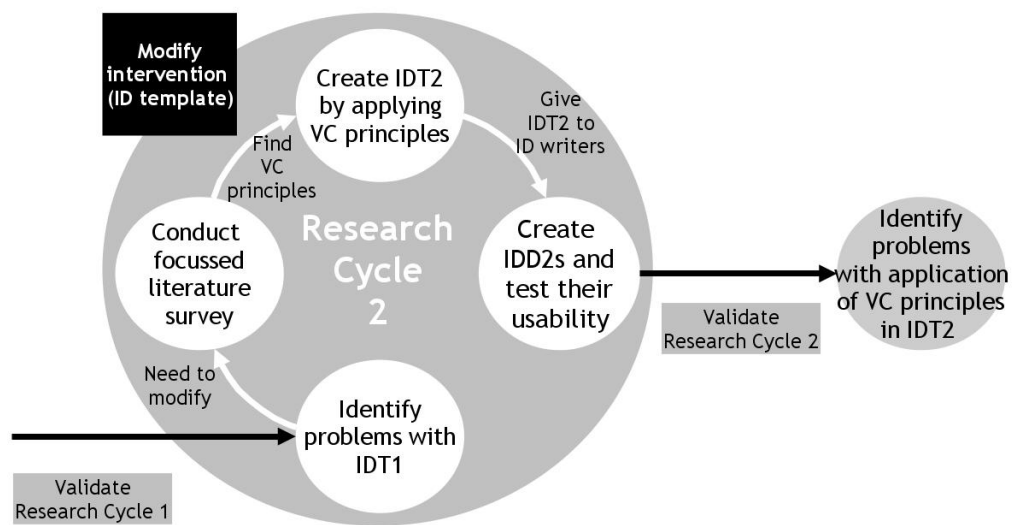


Figure 5.4: Research cycle 2: Modify the intervention

feedback from RC1. SUS score of 36.75 indicated that the IDD was not usable for the animators. In order to identify the problem/s with IDT1, the reasons mentioned by the animators were collated and analyzed in the first stage of RC2. The combination of qualitative and quantitative data was deployed to identify the shortcomings of IDT1.

Analysis of the feedback by animators

The trend of the SUS responses (for the positive and negative statements) and the corresponding explanations provided by the animators, are analyzed in this sub section. The analysis starts with the positive statements.

Trend for the positive statements

The trend in the results for the positive statements (S1, S3, S5, S7 and S9) can be seen in the figure 5.5 given below. Since these are positive statements an important observation is that none of the animators had selected ‘strongly disagree (5)’. The detailed analysis for each of the positive statement is given below:

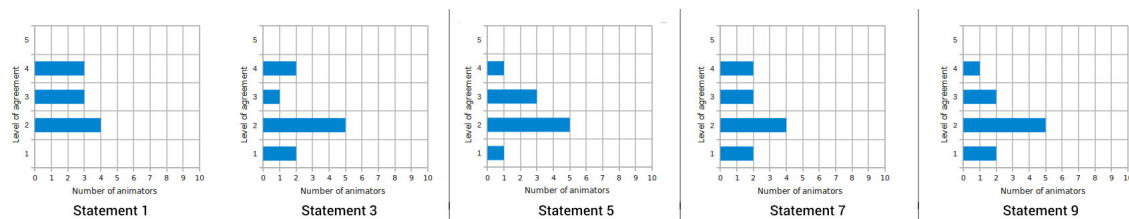


Figure 5.5: SUS scores for the positive statements

S1. I think that I am able to use this IDD to animate.

Mean of the responses of the animators was 3, which translated to ‘Neutral’ (see first graph titled ‘Statement 1’, in figure 5.5). Since this was a positive statement, ‘3’ was a ‘bad’ result and therefore needed investigation. For this, the reasons mentioned by the animators were analyzed. Most of the reasons mentioned the lack of ‘visual information’ in the IDD. Sample responses are given below:

- *There is no visual aid/illustration (I have never seen a rotor machine)*
- *I cannot, because I do not understand the structure*
- *I don't understand what is to be animated and how?*

Probable cause for these responses

There was no section in IDT1 to give a complete picture of the animation in the LO. The visuals were placed in various slides, and the animators were supposed to create the complete picture on their own for animation.

A separate section having the visual information was necessary for the animators in order to understand the IDD.

S3. I thought this IDD was easy to use

Mean of the responses of the animators is 2, which can be translated to ‘Disagree’ (see second graph titled ‘Statement 3’, in figure 5.5). Since this was a positive statement, ‘3’ was a ‘bad’ result and therefore needed investigation. For this, the reasons animators were analyzed. These were mainly about the lack of flow in the overall information in the IDD. Sample responses are given below:

- *No stepwise description or illustration of animations*
- *I did not understand the animation process*
- *Description given is very short so I cannot visualize the LO*

Probable cause for these responses

The sections of IDT1 were lacking the prompts for the SME/ID writer to provide more visual information. Therefore, even though the textual information was correct (content wise), it proved inadequate for the animators, who did not have domain knowledge.

More prompts were required in the IDT1, which could force the ID writers to provide clear instructions to the animators.

S5. I found the various functions in this IDD well integrated

Mean of the responses of the animators was 2, which can be translated to ‘Disagree’ (see third graph titled ‘Statement 5’, in figure 5.5). Since this was a positive statement, ‘2’ was a ‘bad’ result and therefore needed investigation. For this, the reasons animators gave were analyzed. These were mainly about the lack of precise information about timing, and stepwise description. Sample responses are given below:

- *The script says, ‘something is to appear and something to disappear’ but there is no mention of the time interval so I won’t be able to animate it.*
- *Images and details of steps in first page create confusion*
- *Only final output is given but how it will going to come is not given*

Probable cause for these responses

Animators pointed out that some sections of the IDD were clear, but some were not. As a result visualizing the complete LO was not possible.

IDT1 needed prompts for the ID writers, so that the IDDs would have clear demarcation of steps.

S7. I would imagine that most animators would be able to understand this IDD very quickly

Mean of the responses of the animators was 2, which can be translated to ‘Disagree’ (see fourth graph titled ‘Statement 7’, in figure 5.5). Since this was a positive statement, ‘2’ was a ‘bad’ result and therefore needed investigation. For this, the reasons animators gave were analyzed. These were mainly about the lack of information written in a uniform manner, so that ANY animator can follow it. Sample responses are given below:

- *I think most animators will find it difficult work on this IDD, since the (visual) information provided is very less*
- *I strongly disagree because animators will get confused about ‘what to show’ is not explained clearly*
- *I felt so, since the details of steps and the accompanying images were a bit complicated.*

Probable cause for these responses

None of the section in IDT1 explicitly asked the SMEs or ID writers to provide visual information. This was a major lacuna of IDT1, which was used as a

‘storyboard’ by the animators.

Lack of guidelines to be followed by the ID writers were missing in IDT1.

S9. I felt very confident using this IDD

Mean of the responses of the animators was 2, which can be translated to ‘Disagree’ (see fifth graph titled ‘Statement 9’, in figure 5.5). Since this was a positive statement, ‘2’ was a ‘bad’ result and therefore needed investigation. For this, the reasons animators gave were analyzed. These were mainly about their inability to visualize the final LO. Sample responses are given below:

- *I disagree because to understand the procedure, I need visuals to be given clearly*
- *Too much of text creates confusion in some sections*

Probable cause for these responses

Animators were able to see some parts of the LO, but were not confident of completing it fully, using the IDD.

IDT1 provided an option to the ID writers to insert textual information in the IDD, however never prompted them to add corresponding visuals, to make it clear for the animators.

Trend for the negative statements

The trend in the results for the negative statements (S2, S4, S6, S8 and S10) are shown in the figure 5.5 given below. Since these are negative statements, an important observation is that in the responses, none of the animators had chosen ‘strongly agree (1)’. The detailed analysis for each of the positive statement is given below:

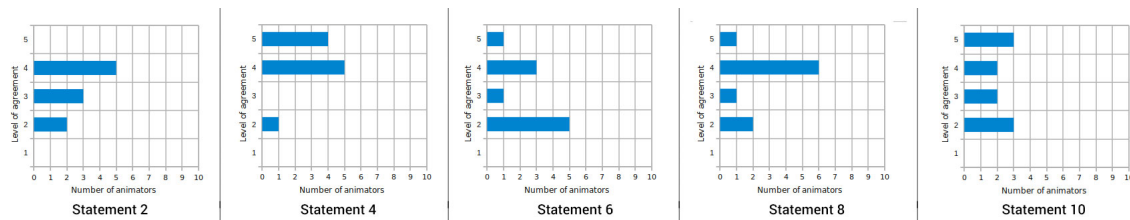


Figure 5.6: SUS scores for the negative statements

S2. I found this IDD unnecessarily complex

Mean of the responses of the animators was 3, which can be translated to ‘Neutral’ (see first graph titled ‘Statement 2’, in figure 5.6). Since this was a negative

statement, ‘3’ was a ‘bad’ result and therefore needed investigation. For this, the reasons animators gave were analyzed. These were mainly about the manner in which the IDD was written. They often had to work hard to understand the instructions in the IDD. Sample responses are given below:

- *No introduction is given for animator, steps are also not there*
- *IDD is neatly presented but many necessary elements like description of the steps to create the animation are missing*
- *Sections like: Aim, procedure and problem statement create unnecessary complexity*

Probable cause for these responses

IDT1 lacked a section where the animator could find the steps to be followed to create the animation in a linear manner. As a result, the animator was dependent on the SME/ID writer to get the details of those.

The information provided in the section ‘Concept details’, was not found useful by the animators. They wanted the steps to be explained explicitly.

S4. I think that I would need to support of a technical person to be able to use this IDD

Mean of the responses of the animators was 4, which can be translated to ‘Agree’ (see second graph titled ‘Statement 4’, in figure 5.6). Since this was a negative statement, ‘4’ was a ‘bad’ result and therefore needed investigation. For this, the reasons animators gave were analyzed. These were mainly about the lack of details given in the IDD. These details were insufficient for them to make decisions. Sample responses are given below:

- *I need more explanation on which part needs to be animated and how*
- *because concepts are there but not explained in proper way, I am not sure how to create the animation*
- *when I read this I did not understand to what I have to animate.*
- *because a lot of information is not clear*

Probable cause for these responses

IDT1 had a section titled ‘Procedure’ but there is no format provided for the SMEs or ID writers to provide the details there. The freedom of explaining the concept in their own way was seen in the IDD, and that variable style of explanation was proving to be a deterrent factor for the animators.

A section along with detailed guidelines was required in IDT1.

S6. I thought there was too much inconsistency in this IDD

Mean of the responses of the animators was 3, which can be translated to ‘Neutral’ (see third graph titled ‘Statement 6’, in figure 5.6). Since this was a negative statement, ‘3’ was a ‘bad’ result and therefore needed investigation. For this, the reasons animators gave were analyzed. These were mainly about the inconsistency of the ID writers in writing the instructions in the IDD. Sample responses are given below:

- *More detailed steps should have been given to make it clear*
- *I am neutral because topics are given but link between them cannot be made*

Probable cause for these responses

IDDs were written in a manner where IDT1 provided relevant pointers. In other places, the ID writers were clueless about the pattern in which they should have shared the information.

More prompts were required in IDT1, so that the ID writers could add the relevant information.

S8. I found this IDD very cumbersome to use

Mean of the responses of the animators was 4, which can be translated to ‘Agree’ (see fourth graph titled ‘Statement 8’, in figure 5.6). Since this was a negative statement, ‘3’ was a ‘bad’ result and therefore needed investigation. For this, the reasons animators gave were analyzed. These were mainly about the lack of clear cut guidelines of placing the data, as per the design template. Preliminary visual design of the LO was given, but the mapping of the IDD content to the actual sections in the LO was missing. Sample responses are given below:

- *might be because an overall layout was not there*
- *too much concept explanation without animation related information*

Probable cause for these responses

IDT1 did not have a list of ALL the sections to be displayed in the final LO. This was a consistency problem with IDT1, as the animators, who animated multiple LOs, were unsure of the exact sections in the LO.

S10. **I needed to learn a lot of things before I could get going with this IDD** Mean of the responses of the animators was 3, which can be (rounded off and) translated to ‘Neutral’ (see fifth graph titled ‘Statement 10’, in figure 5.6). Since this was a negative statement, ‘3’ was a ‘bad’ result and therefore needed investigation. For this, the reasons animators gave were analyzed. These were mainly about the lack of information about the software to be used to create the LO.

Animators mentioned that they were often stuck at a point for the lack of visual design, or an interaction design decision apart from the content related decisions. The examples of these are:

- **IDD instruction:** Show the temperature in a box.
Animator’s dilemma: *What should be the shape of the box? How big should the box be? What colour for the box? What colours for the text? Etc.*
- **IDD instruction:** Show 3 buttons as options for the user.

Probable cause for these responses

Animators had dilemmas like: What should happen when the user ‘hovers’ (action of moving the mouse over a certain area on the computer screen) the mouse over a button? Will it show some changes? What should change? What happens to the other buttons, when the user clicks on one of the buttons? etc.

IDT1 lacked interaction design guidelines for the ID writers.

Out of the ten statements given in the SUS form, the results showed that animators opted to remain neutral to four statements. For the rest of six statements, animators indicated their problems. The problems were identified by calculating a mean of the scores the animators had chosen for a particular statement. Based on the mean scores (quantitative data), and the reason they provided for their choice (qualitative data), the problems were divided in three categories. First one was related to the need of reorganization of the existing sections. The second one was about the need of textual detailing in the existing sections, and the third was about the need for visual detailing required.

Problems identified in IDT1

Need for reorganization of sections (Based on feedback of the statements S1, S6, S7 and S8)

Chunking of the information within the sections of IDT1 was confusing for the animators. Animators expressed their inability to interpret certain important information, owing to the chunking done in IDT1. They agreed that the required information was present in the IDD, but it was difficult to locate the information.

Another example was of the sections ‘Concept details’ and ‘Interactivity and boundary limits’. These were 2 separate sections in the IDT1. The ID writers filled up the information according to the pattern mentioned in IDT1. On the other side, animators found it difficult to interpret it and maintain an overall flow of the LO in which interactivity options come intermittently in the animation section.

Hence, some new sections were required to address the lack of information, which was not found by the animators in the existing sections. One option to address this problem was by reorganizing of the existing sections.

Need for textual detailing of sections

(Based on feedback of the statement numbers: S2, S3, S4, S6, S7 and S10)

1. The sections in IDT1 were created to provide important information to the animators regarding the animation to be created. IDT1 had tables with headings, but the detailing expected was not mentioned explicitly. This resulted in a confusion for the ID writers and eventually to the animators. For example:
 - There was no mention of the time duration in the ‘Concept details’ section, making it difficult for the animators to decide the duration of the animation (see figure 5.7).
 - No categories were mentioned in the ‘Links for further reading’ section, so books, papers, webpages etc. got mixed up.

Step	Details of the step	Image / Diagram	Text to be displayed	Action / Motion in the step
------	---------------------	-----------------	----------------------	-----------------------------

Figure 5.7: Heading of the table in procedure section of IDT1

As shown in 5.7 the information in the columns having the headings titled ‘Details of the step’ and ‘Action / motion in the step’ were found confusing by the animators. Renaming the column titles was required to avoid this problem.

Need for detailed visual information

(Based on feedback of the statement number: S1, S3, S4, S5, and S9)

1. The ‘Image/diagram’ heading in the procedure section as shown in figure 5.7 was found too small to accommodate the required information. This made it difficult

for the animators to create the visuals, and they had to take their own decisions about the motion to be created, on the basis of little information available.

2. In none of the sections, the animators were told/shown the final look of the LO. There was no section in IDT1 to explain the details of the visuals in the LO like: placement of the components, their relative sizes, etc.

Analysis of the feedback provided by the animators to the statements, suggests that IDT1 needed:

1. detailed visual information
2. more textual details in the information provided
3. reorganization of sections

5.2.2 Stage 2: Identify tentative products

As the problems mention, lack of visual communication in IDT1 explicitly, a review of prominent principles from visual communication domains was performed. The review includes four domains of visual communication: graphic design, animation design, multimedia design and interaction design. Well known principles from these domains were chosen for the review, on the basis of their documentation, citation frequency and availability of examples.

Animation principles

The 13 principles mentioned by the animators at Disney animation studios were considered for this review. Research publications (Lasseter, 1987), and the books (Thomas et al., 1995) published on the topic are included in the focused literature review. Summary of the review of animation principles is given below:

Animation principles mentioned in the literature are: Squash and stretch, Anticipation, Staging, Straight Ahead Action, Pose to Pose action, Follow Through and Overlapping Action, Slow In and Slow Out, Arcs, Secondary Action, Timing, Exaggeration, Solid Drawing and Appeal.

Most of the animation principles were initially created for the cell animation domain. Subsequently, they were suitably adapted to other forms of animation like: computer animation, 3D animation, clay mation, etc. Interestingly, all these forms of animation mainly catering to the entertainment domain, which has comic relief as one of the foremost objective. Most of the principles, thus have exaggeration as their primary component.

In animation for educational domain, the primary objective is not to provide comic relief, but to create visualizations, in a form that is *not at all* away from reality.

Based on this criteria, the principles which have exaggeration as the main component, were found unsuitable for their adaptation in educational animation domain. A few were required to be adapted with modifications, and rest were adopted as they are. The list of the principles in these categories is as follows:

Animation principles applied as they are: These principles have an important role to play about the overall animation quality. Given below are the definitions of the principles, and its application in IDT2.

Timing: Timing principle explains, how to achieve slow and fast motion on screen by adding or reducing the number of frames.

Staging: Staging principle helps the animator to plan the animation. It is done by drawing the poses of the character at the critical time positions like: entry, in-between (shown using most important pose during the stay) and exit.

Pose-to-pose action: Pose-to-pose animation is a technique to draw the critical poses in an action (called as keyframes) and later to fill up the gap by drawing the in-between frames.

Arcs: Arcs principle suggests using trajectories to scaffold the animator for creating the path of action.

Secondary action: Secondary action is a natural action occurring along with the primary action. This is mostly the motion of appendages attached to the character, which move along (slightly differently) when the character moves.

Solid drawing: Solid drawing principle expects neatness and accuracy in overall structure of the character drawing.

Appeal: Appeal is the overall impact created by the entire animation as a single unit. In this the various principles, quality of drawing, painting, background imagery, music present a cumulative impact for the viewers.

Animation principles which can be applied with some modification are Anticipation, Follow through and overlapping action, Slow-in and slow-out.

The principles in this category have an intrinsic possibility of getting exaggerated. Barring this possibility, these principles are required in creating a realistic motion of given object. Thus, the modification suggested here is to AVOID exaggeration.

Animation principles which cannot be applied are Stretch and squash, Straight ahead action and exaggeration.

All the principles listed here are exaggeration oriented. The animation of the objects in educational domain, cannot be exaggerated, for the simple reason, that it will immediately go away from reality. Additionally, the students using these animations (having exaggeration) will be misled by showing the incorrect visualizations. Therefore these principles have to be avoided in the educational animation creation process.

Only time when these animation principles can be used is when the script mentions the requirement of distortion and exaggeration in the motion.

Graphic design principles

The 11 principles mentioned from the Gestalt theory of design were considered for this review. Research publication by Chang, published on this topic is selected for this review (Chang, Dooley, & Tuovinen, 2002).

The principles are: Figure-Ground, Focal Point, Proximity, Continuation, Unity/Harmony, Similarity, Balance/Symmetry, Good Form, Closure, Isomorphic Correspondence, Simplicity.

The graphic design principles are created for application in various visual communication domain. Subsequently, they are suitably adapted to other forms like: print media, interior design, information design, etc. A lot of literature is also available which signifies its role in screen design or the interface design.

In parlance of visual design for educational domain, the adaptation of these principles in interface design comes handy. As a result, ALL the principles are found necessary in order to create visual design for educational domain. However, there is a minor categorization, based on the timing of its application in the content creation process. Some principles are helpful for the overall screen design while a few can be used for creating the components of the screen. The list of the principles in these categories is as follows:

Graphic design principles to be applied for the overall screen design in educational animations are:

Figure and ground: This is important to separate the foreground (action area) as compared to the background (Non-action area) in an educational animation. This will enable the users to identify the correct area of action and concentrate accordingly.

Focal point: This principle enables the user to focus on a particular point of importance (at a given time) and start exploring the animation accordingly. Application of this principle helps in avoiding the distraction, and enables focusing.

Proximity: This principle helps the designer to create chunks (groups) of components related to each other so that the user locates them easily.

Continuation: Application of this principle provides a path or a visual flow for the information in a sequence desired by the SME.

Unity: Unity principle helps in creating a harmonious visual of ALL the components present in the animation.

Balance: Principle of balance applies not only to the parts of LO but also to the whole screen design of the LO. A well balanced design of an LO becomes easy for

navigation for the user.

Similarity: This principle works across a series of animations, as the user is able to understand that these belong to a similar topic.

Graphic design principles to be applied for the creation of individual components of educational animations are: Closure, Isomorphic correspondence and Simplicity.

These principles are useful in the process of creating the components of the LO. Every component or a element of an LO should be such that it should match the overall design strategy. These principles are useful in creating such components.

Interaction design principles

The principles of interaction design are more in the form of guidelines. It is also observed that because these principles are for ‘interaction’ they are mostly applicable to the ‘computer’ or other digital devices easily.

Forming a subset of principles from the given list is indeed not necessary. Almost all principles qualify to be in the list. However, in order to facilitate operationalization of principles for the IDT, the principles having overlap with other domains like graphic design, multimedia design and animation were not included in this list.

The principles those were mentioned in the literature, and proven to be useful in LO creation process are: **Visibility, Feedback, Constraints, Mapping, Affordance and Consistency** (Sharp et al., 2003).

Visibility: User should be able to see everything that is required, and more importantly, should not be able to see all other things which are not required. The LO design should facilitate the user to get to the desired information as quickly as possible.

Feedback: User should be able to use the LOs even in isolation. Design appropriate feedback to every action taken by the user.

Constraints: User should get clear indication/feedback about the options which are possible and the options which are not. LO design should show the range of options, however should also show a clear demarcation of the range of options possible and not possible (at a given instance).

Mapping: User should be able to envisage the relationship between the input provided and the corresponding output. Consider providing pointers for the user to establish the relationship.

Affordance: User should be able to understand the function of a given element by its appearance.

Consistency: User should be able to find a common theme in within a LO or

within a series of LOs. LOs with consistent design makes it easy for the user to recall and use the LOs more effectively.

Multimedia design principles

Adaptation of overall multimedia principles from entertainment domain to the educational domain has been done by a few researchers (Clark & Mayer, 2011), (Mayer, 2005) and (Mayer, 2002). The principles are: multimesia, contiguity, modality, redundancy and coherence. Since, all the principles are tested and validated for eLearning domain, all of them are selected to be applied while creating IDT2.

Multimedia: Users learn better from words and pictures than from words alone. While designing LOs, the concepts should be explained using words and graphics rather than words alone.

Contiguity: Users understand an explanation when corresponding words and pictures are presented at the same time instead of presenting at separate time. Timing for the text to be shown on screen (on screen text) should be matched to the animation being shown.

Modality: Users learn better if words are presented as speech (audio), rather than text. This makes it easy for the user to see the image and hear the text, rather than increasing the cognitive load where image and text, both have to be seen. Consider replacing on screen text with an audio narration (voice over) to match the animation.

Redundancy: Users learn better from animation and narration than from animation, narration, and on on-screen text. Consider having visuals with words in one of the two: audio or text. Avoid using both.

Coherence: Users learn better from when extraneous words, pictures, and sounds are excluded rather than included. Consider avoiding extraneous material, since it can hurt learning.

5.2.3 Stage 3: Create tentative products and theories

In this stage, using the review of the principles from the VC domains, and the problems analyzed in the Stage 1 of RC2, a new template was designed. Over all more information was asked to the ID writer, so that the LO is searchable on the web. This template was a tentative product, to be tested in the next stage. The theories applied in this stage/product were tentative, to be finalized based on the feedback received. The first step was to operationalize the short listed principles, and the second step was to modify IDT1 and create IDT2.

Section 1: Information

This section was kept almost the same as IDT1. The ‘Information’ section in IDT2 had the following subsections:

1. Title of the LO.
2. Domain (Subject area of the LO).

This was useful at a later stage, when the users search the repository.

3. Short write up about the LO.

This was mainly based on the feedback of the animators for the statements S4 and S9 in the SUS forms. First one was about the requirement of a technical person to be able to animate the IDD, and the second one was about the confidence of animating the IDD. This write up gave the animator and the users a general overview of the concept.

4. Definitions of the important keywords in the LO.
5. Addition of new sections to provide more visual information.

A new section ‘**Master layout**’ was introduced. This section expected the SME and ID writer to create an image of the elements present in that LO, shown at their respective positions. It also expected the scale of these elements to be depicted, so that the relative proportions and the distance between the elements were clear to the animator. In addition to this the master layout also depicted the extreme positions in the animation, so that the animator got information about the area to be covered. This addition was based on animation layout and staging principles (from animation domain) and mapping and visibility principles (from interaction design domain).

Section 2: Concept details

This section was about creating a format for the SMEs/ID writers so that they can write the steps of the animation in a way that it was usable for the animator:

The SMEs and ID writers are well versed with the concept, and also are aware of the motion involved in the concept. IDT1 has few pointers to the writers to explain the motion of the concept in detail. In such conditions, wherever the writers fail to write the exact details, the animators were left to assume things on their own. The animators, who are not the content experts, may make a mistake in the visualization and movement of the unexplained portions.

The ‘Concept details’ section in IDT2 had the following subsections:

1. **Analogy** Using a day to day example to explain the concept was planned to be included so that the animator and the user is aware of the concept, prior to watching the animation of the concept.
2. **Step wise description:** The step wise description sub section was modified with detailed guidelines for the writers. It strongly recommended using images for each and every step. The format for writing the instructions was designed with an bigger empty box for inserting an image in every step. This provideg a prompt to the writers to add an image at every step. It also recommended use of a new slide for each step. This was to avoid the confusion the animators had mentioned about the flow of action (with IDT1).

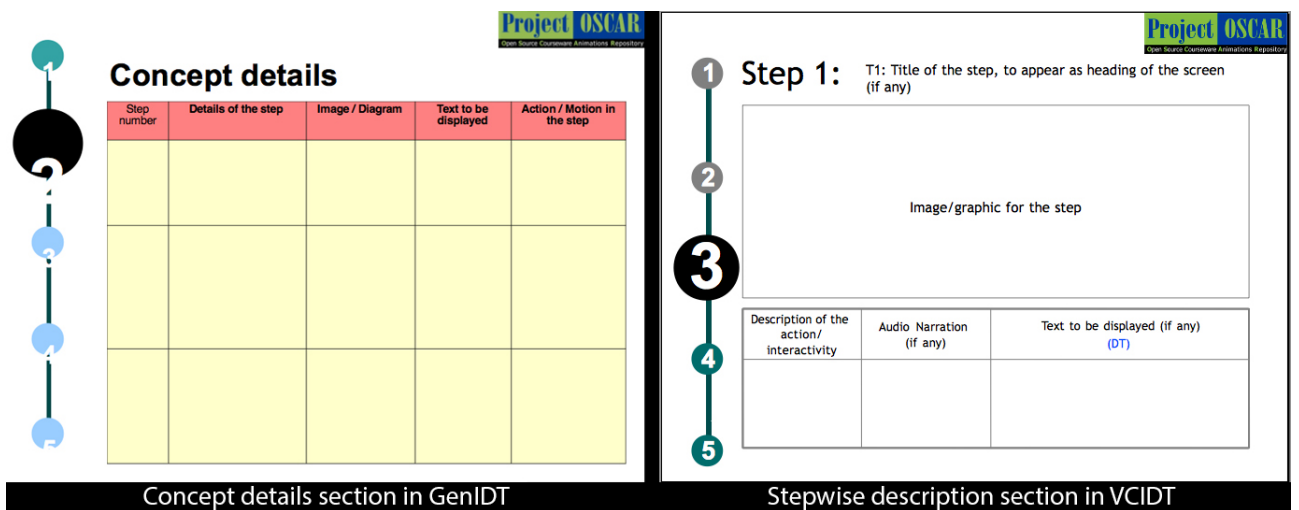


Figure 5.8: Stepwise description screen in IDT1 and IDT2

Separate columns were made in the table to segregate the on screen action details, on screen text and the voice over text. This was to avoid the confusion of what was to be shown on screen and what was NOT to be shown on screen.

3. **New section introduced titled Animation design** A default animation design template was provided in a separate section. This was a suggestive layout which showed default sections in an LO. There was an option to add or delete sections. Writers were expected to map the slide numbers with the sections on the animation design where the information was displayed. See figure 5.9.

This addition was based on animation layout and staging principles (animation domain) and mapping and visibility principles (interaction design domain).

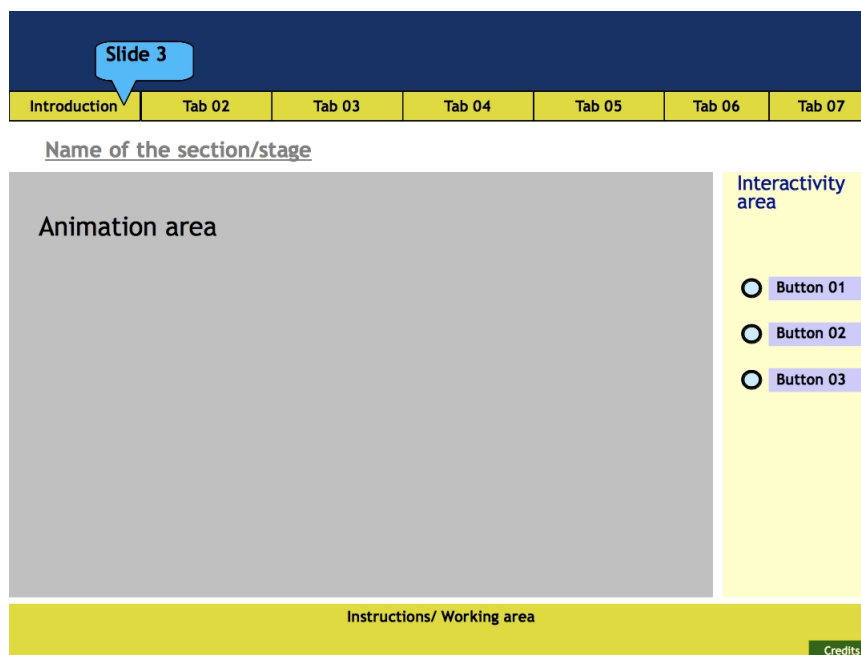


Figure 5.9: Animation design screen in IDT2

Interactivity and boundary limits

The interactivity section was one of the most important sections in an LO. Usability of this section depended heavily on the clarity of instructions given to the animator. Since the SMEs and the ID writers were not (expected) to be well versed with the amount of details required by the animators, a format was proposed in the IDT2. This was a comprehensive table which had columns for the data required. See figure 5.10:

Interactivity type	Instruction to the learner	Boundary limits	Instructions for the animator	Results and Output
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Figure 5.10: Column headings of Interactivity and boundary limits section in IDT2

- Sample interactivity types were mentioned in the instructions slide to facilitate the choice of interaction. This was done, as the ID writers may not be well versed with the theories of choosing the interactivity options.
- The next column expected the ID writers to write specific instructions to be displayed (on screen text) or conveyed (voice over audio) to the learners. Example: Select any one metal from the options given below.
- Third column expected the ID writers to write about the boundary limits of the interactivity option. Example: The temperature box should only allow numerical

entries and the number should not exceed 16. Do not allow decimal points in this box. Display an error message, when the user tries to enter either of these by showing a pop-up next to this box with the text: ‘Enter values 0 to 16. Do not enter values with decimal points’.

- The fourth box had the instructions to the animator about animation of the interaction.
- The final column was for writing the results to display for the various scenarios possible for the corresponding interactivity options. This was added, as the feedback from animators mentioned that they were unable to visualize certain motion and action in the LO.

This addition was based on animation layout and staging principles (from animation domain) and mapping and visibility principles (from interaction design domain).

Assessment

The section about the assessment of the users had few instructions for the ID writers in IDT1. In IDT2, pointers were provided for creating questions which the user can answer after interacting with the LO.

The instructions slide for the Assessment section in IDT2 had the following instructions:

Please provide a set of questions that a user can answer based on the LO. They can be of the following types:

- Should have (minimum) 5 questions of objective type (like multiple choice, match the columns, Yes or No, sequencing, selecting odd one out etc.).
- The questions could be open-ended. The user would be asked to think about the question. The authors were requested to provide hints.
- Include questions, for which the user should interact with the LO (with certain parameters) in order to answer it.
- Avoid questions based purely on recall.

References

The final section of references had pointers for the writers to segregate their information in various types like websites, research papers or books.

This addition was based on chunking principle (from interaction design domain).

5.2.4 Stage 4: Prototyping and assessment

Collecting feedback about IDD2s created using IDT2

Feedback from RC1 showed that, the animators did not find the IDD1s (created using IDT1) usable. In the stages 2 and 3 of this RC, IDT2 was created by addressing the problems which were mentioned in the feedback of RC1. In this stage, IDT2 was validated by the users (animators and also the ID writers) to provide the usability feedback.

IDT2 was given to the ID writers first to create IDDs. The IDDs created were named as IDD2s. Later, usability feedback was collected not only from the animators, but also from ID writers. A sample screenshot of IDT2 is given in figure 5.11.

Project OSCAR
Open Source Computer Animations Repository

1 Step 1: T1: Title of the step, to appear as heading of the screen (if any)

2

3 Image/graphic for the step

4 Description of the action/ interactivity	Audio Narration (if any)	Text to be displayed (if any) (DT)
5		

Figure 5.11: Screenshot of the section on stepwise description in IDT2

The details of the validation study are given below. The feedback was collected from animators primarily to see if the problems that they had mentioned for IDT1 are addressed in IDT2. Additionally, feedback was also collected from ID writers this time. This was done, since IDT1 was almost similar to the generic templates used in the industry. The feedback was collected to study the usability feedback for the modified intervention: IDT2. A table showing the modifications done to IDT1 is added on the next page.

The details of the study in terms of sample, tool and process are written with two subsections for the two stakeholders (animators and ID writers) to simplify the formatting.

Modifications done to IDT 1 to create IDT 2 (with rationale)

IDT 1	IDT 2	Reasons for the changes	Principles used to decide the change (Domain)
Information:	Information:	More information is asked to the ID writer in order to get more metadata.	
Basic information about the domain area, course name,	Title of the LO	No changes	
Aim/Learning objectives: What is the aim of creating this LO, OR what will the users be able to do by using this LO.	Brief description of the LO	No changes	
	Learning objectives of the LO	No changes	
	Names of the authors and their affiliation	More inputs for metadata	
	Master layout	1. To get text+visual information about ALL the components in the LO 2. To understand the relationship between the components	Staging (Animation) Mapping (Interaction design) Visibility (Interaction design) (Pedagogy)
Definitions of keywords,	Definitions of the components in the LO	Additional textual information about the components in the LO	
	Explain the process: Analogy/Scenario / Action / Example to explain the process to the animators	To make it easy for the animators to understand the concept of LO	Analogy (Pedagogy) Mapping (Interaction design)
2. Concept details: This has a table to insert detailed and stepwise explanation of the animation in the LO.	Stepwise description of the process: Details of the action in the LO, along with images to support the text	Bigger sizes of images are requested to avoid ambiguity for the animators Additionally, more information is requested to help the animators like: duration of animation,	Timing (Animation)
	Animation design: Sample visual layout is provided to the ID writer. It is customizable.	To help animators visualize final look of the LO. Customization available to make it flexible	Staging (Animation) Mapping (Interaction design) Visibility (Interaction design)
3. Interactivity and boundary limits: Details of how users can interact with the LO	Details of the interactivity section in the LO	Bigger sizes of images are requested to avoid ambiguity for the animators. Additionally, columns like 'Results and outputs' added for providing more textual details of the interactivity options to the animators.	
4. Assessment questions: MCQ questionnaire to test whether the users have understood the concept	Assessment questions: MCQ questions to test whether the users have understood the concept	More textual inputs are requested like, 'Hints for the answer'. Etc. Additionally, more pointers are provided for the ID writers to help them create questionnaire	(Pedagogy)
5. Further reading: Mainly references section	References (this is part of the information, but placed at the end of	Classification given in terms of various options the ID writer may want to choose..like books, websites etc	Similarity (Graphic design)

Creation of artifacts

The artifacts required in this study were the IDD2s created using IDT2. The topics for creating IDD2s were similar to those in RC1. This decision was taken to have internal validity. However, in order to have generalization, two new topics were added to the list of existing topics.

Sample

- **Animators:** Same 6 animators who earlier participated in the RC1 participated again in this study.
- **ID writers:** Sampling characteristics for selecting ID writers for the study were: basic graduation in science, formal education in ID or minimum 6 months work experience in eLearning content creation.

Totally three ID writers were selected for the study, from the project OSCAR, using convenient sampling. Two ID writers were trained in ID, while the third had 6 months experience of creating ID for eLearning.

Tool

- **Animators:** Same tool (SUS) used in RC1 was used in this study. 5.1.4.
- **ID writers:** The tool used for the study was SUS, which is the same as used in RC1 5.1.4.

Additionally, to get more information about the usability about IDT2, the ID writers were interviewed. This was done to get qualitative data to augment the quantitative data gathered using SUS. The questions used in the interview were:

1. What are the problems you face while writing the IDDs?
2. Are you able to encapsulate the entire data in the template? Is something still remaining which is supposed to be told the animator, but the template does not have provision to insert it?
3. How difficult is the template? Complex or Cumbersome?
4. Is it possible to keep your pedagogy method intact while the IDD/or you alter it because of the structure of the template?
5. What would you add to this template? What would you remove? What would you alter/rephrase? And how?

Process

- **Animators:** The IDD2s selected for this study were given to the animators (two each). Each animator studied one of the assigned IDD2 for 30 minutes approximately. Later they were given SUS form to indicate their feedback about the usability of the respective IDD2. Apart from indicating their choice on the Likert scale, animators were requested to write a one line reason for the choice they were making. Same process was repeated for the second IDD2 assigned.
- **ID writers:** IDT2 was given to the ID writers. They were also given the concept proposal form (CSF) for the respective concepts. ID writers created IDD2s using IDT2. After the IDD2s were ready, they saved the files in the prescribed format (.ppt).

Later the ID writers were given SUS forms to be filled up by indicating their feedback about the usability of IDT2. After filling the SUS forms, an interview was conducted, using the questions mentioned in 5.2.4.

Results

- **Animators:** The results showed that the mean of SUS score for the 12 IDD2s was 68.75 (see figure 5.4). Based on the recommended good score of 68, prescribed by the creators of SUS, this was marginally above average (Bangor et al., 2009). This score was translated to: **IDT2 was usable for animators**. It also showed around 90% increase over the SUS score of RC1 which was 36.75, (section 5.1.4).
- **ID writers:** The results showed that the mean of the SUS scores of the feedback for the IDT2 was 54.16 (see table 5.5). Based on the recommended good score of 68, prescribed by the creators of SUS, this was less (Bangor et al., 2009). This score was translated to: **IDT2 was non-usable for ID writers**.

	1	2	3	4	5	6	7	8	9	10	Total score	SUS score
1	1	2	2	3	3	3	3	2	2	1	22	55
2	3	3	3	3	3	3	3	3	3	3	30	75
3	2	1	1	1	2	3	1	1	1	0	13	32.5
											Avg	54.16

Table 5.5: Collated SUS scores of the feedback collected from ID writers for IDT2

This was an indicator, that IDT2 needed refinement so that the ID writers found

	1	2	3	4	5	6	7	8	9	10	Total score	SUS score
1	4	3	3	3	3	3	3	3	3	1	29	72.5
2	3	3	3	3	3	3	3	3	3	3	30	75.0
3	3	3	3	3	3	3	3	3	3	3	30	75.0
4	4	4	4	2	4	4	4	4	4	0	34	85.0
5	4	3	3	3	3	3	3	3	1	2	27	67.5
6	3	3	3	2	3	3	3	3	3	2	28	70.0
7	1	1	1	1	1	1	1	1	1	3	12	30.0
8	3	3	3	2	3	3	3	3	3	1	27	67.5
9	3	3	3	3	3	3	3	3	3	3	30	75.0
10	3	1	3	2	1	1	2	2	2	0	17	42.5
11	1	2	3	1	3	1	2	3	2	1	19	47.5
12	3	3	3	2	3	3	3	3	2	2	27	67.5
												68.75

Table 5.4: Collated SUS scores of the feedback collected from animators for IDT2

it usable. This refinement was carried out in RC3.

Summary of RC2

At the end of the stage 4, RC2 was complete. Figure 5.12 shows the completion of RC1 and RC2 (grayed out). In this cycle the intervention (IDT2) was created by modifying IDT1 based on the analysis of the feedback. The modifications and the rationale for these modifications are shown in the section 5.2.4. The new version, IDT2 was created by applying visual communication principles. It was validated by the animators and was found usable, as compared to IDT1, which was found non-usable by animators. However, ID writers found IDT2 not-usable. In the next research cycle (RC3) the usability feedback from the ID writers would be analyzed to identify the problems in IDT2. The challenge was to address the problems of the ID writers and refine IDT2, without reducing the visual information present (which was already acknowledged by animators).

RC1	RC2
Usability score for IDT1	Usability score for IDT2
Animators	Animators
34.75	68.75
	ID writers
	54.16

Table 5.6: Overview of the results for RC1 and RC2

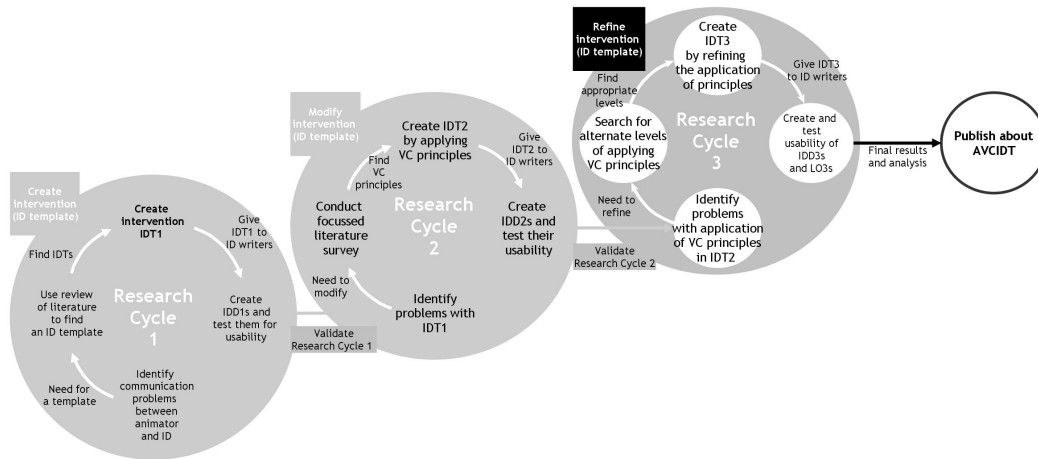


Figure 5.12: RC2 complete and the results validation to be done in RC3

5.3 Research Cycle 3 (RC3)

Primary objective of this RC was to analyze the feedback gathered from the ID writers and refine the IDT2. In the first research cycle (section 5.1) intervention IDT1 was created and the animators tested it for its usability. In RC2 (section 5.2) the animators found the modified version (IDT2) usable. However, IDT2 was found non-usable by the ID writers in RC2. In this cycle, the results of the user testing in RC2 were analyzed, and the problems emerging out of that were addressed by following the DBR method. Figure 5.13 shows the stages in this cycle:

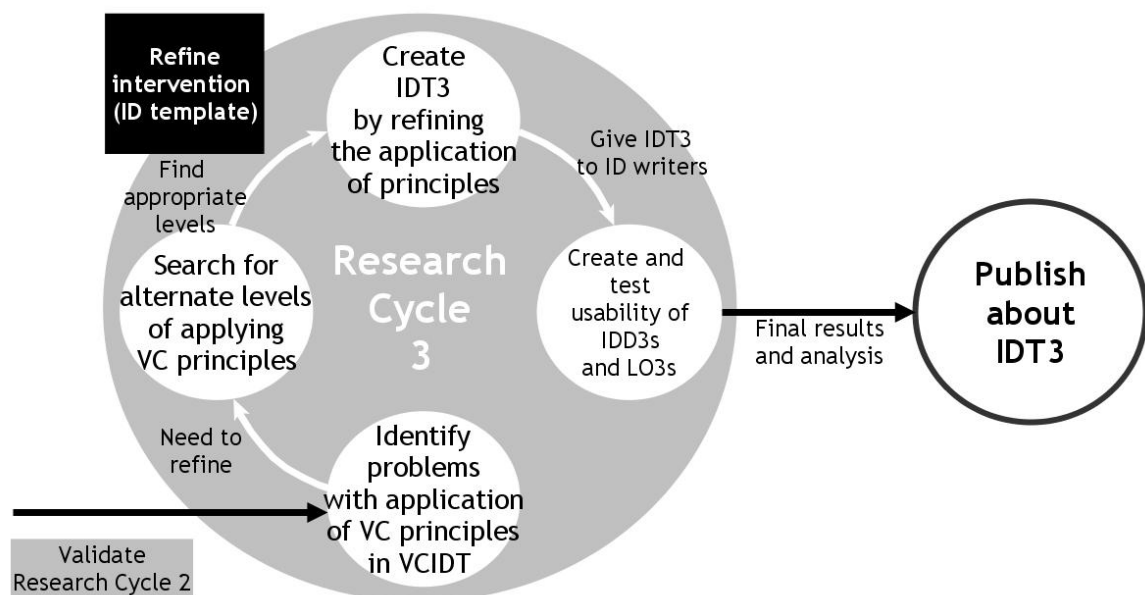


Figure 5.13: Research cycle 3: Refine the intervention

5.3.1 Stage 1: Problem identification

In this stage, the feedback collected from the animators and the ID writers was analysed and the problems were identified. The major problems mentioned in the feedback were as follows:

P1: There was still a disconnect in the visual and textual description.

This led to mistakes in the execution or forced the animator to take decisions on the topics he/she was not an expert on.

ID writers were unable to understand the master layout. Most of the master layouts were found having only visuals, and less supporting text. Some times the elements in the LO had longer and complex names. In other sections of the IDD, the ID writers had written abbreviations for the longer names. These abbreviations are well known for the domain experts, but animators struggled to figure out the details of these new elements in the IDD. This resulted in lack of understanding the description.

P2: ID writers were not able to write certain details.

IDT2 lacked self check procedure to prompt the ID writers about the missing details.

There were two reasons for the occurrence of this problem: a) ID writers provided insufficient details for an action or interactivity, and b) the template lacked the prompts to ensure that the ID writer writes these details. There was absence of some table columns which could capture these essential information.

P3: Details written in wrong section, were non-traceable for animators.

In addition, they were also unable to place it in the suitable section during LO creation.

This problem was because of the confusing section headings, which were unable to provide clear idea about content to be displayed in the LO.

P4: Unable to understand the relationship between the elements of the animation.

The animators were not experts in the given subject domain, therefore, the elements in the animation were new to them.

Animators find themselves in situations where there was contradictory data available for certain elements/actions in the LO. Ex: The instruction written in the IDD was that 'electrons won't pass through the atoms'. However, the accompanying image shows that it has passed through the atom. In such conditions animators have to

take some decisions on their own. These decisions may/may not be correct (as per the subject domain specifications), and therefore the LO will show incorrect concept.

P5: Wrong or confusing chunking of the sub-sections

This created a situation where the entire content was present in the IDD but since the animator was not an expert for the chosen concept, he/she could not locate it. The content was not present in a coherent manner, for the animator to find and use it.

P6: Certain instructions for writing the sections were not clear, as a result, the ID writers have written the instructions in a different way than expected.

P7: Animators were unable to understand the description, if it was explained in a cryptic manner

P8: Slides having a lot of data/information

Animators animate one shot at a time. One shot, typically has one action. Some slides in the IDD had lots of description to be animated. This was difficult for the animator to create the animation ‘shot-by-shot’, as the shot description was too long. Creating smaller chunks of action was needed.

P8: Some technical points were left to the animator to decide

The animator was unable to take a correct decision, as he/she was not an expert in the subject area of the concept

P9: Animators feel that they need to have knowledge of User Interface design and Interaction design

Most of the animators in the eLearning content creation industry, are graduates from varied disciplines other than visual arts. As a result, most of them rely on instructions for creating graphics. If no instructions are given in the IDD (which is possible, as ID writers/SMEs are not visual design experts either) then these animators were clueless about the aesthetic decisions to be taken.

5.3.2 Stage 2: Identify tentative products

In this stage, the problems enlisted in section 5.3.1, were addressed by refining the application of VC principles in IDT2. The subsection numbers of the corresponding problems are mentioned in the solutions in this stage.

List of Elements (Problems P1 and P4, mentioned in 5.3.1)

The inclusion of master layout was done based on staging principle of animation domain, ID writers were not well versed with the concepts from the animation domain.

Therefore, instead of an approach which was more visual in nature, a decision was taken to make it textual base. In this approach, the IDT started with: ‘What are ALL the elements required in this LO? Please list them in the table below’. Various columns of the table prompted the ID writer to suffice the details of the elements. These included: images, functional details (like behavior, physical properties etc), abbreviations (standard or new), and other elements.

List of element groups: This was for creating groups of elements which were together, in the LO. These groups were displayed together and also helped in creating a hierarchy in terms of their visual presence in the LO.

Inclusion of a checklist (Problem P2, mentioned in 5.3.1)

- A There was a checklist at the end of the template, which prompted the ID writer to crosscheck whether ALL the necessary details were given, and also if these details were placed in appropriate sections.
- B More columns and sub-sections were created for getting additional important data from the ID writers.

IDT similar to LO (Problems P3 and P5, mentioned in 5.3.1)

Created a visual design in the IDT, which was like the final LO. The ID writers filled up the required data there. This made it easy for both the stakeholders: ID writer (to decide where to give particular information) and Animators (for getting the content in appropriate sections)

Instruct animator to go through the references (Problem P9 mentioned in 5.3.1)**Create a design guidelines document (Problem P10 mentioned in 5.3.1)**

A Design Guidelines Document (DGD) was planned for the benefit of the animators, as a part of future research. This document had visual design guidelines / solutions for various scenarios which were most likely to arise in the LO content creation process. These guidelines were based on the well known principles from the respective domains.

5.3.3 Stage 3: Create tentative products and theories

In this stage IDT2 was refined to create a new intervention. This new intervention had advanced application of VC principles, therefore it was named as IDT3. The details of IDT3 are given below:

- **Introduction:** This section was modified further to create scope for some additional information. The new subsections were: Title, authors, Definition of keywords, Learning objectives, Brief description of the concept and Pre-requisites.
- **Visual information:** This section was mentioned by the ID writers to have maximum problems in IDT2. Therefore modifications were done to refine the application of visual communication (VC) principles. ID writers had mentioned in their feedback about their inability to understand the section titled ‘Master layout’, therefore, it was renamed as ‘Placement diagram’. The word ‘diagram’ was used since, the ID writers were more familiar to this word as compared to the word ‘layout’. However, the functionality remained almost the same as ‘Master layout’.

In addition, detailed guidelines were provided in the ‘Instructions slide’, in the beginning of this section. A new slide having an ‘Example’ was also added to explain the format of providing information.

The visuals were augmented by adding ‘Definitions of elements’ slide immediately after the ‘Placement diagram slide’. The ID writers were prompted to provide working/functional definitions of the elements shown in the ‘Placement diagram’. In addition, a ‘Placement details’ slide was also added to provide ‘ideal’ placement scenario of the elements in the LO. The animators had queries regarding the placement of the elements, and in case of absence of this information, they were forced to take their own decision, which resulted in incorrect positioning of the elements.

- **Stepwise details:** This section was modified further to accommodate the concerns raised by the ID writers. The ‘instructions slide’, was rewritten with added description for writing this section. An example was included to show, the level of details expected to be written. Separate slide for images (optional), was permitted to enable the ID writers to provide bigger images, which had a lot of details.

ID writers were informed to customize the template, in cases where they felt that the template was not allowing them to provide the desired information in a particular format.

The section titled ‘Interactivity and boundary limits’ was merged with this section. It was found that ID writers were coming up with ID strategies, having interactivity not as a separate section, but as a part of the main concept explanation. They were unable to create IDD, for such strategy, where there were two separate sections. The ‘Instructions slide’ in the beginning of this section, mentioned this, and also underlined the advantages of the merger.

A guidelines slide on ‘Basics of Interaction design for LOs’, was added specifically to inform the ID writers about the possible interactions they could implement.

- **Assessment:** This section was mostly unchanged, except for some detailing in the ‘Instructions slide’. Emphasis was given to provide justification for the correct/incorrect answer.
- **References and additional reading:** No changes were done to this section, as compared to IDT2.

Overall, the refinement was done in the ‘Instructions slides’ of the IDT3. Addition of ‘Guidelines slide’ and ‘Examples’ were also important additions. The modifications and the rationale for these modifications are shown in the table on the next page (5.3.3). A sample IDD created using IDT3 is shown in Appendix A.

IDT 2	Problems	Solution	Changes done in IDT 3	Justification (principles applied)
Section 1: Introduction				
Title, authors		Title, authors		
Definition of keywords	No problems reported. ID writers could write the information as per the format. Animators could use it to create the LO.	No changes	Definition of keywords	
Learning objectives			Learning objectives	
Brief description of the concept			Brief description of the concept	
	No mention of prior knowledge for users	Ask the SME/IDs to provide it	Pre requisites	Pedagogy principle
Section 2: Visual information				
Option 1				
Master layout	ID writers did not understand the meaning of 'Master layout'. They did the following mistakes: 1. not creating a diagram of the concept 2. not mentioning all the labels, and not providing the definitions of the labels mentioned 3. not creating multiple layouts to explain different stages of the LO	Rename the section by changing the word 'layout'	Rename the section as 'Placement diagram'. Guidelines/Example slide for this section.	Multimedia (Multimedia), Mapping, Visibility (xD), Staging, Proximity (Graphic design)
Definitions of elements		Modification and addition of the instructions written	Definitions of elements	Mapping (xD),
		Adding the 'animation design' to his section, (and rename it) since these two are correlated.	Placement details	Mapping, Visibility (xD), Staging, Proximity (Graphic design)
Option 2				
		Merging the 'master diagram' and 'animation design' sections to get the placement information of the elements in the LO	Master diagram with placement information (schematic)	Visibility (xD), Appeal, good form (Graphic design)
		Add functionality information to the definitions column	Definitions and functional details of elements	Mapping (xD),

IDT 2	Problems	Solution	Changes done in IDT 3	Justification (principles applied)
Section 3: Step wise description				
Step wise description	<ol style="list-style-type: none"> 1. Images not provided with the text 2. Details about timing (like: how many seconds should this motion is to be shown?) not provided 3. Labels used in the master layouts not mentioned 4. New elements added, which are not listed/drawn in master layouts 5. Description is too long. Action is not split in parts, so animator had problems in animating it. 	<ol style="list-style-type: none"> 1. Modify the instructions 2. Add timing column 3. Remind the ID writers to use labels 4. Introduce chunking, so that the ID writers will split the action details in small chunks, which are useful for the animators 	Rewrite description for writing this section.	Mapping, Visibility (ixD), Staging, Proximity (Graphic design)
Separate area for the images	Not followed in some IDD	Remind the ID writer in the instructions to provide separate images for each step	Separate slide for images (optional)	Visibility (graphic design)
Section 4: Interactivity and boundary limits				
Separate section	Chronology of the events (between steps and the interactivity options) was not understood by animators (ex: Is interactivity 1 to be animated after Step 1 in the stepwise section or before it?)	<ol style="list-style-type: none"> 1. Explain different types of LO writing formats to the ID writers. Give guidelines for creating LOs which have interactivity combined with concept explanation. 2. Merge interactivity section with stepwise details section 3. Guide ID writers to include interactivity along with the concept explanation 	<p>Merge with Section 3: Stepwise description</p> <p>Create columns which can accommodate interactivity information</p>	Mapping, Visibility (ixD), Staging, Proximity (Graphic design), Guided discovery (Pedagogy)
	Interactivity options selected were not appropriate for the data / learning outcome of the LO. (ex: when to use drop-down and when to have radio buttons)	Provide basic guidelines on interaction design (ixD) for LOs	Guidelines slide on 'Basics of IxD in LOs'	

Selecting IDD3s created using IDT3

The IDD3s were created for the similar domains as mentioned in RC2. This was done to maintain consistency. Eleven IDD3s (one per ID writer) were selected from the available resources at project OSCAR.

5.3.4 Stage 4: Prototyping and assessment

In the first two RCs, the feedback was collected from the ID writers and animators. This was because of the fact that these stakeholders were the direct users of the ID template. ID writers used the ID template to write the ID documents (IDDs), where as animators used the IDDs to create the animations or learning objects (LOs). IDT2 got satisfactory feedback from animators, however the feedback from ID writers suggested that the template needed refinement. Accordingly, IDT2 was refined and IDT3 was created. Usability study was repeated to validate IDT3, by conducting an usability test for ID writers.

Sample

ID writers matching the sampling characteristics (as mentioned in section 5.2.4) were selected for this stage using convenient sampling. These were eleven practicing ID writers from industry, having a professional experience between 6 months to 1 year of creating eLearning content.

Tool

Same tool (SUS) used in RC1 and RC2 was used for this stage (see details of SUS in section 5.1.4).

Process

Usability test was carried out only for the ID writers, since their feedback was below the average 'good' score mentioned by the creators of SUS. Same process as performed in RC2 was repeated in this stage to gather the usability feedback. ID writers studied IDT3 and created IDD3s. Later, they are asked to fill up the SUS form, and give their usability feedback about IDT3.

Results

Results showed that the mean of the SUS score for the 10 IDD3s was 69.24. Based on the recommended good score of 68, prescribed by the creators of SUS, this was above

average (Bangor et al., 2009). This score was translated to: **IDT3 was usable for ID writers** (see table for detailed scores 5.7).

	1	2	3	4	5	6	7	8	9	10	Total score	SUS score
1	3	2	2	1	2	3	3	2	2	1	21	52.50
2	2	3	2	3	3	4	3	2	1	4	27	67.50
3	3	4	3	4	3	3	1	3	2	3	29	72.50
4	3	3	1	4	2	3	3	4	3	3	29	72.50
5	2	3	2	4	2	3	3	2	2	2	25	62.50
6	3	3	2	3	4	3	4	3	1	3	29	72.50
7	3	3	3	1	2	3	3	2	2	3	25	62.50
8	2	3	1	3	2	1	2	3	2	4	23	57.50
9	3	3	2	3	3	1	2	3	2	4	26	65.00
10	3	3	2	3	3	1	3	3	1	3	25	62.50
11	3	4	3	3	4	4	4	4	4	3	36	90.00
											Mean	69.24

Table 5.7: Collated SUS scores of the feedback collected from ID writers for IDT3

Since, the two stakeholders in the LO creation process (ID writers and animators) found IDT usable, the iterations of IDTs was stopped. Table 6.1 shows the usability scores of animators and ID writers for the iterations created. IDT iterations have shown ascending trend in the usability scores, for both the stakeholders.

RC1	RC2	RC3
Usability score for IDT1	Usability score for IDT2	Usability score for IDT3
Animators	Animators	
34.75	68.75	
	ID writers	ID writers
	54.16	69.42

Table 5.8: Overview of the results for 3 RCs

Apart from the usability of the content creators (ID writers and animators), it was important to ascertain the usability of the final product, in order to test the hypotheses. The end product of the IDT is a learning object (LO). Therefore, an usability experiment was conducted to gather the end user's (student's) feedback about the LOs created using the IDT. In order to test the hypotheses, the experiment was conducted by comparing two end products: LOs having basic VC principles applied and LOs having advanced application of VC principles. This experiment was designed

in such a way, that the feedback would be useful in accepting or refuting the hypotheses. Details of the final experiment are given in the following chapter.

Chapter 6

Usability experiments

In the first two research cycles (RCs), the feedback was collected from the instructional design (ID) writers and animators. This was because these stakeholders were the direct users of the ID template. ID writers use the ID template (IDT) to create ID documents (IDDs), where as animators use the IDDs to create the animations or the learning objects (LOs). Data obtained in RC3 showed that the IDT3 (used in that RC), had usability score of 69.42 by the ID writers. Since this score reflected that the product was ‘acceptable’, to the ID writers, we did not modify the template further. This way the two stakeholders: ID writers and animators had found the iteration IDT3 usable. IDT3 had evolved out of earlier iterations IDT1 and IDT2, which were found usable earlier (see table 6.1), therefore, a decision was taken to stop further modification of IDTs.

RC1	RC2	RC3
Usability score for IDT1	Usability score for IDT2	Usability score for IDT3
Animators	Animators	
34.75	68.75	
	ID writers	ID writers
	54.16	69.42

Table 6.1: Overview of the results over the 3 research cycles

Finally, to ascertain the usability feedback of the end users: the students, usability experiments were conducted to compare the outputs (LOs) of IDT2 and IDT3.

IDT2 had operationalization of VC principles at basic level and IDT3, had operationalization of VC principles at advanced levels. Respective IDDs and LOs were created using both these IDTs. Two topics from computer science engineering domain were chosen for this experiment, which are: (i) Image thresholding and (ii) Line

coding. A separate LO was created for each of the topic, using respective IDT. As a result, there were 4 LOs, 2 each for each subject (see details in table 6.2).

Topic	1. Image thresholding		2. Line coding	
	Basic	Advanced	Basic	Advanced
Level of VC principles	Basic	Advanced	Basic	Advanced
IDT used	IDT2	IDT3	IDT2	IDT3
IDDs created	IDD2 ₁	IDD3 ₁	IDD2 ₂	IDD3 ₂
LOs created	LO2 ₁	LO3 ₁	LO2 ₂	LO3 ₂

Table 6.2: Artifacts created for the experiment

These experiments measured usability, engagement of students, and perceptions of teachers (SMEs) on usefulness of LOs for learning. It was important to know whether the students find the LOs engaging, and get feedback from the SMEs, on the content, interactivity and the visual aspects of the LO. For this study, the samples were randomly chosen from the SMEs and students both. Validated questionnaires based on constructs like (engagement and learning) were used to gather data form the SMEs as well as the students. This study is summarized in table 6.3.

	Students	SMEs
Constructs	Engagement	Usefulness for teaching
Sample	10 (subset of the main sample of 128 students)	3
Tools	Questionnaire	Questionnaire

Table 6.3: Study to test engagement of LOs for students and usefulness of LOs for SMEs

As mentioned earlier, four LOs were created for this experiment, on the two topics. Screenshots of the LOs created for line coding topic are given below. Figure 6.1 shows screens of LO2₂ (created using IDT2) and LO3₂ (created using IDT3). The screenshots of the sections and interactivity options from these LOs are given in Appendix C.

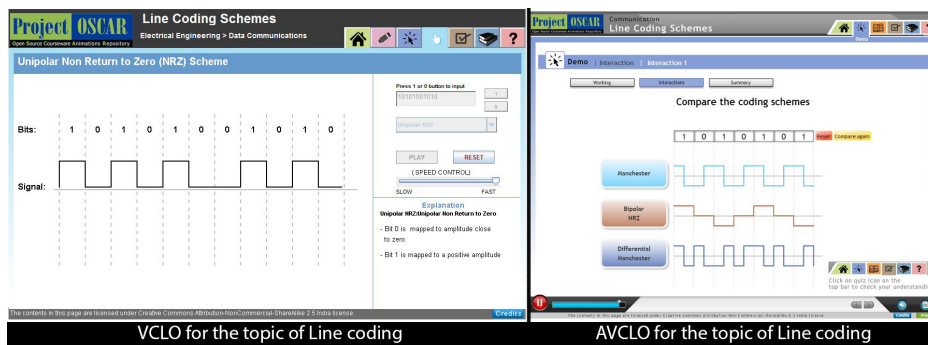


Figure 6.1: Screenshots of LO2₂ and LO3₂

6.1 Objectives of the experiments

The LOs were created on two topics in computer science, using two IDTs. In this experiment we compared the usability of the two types of LOs: LO2s created from IDT having basic application of VC principles (IDT2) and LO3s created from IDT having advanced application of VC principles (IDT3).

The objective of the experiments were to identify the impact of advanced visual communication principles applied in LOs as compared to other LOs having basic application of VC principles.

Usability of the LOs from the point of view of the SMEs was also tested. Additionally, the engagement of the students for these LOs was measured by getting feedback from a subset of the students.

6.2 Hypotheses

1. **Null:** No difference would be seen in the usability scores of the LOs created using ID templates having VC principles embedded in it and LOs created using ID template without VC principles embedded in it.
2. **Alt:** There would be increase in the usability scores of the LOs created using ID templates having VC principles embedded in it and LOs created using ID template without VC principles embedded in it.

6.3 Artifacts

Since the usability was tested for the students, artifacts created for this experiment were LOs. Two topics from computer science domain, were selected for this study to test whether the IDTs were generalizable. Two LOs were created for each topic, using IDT2 and IDT3 respectively. In all four LOs (LO2₁, LO3₁ for topic 1 and LO2₂, LO3₂ for topic 2) were used in the experiment. Table 6.4 show artifact creation plan.

	IDT2	IDT3
Image thresholding	LO2 ₁	LO3 ₁
Line coding	LO2 ₂	LO3 ₂

Table 6.4: Plan for creating artifacts for this research

6.4 Sample

The sample for this experiment was a single group of students, which will evaluate the usability of two types of LOs (created using basic and advanced VC principles).

6.4.1 Sampling characteristics:

Under graduate students from engineering colleges affiliated to Mumbai University were inducted for the test. They had undergone a course on Image Thresholding OR Line Coding. In Mumbai University, this course is offered for computer science, information technology, electronics and telecommunication and electrical engineering streams. Therefore, students from any of these streams were eligible to be inducted for the test.

6.4.2 Sampling technique

Convenient sampling was done to choose students from three colleges from Mumbai University. These are: Don Bosco Institute of Technology (DBIT), Somaiya college of engineering (SCOE) and DJ Sanghavi College of Engineering (DJSCOE). Availability of labs, in terms of number of terminals available in the lab and their configuration (as required for the experiment) was checked before finalizing the colleges for the experiment. Three colleges were included in the sample, to test the generalizability of the intervention. The sample was therefore split such that students from two colleges would be providing their feedback for each topic .

Students from the final year of engineering (from computer science and information technology streams) were selected for the experiment. It was confirmed that these students have undertaken respective course (Image Thresholding OR Line Coding) in the earlier semesters.

Table 6.5 shows the details of the students who participated from various institutions, and the topics allotted to them.

Topic	1. Image thresholding	2. Line coding
College 1	23 students	-
College 2	45 students	22 students
College 3	-	42 students
Total	68 students	64 students

Table 6.5: Composition of the two groups in the final experiment

6.5 Testing instrument

Testing instrument having seven statements is created, where respondents are supposed to give their opinion using a three point Likert response scale. The three levels in the scale are: Agree, Neutral or Disagree. The statements in the instrument direct to multiple usability constructs. The process followed for creating the testing instrument is based on a published process (Radhakrishna, 2007). It is summarized in the figure 6.2 and is explained in the following subsections.



Figure 6.2: Process followed for created the testing instrument

6.5.1 Background

In the first step, the background of the usability test was studied in detail. This was done by interacting with the teachers in the respective colleges to confirm, that image processing and line coding courses were taught. It was ensured that curriculum for these courses justified the content of the LOs used in the test.

6.5.2 Questionnaire conceptualization

The objective of the experiment was evaluating the usability of the LOs. Therefore a survey instrument was created to address this objective. In this step, the link among the objectives of the study and their translation into content was established. In the usability studies related to LOs (Abdinnour-Helm et al., 2005), (Davis, 1989), and (Gould et al., 2008), following constructs were finalized for the usability test: **Perceived usefulness; Ease of use in terms of navigation and interactivity options; Feedback of the interactive elements and response features; Accuracy and correctness of the content.**

It was ensured that the statements were not leading the respondents to a particular answer in any way. In the subsequent steps, the instrument was formatted and tested for validity and reliability.

6.5.3 Format

The respective statements for constructs shortlisted for this experiment are given in table 6.6. Sample instrument is attached in Annexure 1.

Construct	Actual statement in the questionnaire
Perceived usefulness	Concept is presented in an interesting manner in the animation
Ease of use	Interaction design features like buttons, tabs and other options help navigation through the animation
	Interaction design features like sliders, buttons, drop downs and other options in the animation are easy to use
Format	Features like sliders, buttons, drop downs and others display the output as expected after using them
	Feedback of the response features like, pop-ups, explanation instructional text and others help in interacting with the animation
Content	Animation provides sufficient examples to understand the concept

Table 6.6: Constructs and corresponding statements in the questionnaire

Scale used for getting feedback

The instrument is a single page paper (front and back). A screenshot of the LO is added on the the top, to make it clear to the participants about the LO, they review. The participants have an option to be anonymous if they feel so. Three point likert scale is provided for the participants to provide their feedback. These are: Agree, Neutral and Disagree. Boxes are provided in front of each statement and the participants are supposed to put a ‘tick’ mark in front of the statement of their choice. The font type and size is chosen to provide readability to the participants. This form can be seen in the Appendix D.

Sample questions from the instrument

1. Image thresholding concept is presented in an interesting manner in the animation

Disagree: Interactions are rudimentary (simple). They are not presented in interesting way	
Neutral: Few interactions are interesting, others can be better	
Agree: Interactions are interesting. Playing with the parameters is enjoyable	

2. Interaction design features like sliders, buttons, drop downs and other options in the animation are easy to use

Disagree: Most of the buttons are difficult to use, in terms of their working, placement and behavior	
Neutral: It is bit difficult at times. Some buttons are easy to use, however, some are not	
Agree: They are easy. I can easily decide when to press, drag, and click to see the desired results	

6.5.4 Establishing validity

As a result of steps 1-3, a draft instrument was ready. Interviews with (three) experts provided insights about the draft version of the instrument. These experts were researchers in the area of educational technology and usability. The feedback was sought about the content, constructs being applied and formatting of the statements in the instrument, by using few questions. Given below are the questions, comments by the experts and the modifications done to the survey.

- Do the statements in the instrument address the respective construct/s?

Comments: Classify the questions regarding the interaction features in two constructs: ease of use and format, by changing the question. Ex. Create explicit statements for ‘ease of use’ and ‘format’ constructs.

Modifications done: Separated the statements and created two statements.
Ex:

- *Features like sliders, buttons, drop downs and others display the output as expected after using them.*
- *Interaction design features like sliders, buttons, drop downs and other options in the animation are easy to use.*

- Is the instrument appropriate for the sample/population?

Comments: The current statement/s may get vague replies. Need to have clarity in the language for getting deeper insights. Ex: Do not limit to the question like: ‘Are interactions interesting?’. Explain details about the range of ‘interactions’ by listing examples.

Modifications done: Added details of the interaction design features to the statement. Ex: *Interaction design features like buttons, tabs and other options help navigation through the animation.*

- Is the instrument comprehensive enough to collect all the information needed to address the purpose and goals of the study? Will it leave some pieces of information?

Comments: Add a question regarding the examples provided in the LO. This is important for this experiment, since the LOs to be tested have few examples explained during the explanation of the concepts.

Modifications done: Added the following statement to the survey:

Animation provides sufficient examples to understand the concept.

- Will the participants understand how to use the instrument?

Comments: Add short but clear instructions in the beginning of the instrument. Since each student is supposed to evaluate two LOs, add a picture of the LO on the corresponding instrument, to avoid confusion.

Modifications done: Added a screenshot of the opening screen of each LO on the respective survey form. Also added the following instructions:

See the questionnaire below, and give feedback by selecting your option for each of the animation. Place a tick mark in front of the option of your choice for BOTH the animations.

- Is the order of the statements correct in the instrument?

Comments: Keep the statement about overall feedback in the end, so that students will be in a better position to provide answer.

Modifications done: Moved the following statement to the end.

Select one of the statements below: (i) Animation is usable, (ii) Animation is partly usable, (iii) Animation is not usable; and provide justification (using one example) for your choice above.

Based on the comments of the experts, the instrument was modified accordingly.

6.5.5 Establishing reliability

In the final step, reliability of the questionnaire using a pilot test was carried out. The pilot test was performed to seek an answer the following question: *Does the questionnaire consistently measure whatever it measures?*

Internal consistency to assess reliability of questions was measured by administering a test of 10 students not included in the sample. The instrument was found reliable, since Cronbach alpha for the feedback given by 10 students (for seven statements) was found greater than the accepted value of 0.6 (see table 6.7). The alpha was calculated using free online calculator (Wessa, 2012).

Cronbach Alpha and Related Statistics				
Items	Cronbach Alpha	Std. Alpha	G6 (smc)	Average R
All items	0.6564	0.6648	0.8935	0.2208

Table 6.7: Cronbach alpha measured for the instrument reliability

6.6 Process for conducting the experiment

The distribution of the total sample (n=128) was done as per the availability of the students. As shown in table 6.8, the distribution was planned. Sample 1 consisted of 68 students (6.5) who tested LOs on topic: Image thresholding (LO₂₁ and LO₃₁). Sample 2 consisted of 64 students (6.5) tested the LOs created for other topic: Line coding (LO₂₂ and LO₃₂).

Topic	Image thresholding	Line coding
LOs	LO ₂ ₁ and LO ₃ ₁	LO ₂ ₂ and LO ₃ ₂
College 1	23 students	-
College 2	45 students	22 students
College 3	-	42 students
Total	68 students	64 students

Table 6.8: Number of students(n) who participated in the experiment

As seen in table 6.8, each sample evaluated two levels of LOs for a topic. The sample distribution design ensured that students from two colleges evaluate the LOs for a topic.

6.6.1 Ethical issues

The entire class was briefed about the experiment, and assured that the experiment was ONLY for research purpose and no commercial usage was done of their contribution. No remuneration (in the form of cash or kind) was given to the participating students. A written consent was also obtained from the participants.

6.6.2 Conduct of experiment

The experiment was conducted in the computer labs of the respective colleges. It was insured that the computer terminals in the labs have the requisite hardware and software to run the LOs in real time. Based on the size of the computer lab, students were divided in batches such that each one gets a terminal.

1. Students were asked to open LO2 (having basic VC principles) on their respective computer terminal.
2. Usability questionnaire A (paper based) was given to the students to give feedback about the LO2.
3. 20 minutes were given to interact with LO2.

4. Additional 10 minutes were given to fill up the questionnaire.
5. The feedback forms were collected.
6. Students were instructed to open LO3 (having advanced VC principles) on their respective terminal.
7. Usability questionnaire B was given to the students to give feedback about the LO3.
8. 20 minutes were given to interact with LO3.
9. The feedback was collected.
10. The researcher thanked the students for their participation.

The order of LOs (basic and advanced) was swapped for the next group of students to counter balance and avoid bias. In order to make sure that the order of LOs did not matter, half the students interacted with LO1 first and LO2 next, while the other half did the reverse. Table 6.9 shows an illustration of the counter balancing of the samples. (The x in the table are the topics IT or LC). This process was repeated in all the three colleges.

	Order of assigning	
	First LO	Second LO
Group 1	LO2 _x (Basic)	LO3 _x (Advanced)
Group 2	LO3 _x (Advanced)	LO2 _x (Basic)

Table 6.9: Counter balancing by changing the order of the levels of LOs

6.7 Data analysis method

The type of data gathered from the experiment was ordinal (three point likert scale as explained in 6.5). The weightages assigned are shown in table 6.10.

	Likert item		
	Agree	Neutral	Disagree
Weightage	3	2	1

Table 6.10: Weightages assigned to the Likert items

In this scenario, Wilcoxon matched pair signed rank test was found appropriate for this the data analysis of the experiment (Bruin, 2011), since it is recommended under the following conditions:

- Data are paired and come from the same population (Same population in this research).
- The data are measured at least on an ordinal scale (3 point Likert), but need not be normal

6.8 Student engagement level of the LOs

Experiment was performed to understand the feedback about the engagement from a subset of the student sample in the usability experiment. The objective of this experiment was to gather information about the engagement provided by the LOs for the student users. The details of this experiment are given below:

Sample

All the students from the total sample (n=128) were notified online, to participate in the engagement study. Participation was optional and was subject to receiving the notification, and availability of time for the students. A subset of those responded to the notification, however ten students (n=10) participated in the study.

These ten students were divided in two groups (5 each) to provide feedback for the two topics: topic 1 image thresholding and topic 2: line coding.

Tools

A survey was administered using a form having five statements. The statements were based on the constructs operationalized by various researchers. The students were supposed to select their responses using a three point likert scale (agree, neutral and disagree). In the end, there were two open ended questions about 'what they liked and disliked' in the LO. Students were expected to provide detailed responses in answer to these two questions. Constructs include engagement and learning. (LOESS by Kay and Knaack, 2008).

Process

Students: Each student was given the survey form to be filled online by sending the link. The form consisted the link for the LOs followed by the statements. Student first interacted with the LOs and subsequently, filled up the survey form.

Data analysis

Data gathered from students also was small (n=5 per topic) for any statistical method to be applied, in order to conclude. However, frequencies were analyzed to observe the trend in the responses. In addition, the descriptive responses for last two questions were helpful in analyzing the trends of the students feedback.

6.9 SMEs perception of learning from the LOs

Experiment was performed to understand the learning outcomes of the LOs from the subject matter experts (SMEs). The objective of this experiment was to gather information about the usefulness and content quality of the LOs. The details of this experiment are given below:

Sample

Three faculty members who were SMEs of the LO topics were selected using convenient sampling method. Two faculty members were from a college in Mumbai university, and faculty member from IIT Bombay. These SMEs have taught this topic in their respective organizations.

Tools

The usability feedback from the SMEs was gathered using a questionnaire having seven questions. The survey covered the usability constructs which were operationalized by the set of questions included. The constructs included interactivity, reinforcement, interface design and learning (QAMLM, SREB). The responses were likert scale based having a range of 1 to 5. The responses were not in the typical format of ‘Strongly agree to Strongly disagree’, but were articulated specifically to correspond to the statements.

In addition, unstructured interviews were conducted with the SMEs, in the light of their answers given in the survey. This was conducted for getting deeper insights about their feedback.

Process

As mentioned earlier, feedback was sought for the two levels of learning objects (LOs) for both the topics, since each of the SME was well versed with both the topics. One LO (level 1 or 2, randomly selected between two levels) was opened on the computer, and the SME interacted with the LO. After spending about 25-30 minutes with the

LO, the SME was given the survey to be filled up. Later, an unstructured interview was conducted based on their answers submitted in the survey, to get the rationale behind the choices. Same process was repeated for the second LO (other level).

Data analysis

The data gathered from the SMEs was quantitative (survey responses) and qualitative (transcripts of unstructured interviews) in nature. Number of data points were quite small (n=3), therefore, no statistical analysis methods were applied. Emphasis was given to the interview data primarily. Differentiating factors between LO2s and LO3s mentioned by SMEs, were analyzed.

The details of the results and the analysis is presented in the next chapter.

Chapter 7

Analysis and results

7.1 Overall results

The data collected for the final experiment was from a single group which gave feedback about the two levels of LOs (basic and advanced). The type of data was ordinal as three point Likert scale was administered. The statements in the tool addressed various constructs of usability. The last (seventh) statement was about the overall usability of the LOs. Therefore, the feedback for the seventh statement was used to understand the overall feedback of the participants (see figure 7.1). Data for other statements are also analyzed later in this chapter.

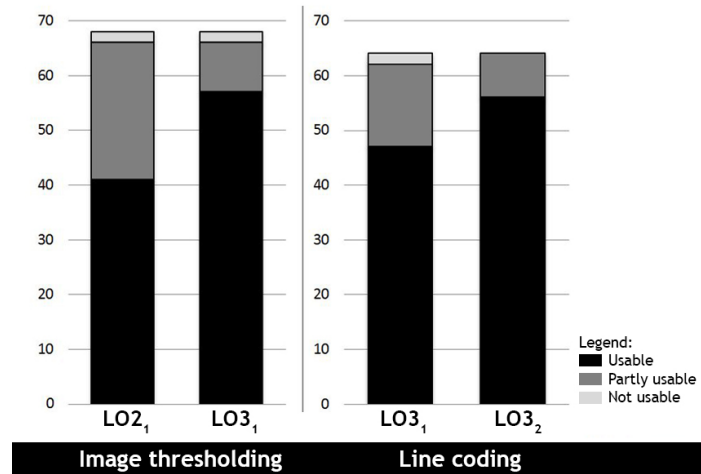


Figure 7.1: Feedback comparison about usability of LO2s and LO3s (both topics)

The horizontal axis shows the LOs of two topics: Image thresholding (IT) and Line coding (LC). There was a LO created for each topic and for each level. Therefore, there were 4 LOs in all. Two LOs created for topic 1 (IT) were: LO2₁ (created using basic principles: IDT2) and LO3₁ (created using advanced principles: IDT3). Similarly, the

two LOs created for topic 2 (LC) were: LO2₂ (created using basic principles: IDT2) and LO3₂ (created using advanced principles: IDT3).

In the figure, the first two bars (from left) show the feedback for Image thresholding LOs. The next two bars show the feedback for the Line coding LOs. The vertical axis shows the number of participants (IT: n=68, and LC: n=64).

As seen in the graph, for the topic 1, 41 participants found LO2₁ usable, 25 participants found it partly usable and 2 participants found it non-usable. For the same topic, 57 participants found LO3₁ usable, 9 participants found it partly usable and 2 participants found it non-usable. This shows that LO3₁ created using IDT3 (which has operationalization of advanced VC principles) were been found usable by the students.

For topic 2, 47 participants found LO2₂ usable, 15 participants found it partly usable and 2 participants found it non-usable. For the same topic, 56 participants found LO3₂ usable, 8 participants found it partly usable and no participant found it non-usable. This shows that LO3₁ created using IDT3 (which has operationalization of advanced VC principles) were been found usable by the students.

The table 7.1, shows the detailed feedback in terms of the three options in the instrument: agree(A), neutral(N), and disagree(D) for IT LOs (LO2₁ and LO3₁)

	S1		S2		S3		S4		S5		S6		S7	
	LO2 ₁	LO3 ₁	LO2 ₁	LO3 ₁	LO2 ₁	LO3 ₁	LO2 ₁	LO3 ₁	LO2 ₁	LO3 ₁	LO2 ₁	LO3 ₁	LO2 ₁	LO3 ₁
A	38	53	34	52	41	51	44	56	39	49	43	52	41	57
N	23	13	24	12	18	13	17	11	22	16	22	13	25	09
D	07	02	10	04	09	04	07	01	07	03	03	03	02	02

A: Agree, N: Neutral and D: Disagree

Table 7.1: Frequency of responses for the LOs on topic Image thresholding

A common trend of increase was seen, in the ‘Agree’ scores of LO3s as compared to LO2s, for each statement. Particularly, for statements S1, S2 and S3 (which address constructs like perceived usefulness, and ease of use), the increase was 30-50%. Table 7.2, shows the feedback for LC LOs. Trend similar to IT LOs is visible across the statements. ‘Agree’ scores of LO3s were higher those of LO2s, for each statement.

7.2 Difference in usability for IT LOs

For the IT LOs, the sample size is 68 ($n=68$). As mentioned earlier, since the data collected was ordinal and the sample was a single group, for both the interventions tested, Wilcoxon signed-rank test is used to analyze the results. Figure 7.3 shows the p values and the z scores, for the seven statements. The alpha value for this experiment was set at 0.05 and the z score at +/- 1.96.

	S1		S2		S3		S4		S5		S6		S7	
	LO2 ₂	LO3 ₂	LO2 ₂	LO3 ₂	LO2 ₂	LO3 ₂	LO2 ₂	LO3 ₂	LO2 ₂	LO3 ₂	LO2 ₂	LO3 ₂	LO2 ₂	LO3 ₂
A	38	48	46	49	42	53	41	50	40	48	35	46	47	56
N	19	15	16	15	15	10	22	14	19	15	26	18	15	08
D	07	01	02	00	07	01	01	00	05	01	03	00	02	00

A: Agree, N: Neutral and D: Disagree

Table 7.2: Frequency of responses for the LOs on topic Line coding

The details of the difference in the usability is given in following subsections. The overall usability of IT LOs was summed up using statement seven (S7).

Null hypotheses was rejected, as the Wilcoxon signed-rank test showed that there is a significant effect of adding VC principles to LO3₁ as compared to LO2₁ (values for S7: $p: 0.000 < 0.05$ and z score: $-3.771 > -1.96$) for the topic of image thresholding.

Image thresholding LOs (LO2 ₁ and LO3 ₁)		
Statements	p Values	z Scores
S1	0.000	-3.704
S2	0.000	-3.874
S3	0.005	-2.777
S4	0.002	-3.106
S5	0.002	-3.116
S6	0.039	-2.324
S7	0.000	-3.771

Table 7.3: Results of Wilcoxon signed-rank test for LO2₁ and LO3₁

In the following subsections, the data for individual statements is discussed in detail.

S1: Concepts in the animation are presented in an interesting manner

The first statement was directed towards preliminary feedback about the nature of the LOs. LO3₁ was found more interesting by students over the LO2₁.

As seen in table 7.4, 53 students agreed that LO3₁ was interesting as compared to 38 students who agreed for LO2₁. On the other hand, only 2 students disagreed that LO3₁ was interesting as compared to 8 students who disagreed for LO2₁.

Wilcoxon signed-rank test conducted for the LOs on the topic of Image thresholding

	Actual Score (Agree/Neutral/Disagree)	p value	z score
LO2 ₁	38/23/07	0.000	-3.704
LO3 ₁	53/13/02		

Table 7.4: Comparative scores for S1

showed that LO3₁ created using the IDT3 **presented the concepts in interesting manner** as compared to LO2₁ created using IDT2 and has statistically significant usability for the students (**LO2₁-LO3₁: p=0.000, Z=-3.704**).

S2: Interaction design features like sliders, buttons, drop downs and other options in the animation are easy to use

The second statement was about interactivity offered by the LOs. Based on the data, it was seen that students found LO3₁ more usable as compared to LO2₁.

As seen in table 7.5, 52 students agreed that LO3₁ was interactive as compared to 34 students who agreed for LO2₁. On the other hand, only 4 students disagreed that LO3₁ was interactive as compared to 10 students who disagreed for LO2₁.

	Actual Score (Agree/Neutral/Disagree)	p value	z score
LO2 ₁	34/24/10	0.000	-3.874
LO3 ₁	52/12/04		

Table 7.5: Comparative scores for S2

Wilcoxon signed-rank test conducted showed that LO3₁ created using the IDT3 **had easy to use interaction design features** as compared to LO2₁ created using IDT2 and had statistically significant usability (**p=0.000, Z=-3.874**)

S3: Interaction design features like buttons, tabs and other options help navigation through the animation

The third statement was also about interactivity offered by the LOs. Based on the data, it was seen that students found LO3₁ more usable as compared to LO2₁.

As seen in table 7.6, 51 students agreed that LO3₁ was interesting as compared to 41 students who agreed that LO2₁ interesting. On the other hand, only 4 students disagreed that LO3s was interesting as compared to 9 students who disagreed that LO2₁ was interesting.

	Actual Score (Agree/Neutral/Disagree)	p value	z score
LO2 ₁	41/18/09	0.005	-2.777
LO3 ₁	51/13/04		

Table 7.6: Comparative scores for S3

Wilcoxon signed-rank test conducted showed that LO3₁ created using the IDT3 **have interaction features to help navigation** as compared to LO2₁ created using IDT2 and had statistically significant usability for the students (**p=0.005, Z=-2.777**)

S4: Features like sliders, buttons, drop downs and others display the output as expected after using them

The fourth statement was about feedback offered by the LOs. Based on the data, it was seen that students find LO3₁ more usable as compared to LO2₁.

As seen in table 7.7, 56 students agreed that LO3₁ was interesting as compared to 44 students who agreed that LO2₁ interesting. On the other hand, only 1 student disagreed that LO3₁ was interesting as compared to 7 students who disagreed that LO2₁ was interesting.

	Actual Score (Agree/Neutral/Disagree)	p value	z score
LO2 ₁	44/17/07	0.002	-3.106
LO3 ₁	56/11/01		

Table 7.7: Comparative scores for S4

Wilcoxon signed-rank test conducted showed that LO3₁ created using the IDT3 **had easy to use interaction design features** as compared to LO2₁ created using IDT2 and has statistically significant usability for the students (**p=0.002, Z=-3.106**)

S5: Feedback of the response features like, pop-ups, explanation instructional text and others help in interacting with the animation

The fifth statement was also about feedback offered by the LOs. Based on the data, it was seen that students found LO3₁ more usable as compared to LO2₁.

As seen in table 7.8, 49 students agreed that LO3₁ was interesting as compared to 39 students who agreed that LO2₁ interesting. On the other hand, only 3 students

disagreed that LO3₂ are interesting as compared to 7 students who disagreed that LO2₁ was interesting.

	Actual Score (Agree/Neutral/Disagree)	p value	z score
LO2 ₁	39/22/07	0.002	-3.116
LO3 ₁	49/16/03		

Table 7.8: Comparative scores for S5

Wilcoxon signed-rank test conducted showed that LO3₁ created using the IDT3 **had easy to use interaction design features** as compared to LO2₁ created using IDT2 and has statistically significant usability for the students (**p=0.002, Z=-3.116**)

S6: Animation provides sufficient examples to understand the concept

The sixth statement was focused on the sufficiency of the examples provided in the LOs. Based on the data, it was seen that students found LO3₁ provided more examples as compared to LO2₁.

As seen in table 7.9, 52 students agreed that LO3₁ was interesting as compared to 43 students who agreed that LO2₁ was interesting. 3 students disagreed that both LO3₁ and LO2₁ provided sufficient examples.

	Actual Score (Agree/Neutral/Disagree)	p value	z score
LO2 ₁	43/22/03	0.039	-2.324
LO3 ₁	52/13/03		

Table 7.9: Comparative scores for S6

Wilcoxon signed-rank test conducted shows that LO3₁ created using the IDT3 **have easy to use interaction design features** as compared to LO2₁ created using IDT2 and has statistically significant usability for the students (**p=0.039, Z=-2.324**)

S7: Select one of the statements:

1. Animation is Usable
2. Animation is Partly usable
3. Animation is Not usable

The last statement expected the students to rate the LOs based on their overall usability. Students interacted with the LOs, and gave the feedback, which suggests that LO3₁ is found more usable as compared to LO2₁

As seen in table 7.10, 57 students agreed that LO3₁ is usable as compared to 41 students who found LO2₁ usable. However, 2 students found both LO3₁ and LO2₁ not usable.

	Actual Score (Usable/Partly usable/Not usable)	p value	z score
LO2 ₁	41/25/02	0.000	-3.771
LO3 ₁	57/09/02		

Table 7.10: Comparative scores for S7

Wilcoxon signed-rank test conducted shows that LO3₁ created using the IDT3 **have easy to use interaction design features** as compared to LO2₁ created using IDT2 and has statistically significant usability for the students (**p=0.000, Z=-3.771**)

7.3 Difference in usability for LC LOs

For the LC LOs, the sample size is 64 ($n=68$). As mentioned earlier, since the data collected is ordinal and the sample is same, for both the interventions tested, Wilcoxon signed-rank test is used to analyze the results. Figure 7.11 shows the p values and the z scores, for the seven statements. The alpha value for this experiment is set at 0.05 and the z score at +/- 1.96.

The details of the difference in the usability is given in following subsections. The overall usability of IT LOs is summed up using statement seven (S7).

Null hypotheses is rejected, as the Wilcoxon signed-rank test shows that there is a significant effect of adding VC principles to LO3₂ as compared to LO2₂ (values for S7: $p: 0.016 < 0.05$ and $z \text{ score: } -2.399 > -1.96$) for the topic of line coding.

In the following subsections, the data for individual statements is discussed in detail.

S1: Concepts in the animation are presented in an interesting manner

The first statement is directed towards preliminary feedback about the nature of the LOs. LO3₂ is found more interesting for students over the LO2₂.

As seen in table 7.12, 48 students agreed that LO3₂ is interesting as compared to 38 students who agreed that LO2₁ interesting. On the other hand, only 1 student

Line coding LOs (LO2 ₂ and LO3 ₂)		
Statements	p Values	z Scores
S1	0.023	-2.675
S2	0.317	-1.000
S3	0.006	-2.739
S4	0.025	-2.236
S5	0.038	-2.071
S6	0.004	-2.858
S7	0.016	-2.399

Table 7.11: Results of Wilcoxon signed-rank test for LO2₂ and LO3₂

disagreed that LO3₂ is interesting as compared to 7 students who disagreed that LO2₂ is interesting.

	Actual Score (Agree/Neutral/Disagree)	p value	z score
LO2 ₂	38/19/07	0.023	-2.675
LO3 ₂	48/15/01		

Table 7.12: Comparative scores for S1

Wilcoxon signed-rank test conducted for the LOs shows that LO3₂ created using the IDT3 **presented the concepts in interesting manner** as compared to LO2₂ created using IDT2 and has statistically significant usability for the students (**LO2₂-LO3₂: p=0.023, Z=-2.675**).

S2: Interaction design features like sliders, buttons, drop downs and other options in the animation are easy to use

The second statement is about interactivity offered by the LOs. Based on the data, it is seen that students find LO3₂ more usable as compared to LO2₂.

As seen in table 7.13, 49 students agreed that LO3₂ is interesting as compared to 46 students who agreed that LO2₂ interesting. On the other hand, none of the students disagreed that LO3₂ is interesting as compared to 2 students who disagreed that LO2₂ is interesting.

Wilcoxon signed-rank test conducted shows that null hypothesis **cannot be rejected for this statement (p=0.317, Z=-1.000)**. Data suggests that LO3₂ created using the IDT3 **does not have easy to use interaction design features** as compared to LO2₂ created using IDT2.

	Actual Score (Agree/Neutral/Disagree)	p value	z score
LO2 ₁	46/16/02	0.317	-1.000
LO3 ₁	49/15/00		

Table 7.13: Comparative scores for S2

However, it can be seen that, as compared to two participants who disagree with this statement for LO2₁ (basic), there are NO participants, who disagree the statement for the LO3₁ (advanced).

S3: Interaction design features like buttons, tabs and other options help navigation through the animation

The third statement is also about interactivity offered by the LOs. Based on the data, it is seen that students find LO3₂ more usable as compared to LO2₂.

As seen in table 7.14, 53 students agreed that LO3₁ is interesting as compared to 42 students who agreed that LO2₂ interesting. On the other hand, only 1 student disagreed that LO3₂ is interesting as compared to 7 students who disagreed that LO2₂ is interesting.

	Actual Score (Agree/Neutral/Disagree)	p value	z score
LO2 ₂	42/15/07	0.006	-2.739
LO3 ₂	53/10/01		

Table 7.14: Comparative scores for S3

Wilcoxon signed-rank test conducted shows that LO3₁ created using the IDT3 **have interaction features to help navigation** as compared to LO2₁ created using IDT2 and has statistically significant usability for the students (**p=0.006, Z=-2.739**)

S4: Features like sliders, buttons, drop downs and others display the output as expected after using them

The fourth statement is about feedback offered by the LOs. Based on the data, it is seen that students find LO3₂ more usable as compared to LO2₂.

As seen in table 7.15, 50 students agreed that LO3₂ has usable feedback as compared to 41 students who agreed that LO2₂ feedback is usable. On the other hand, none of the students disagreed that LO3₂ has usable feedback as compared to 1 student who disagreed that LO2₂ has usable feedback.

	Actual Score (Agree/Neutral/Disagree)	p value	z score
LO2 ₁	41/22/01	0.025	-2.236
LO3 ₁	50/14/00		

Table 7.15: Comparative scores for S4

Wilcoxon signed-rank test conducted shows that LO3₂ created using the IDT3 **have easy to use interaction design features** as compared to LO2₂ created using IDT2 and has statistically significant usability for the students (**p=0.025, Z=-2.236**)

S5: Feedback of the response features like, pop-ups, explanation instructional text and others help in interacting with the animation

The fifth statement is also about feedback offered by the LOs. Based on the data, it is seen that students find LO3₂ more usable as compared to LO2₂.

As seen in table 7.16, 48 students agreed that LO3₂ has usable feedback as compared to 40 students who agreed that LO2₂ has usable feedback. On the other hand, only 1 student disagreed that LO3₂ has usable feedback as compared to 5 students who disagreed that LO2₂ has usable feedback.

	Actual Score (Agree/Neutral/Disagree)	p value	z score
LO2 ₂	40/19/05	0.0038	-2.071
LO3 ₂	48/15/01		

Table 7.16: Comparative scores for S5

Wilcoxon signed-rank test conducted shows that LO3₂ created using the IDT3 **have easy to use interaction design features** as compared to LO2₂ created using IDT2 and has statistically significant usability for the students (**p=0.038, Z=-2.071**)

S6: Animation provides sufficient examples to understand the concept

The sixth statement is focused on the sufficiency of the examples provided in the LOs. Based on the data, it is seen that students find LO3₂ provides more examples as compared to LO2₂.

As seen in table 7.17, 46 students agreed that LO3₂ is interesting as compared to 35 students who agreed that LO2₂ interesting. None of the students disagreed that

LO3₂ did provide sufficient examples as compared to 3 students who disagreed that LO2₂ did provide sufficient examples.

	Actual Score (Agree/Neutral/Disagree)	p value	z score
LO2 ₁	35/26/03	0.004	-2.858
LO3 ₁	46/18/00		

Table 7.17: Comparative scores for S6

Wilcoxon signed-rank test conducted shows that LO3₂ created using the IDT3 **have easy to use interaction design features** as compared to LO2₂ created using IDT2 and has statistically significant usability for the students (**p=0.004, Z=-2.858**)

S7: Select one of the statements:

1. Animation is Usable
2. Animation is Partly usable
3. Animation is Not usable

The last statement expected the students to rate the LOs based on their overall usability. Students interacted with the LOs, and gave the feedback, which suggests that LO3₂ is found more usable as compared to LO2₂

As seen in table 7.18, 56 students agreed that LO3₂ is usable as compared to 47 students who found LO2₂ usable. None of the students found LO3₂ not usable as compared to 2 students who found LO3₂ not usable.

	Actual Score (Usable/Partly usable/Not usable)	p value	z score
LO2 ₁	47/15/02	0.016	-2.399
LO3 ₁	56/08/00		

Table 7.18: Comparative scores for S7

From the statement wise feedback it is seen that (for both the topics) LO3s are more usable, as compared to LO2s.

7.4 Effect size of the results

Since the results show that the inclusion of VC principles was found effective, we continued to calculate the effect size (A-I therapy website, 2013) .

7.4.1 IT LOs

Wilcoxon signed-rank test shows that the effect size is moderate ($r=-0.323$, $W=9.500$, $z\text{-score} = 3.771$, $p < 0.001$) (Cohen et al., 2011).

The graph 7.2 is a histogram of paired difference values: $(LO3_1) - (LO2_1)$. There are 67 differences greater than or equal to zero, and 1 difference less than zero.

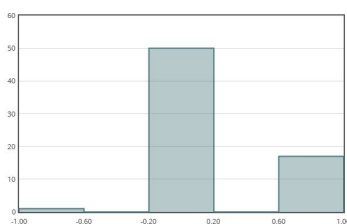


Figure 7.2: Paired difference values for $LO3_1-LO2_1$

7.4.2 LC LOs

Wilcoxon signed-rank test shows that the effect size is modest ($r=-0.212$, $W=99.0$, $z\text{-score} = -2.399$, $p < 0.016$).

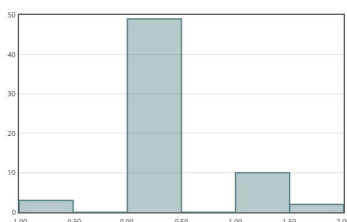


Figure 7.3: Paired difference values for $LO3_2-LO2_2$

The graph 7.3 is a histogram of paired difference values: $(LO3_2) - (LO2_2)$. There are 61 differences greater than or equal to zero, and 3 differences less than zero.

7.5 Results of usability and engagement survey

7.5.1 SMEs

Three SMEs gave their feedback using the survey form. The form had seven statements, and had responses in the form of five point likert scale (1=minimum/low and

5=maximum/high). As mentioned in the details of the tool used for this study 6.9, the survey had statements based on the constructs like: interactivity, reinforcement, interface design and learning.

Data gathered from the survey suggested that SMEs found LO3s to be more effective than LO2s. SMEs chose 5 (high/maximum) in response to almost all statements in the survey for LO3, but there was no instance where they chose 5 in response to a statement. SMEs selected the responses which concluded that LO3s were more interactive, had better reinforcement and interface design and also promoted learning more as compared to LO2s.

The unstructured interviews provided deeper insights for the responses, as the SMEs discussed the rationale for their choices. The qualitative data gathered from the interviews is categorized as per the constructs tested in the survey.

Interactivity (Statements 3 and 5)

All the responses suggest that LO3s had better interactivity as compared to LO2s. SMEs appreciated interesting and innovative forms of interactivity provided in LO3s. Some of the sample feedback from the SMEs is given below:

LO2s: *‘Poor interactivity, pressing the RESET, to replay was cumbersome’.*

‘Entering 11 digits by using the buttons (labelled 1 and 0) was very difficult, need some simple method to enter the numbers’.

LO3s: *‘Interactive movable slider was very good, instant changes in the thresholding levels made the LO interesting’.*

‘Comparative analysis of all coding scheme gives a visual comparison, which is beneficial for the students’.

Interface design (Statement 6 and 7)

All the responses suggest that LO3s have better interface design as compared to LO2s. SMEs mentioned that the ‘look and feel’ of LO3s was very good, user friendly. Some comments by the SMEs are given below:

LO2s: *‘Interface is bit dry, had to search for the required options’.*

LO3s: *‘Very appealing interface!’.*

Learning and reinforcement (Statement 1 and 2)

Most of the responses suggest that LO3s have better interface design as compared to LO2s. SMEs found the combination of interaction design and pedagogy useful in making the LO3s more suitable for learning and reinforcement. Some comments by the SMEs are given below:

LO2s: *‘Adding simulation could have helped students to confirm their concepts’.*

LO3s: *‘The ‘what if’ scenarios will make students curious to interact with LOs’.*

7.5.2 Students

Similar to the SME feedback, the students also found LO3s more engaging than the LO2s. Since the number of data points was small ($n=5$), no statistical analysis was done on this data. This data helped in supplementing the results in the usability test ($n=128$) where LO3s were found more usable than LO2s. The data from this experiment confirms this and adds that LO3s were also engaging for the students. Consolidated feedback for the two topics is presented in tables given below. Table 7.19 shows the feedback gathered for topic 1: Image thresholding and table 7.20 shows for topic 2: Line coding.

Responses for the LOs created for Topic 1: Image thresholding						
Statement	LO2 ₁			LO3 ₁		
	A	N	D	A	N	D
S1: I liked the look and feel of the LO	3	1	1	4	1	0
S2: Look and feel of the LO helped me in learning	3	2	0	3	2	0
S3: I find LO to be engaging	2	3	0	4	1	0
S4: Working with LO helped me learn	2	2	1	3	1	1

A: Agree, N: Neutral and D: Disagree

Table 7.19: Scores showing engagement levels of students for topic 1 (LO2₁ and LO3₁)

The responses to the last two questions in the tool, got descriptive responses. Students cited features of LOs in order to provide rationale for their choices. Following are some of the verbatim responses to both the questions:

- Feedback about LO2s
 - *‘Simple, to the point and easy to understand’.*
 - *‘Few interactions, should have been more! Interactivity is not instant’.*
- Feedback about LO3s
 - *‘I liked the user interface. It provides alot of information’.*
 - *‘I liked the interactive session as it facilitated learning’.*

These statements support the results for the likert scale responses presented above. Students mentioned a specific preference for LO3s in terms of the interactivity and engagement.

7.6 Discussion

The research question for this research was: **Would students find the LOs created using a template having VC principles embedded, to be more usable than**

Responses for the LOs created for Topic 2: Line Coding						
Statement	LO2 ₂			LO3 ₂		
	A	N	D	A	N	D
S1: I liked the look and feel of the LO	2	2	1	3	1	1
S2: Look and feel of the LO helped me in learning	2	3	0	3	1	1
S3: I find LO to be engaging	2	1	2	3	2	0
S4: Working with LO helped me learn	1	3	1	2	2	1

A: Agree, N: Neutral and D: Disagree

Table 7.20: Scores showing engagement levels of students for topic 2 (LO2₂ and LO3₂)

the LOs created using a template without VC principles?

This also had sub questions about finding out whether the ID writers and animators find IDTs embedded with visual communication (VC) principles usable. Design based research, was used to perform iterative cycles of modifying generic IDT until it was found usable by ID writers and animators. For confirming the usability of the products created using IDT3 (which are the LOs) an usability experiment was conducted (see Chapter 6).

Primary objective of the experiment was to compare the usability of the LOs created by advanced application of VC principles and the LOs created by basic application of VC principles.

Therefore, two types of LOs (LO2s and LO3s) were created using the two levels of IDTs (IDT2 and IDT3). These LOs were created for two topics (instead of one) from the same domain (computer science) to see if the decision of advanced application of VC principles was found generalizable. These were: Topic 1: Image thresholding and Topic 2: Line coding. The details of the creation of these artifacts used in this research are given in section 6.3. The data gathered for the usability experiment is for four LOs: LO2₁, LO3₁ for topic 1 and LO2₂, LO3₂ for topic 2.

Survey data was gathered for the two topics of the LOs, from two student groups (topic 1: n=68 and topic 2: n=64). The students interacted with both the levels of LOs (LO2 and LO3) for the given topic (1 or 2), and provided feedback using a survey having a three point likert scale. The null hypotheses for this research was as follows:

H₀ No difference would be seen in the usability scores of the LOs created using ID templates having VC principles embedded in it and LOs created using ID template without VC principles embedded in it.

Since this data was ordinal, Wilcoxon signed rank test was used to analyze the data. The alpha (p) value for this experiment was set at 0.05 and the z score at +/-

1.96. The collated data of all seven statements (S1-S7) for both the topics (topic 1 and 2) and both the values (p value and z score) are shown in table 7.21 given below.

Results of the 2 related sample				
Non parametric test (Wilcoxon matched pair signed rank test)				
LO topics: Image thresholding (LO ₂ ₁ and LO ₃ ₁) and Line coding (LO ₂ ₂ and LO ₃ ₂)				
Statements	p values		z scores	
	LO ₂ ₁ -LO ₃ ₁	LO ₂ ₂ -LO ₃ ₂	LO ₂ ₁ -LO ₃ ₁	LO ₂ ₂ -LO ₃ ₂
S1	0.000	0.023	-3.704	-2.675
S2	0.000	0.317	-3.874	-1.000
S3	0.005	0.006	-2.777	-2.739
S4	0.002	0.025	-3.106	-2.236
S5	0.002	0.038	-3.116	-2.071
S6	0.039	0.004	-2.324	-2.858
S7	0.000	0.016	-3.771	-2.399

Table 7.21: Wilcoxon signed rank test results

Null hypotheses was rejected, as p values and z scores were found below the set alpha for both the topics: LO₂₁-LO₃₁ (p values: column 2 and z scores: column 4) and LO₂₂-LO₂₂ (p values: column 3 and z scores: column 5).

The alternate hypotheses for this research was:

H₁ There would be increase in the usability scores of the LOs created using ID templates having VC principles embedded in it and LOs created using ID template without VC principles embedded in it.

Alternate hypotheses was not rejected, as increase was found in the usability scores of the LO₂₁-LO₃₁ (p values: column 2 and z scores: column 4) and LO₂₂-LO₂₂ (p values: column 3 and z scores: column 5).

We also gathered feedback from the students about the engagement level of LOs. Even though the sample size was small, all the students reported that LO3s were more engaging than LO2s.

The unstructured interviews with the SMEs confirmed that LO3s promoted learning, in addition to being usable for the students. SMEs found LO3s superior than LO2s in aspects like interactivity, interface design, reinforcement. According to the SMEs, LO3s were more inviting, for students to spend more time in interacting with the LOs, thus helping them to learn the topics.

Based on the various data sources in this research like: usability and engagement feedback from the students and learning effectiveness feedback from SMEs, LO3s were found better than LO2s in usability, learning and engagement. The result underlines application of visual communication principles in the ID template.

Chapter 8

Summary and Conclusions

Learning object (LOs) creation is a complex process. It involves multiple stakeholders, which come from various domains. Error-free communication between these stakeholders results in usable LOs. The idea envisioned by the subject matter expert (SME), is transformed by the instructional design (ID) writer and the animator or graphic artist into an interactive eLearning content, like LO. Correct communication between these stakeholders, is vital. Errors in these communications may result in delayed production or a non-usable LO.

Out of the entire process of LO creation, the focus of this research was the communication between the ID writer and the animator. This communication is vital in the LO creation process because, the textual information gets translated to visuals during this stage. Templates are used to facilitate this communication. The ID writers use ID templates (IDTs) and generate ID documents (IDDs) to communicate with the animators.

Literature has deliberations about various solutions to address this gap. Most commonly applied solution is having frequent face-to-face interactions in addition to the IDDs between the ID writers and animators to get clarity. These clarifications are mostly about the visual details, ID writers either fail to write or don't find suitable place in the IDTs to provide it. Face-to-face interactions often result in better quality LOs, but at the cost of important resources like time and money.

However, this solution turns into a bottleneck in developing countries due to limitation of these resources. Based on this scenario, this research was initiated to find out solutions to the problem of creating usable LOs, but not by emphasizing face-to-face interactions but modifying IDTs to accommodate the vital information required by the animators. The crucial aspect was to maintain (or increase if possible) the usability of the LOs (for the end users: students), as it is achieved through the face-to-face interactions. Based on this preamble, the research questions for this research were as

follows:

Would students find the LOs created using a template having VC principles embedded, to be more usable than the LOs created using a template without VC principles?

Since, the LO creation process is chain of interdependent stages, the research question was split into the following three sub questions:

- 1a. Do ID writers find our ID templates having VC principles usable?
- 1b. Do animators find IDD3s created by the above ID writers usable?
- 1c. Do students find the LOs created by the above animators usable?

The research approach was to analyze the problem, design a solution and test it. However, since there are multiple stakeholders, it was evident, that this cannot be achieved by creating a single version of the intervention (IDT). Therefore, design based research (DBR) method was chosen to create the IDT. DBR was selected, because it supports iterations, multiple interacting variables and also helps in documenting the process of creating the iterations. These iterations are carried out by conducting research cycles (RCs). The research questions 1a and 1b were addressed by conducting three RCs in this research.

8.1 Summary of results

In RC1, the intervention (IDT1) was validated by the first hand users (animators) of the output created using the intervention. The usability score according to the System Usability Scale (SUS) (Brooke, 1996), was found to be 34.75. Since this score is below the suggested ideal score (Bangor et al., 2009), IDT1 was found non-usable, and was refined in RC2.

In RC2, the inclusion of the visual communication principles (to IDT1), was done and the test was repeated. The modified version, IDT2 was found usable by the animators (SUS score: 68.75). Based on this score it was concluded that IDT2 is usable for animators. Within the same RC, IDT2 was also validated with the ID writers. The usability score for the ID writers was 54.16, which was below the prescribed score of SUS. Based on this response, modifications were done to IDT2 and an ‘advanced’ version IDT3 was created.

In RC3, IDT3 was used by the ID writers to create IDD3s. Feedback of the ID writers suggested that IDT3 was usable (SUS score: 69.42). The details of the RCs and their outputs are given in table 6.1:

After IDT3 was found usable by both the animators and the ID writers, experiments

were conducted to validate the application of VC principles by the students (end users). These included usability and engagement surveys by the students (end users) as well as learning usefulness survey by the SMEs (content experts).

IDT2 had basic level while IDT3 had advanced level application of VC principles. Therefore experiments were designed to compare the LOs created using these two IDTs. Two topics from computer science domain, were chosen (instead of one) test the generalization of the research. In this manner, totally 4 LOs (two LOs each for two topics) were created for the experiments.

In the usability experiment, students interacted with the LOs and compared the usability, between the basic and advanced application of VC principles.

The likert scale based usability survey (having seven statements) was used to gather feedback from the students (topic 1: n=68, and topic 2: n=64). Wilcoxon signed rank test was used to analyze the ordinal and non-normal data, collected from a single group, for the two levels of LOs.

Based on the responses provided by the students **null hypothesis was rejected**, since the data showed LO3s were significantly usable than LO2s ($p=0.000$; $z=-3.771$ for topic 1 and $p=0.016$; $z=-2.399$ for topic 2).

Since there was increase in the usability scores of LO3s, as compared to LO2s, the **alternate hypothesis was not rejected**.

The findings of this research confirms the theory, of adding VC principles makes the product usable. However, this research specifically highlights the communication between ID writer and animator, using this theoretical background. The research was focused for computer science domain, however, it can be extended to other engineering and science domains.

8.2 Conclusions

The engagement experiment conducted for the students also supported this results, where the students found LO3s more engaging than LO2s. In addition to these results, the unstructured interviews with the SMEs supported another important aspect of the LOs, which was its usefulness in terms of learning. SMEs confirmed that the interactivity and the interface design of LO3s was more appealing than LO2s. Stakeholders found the LO3s engaging because of the interactivity and the visual design aspects incorporated at the IDT level.

It was concluded that the intervention created in this research was usable for the respective users. The answer to the main research question was affirmative, based on these results.

8.3 Contributions

This research has contributed in terms of the theory as well as tangible artifacts. This research documented few processes like:

- Identifying the VC principles applicable for LO creation: This was task spread over multiple domains in visual communication. This research provides the seminal resources for the pioneering research in these domains.
- Operationalizing the VC principles in an IDT: Identifying the VC principles and operationalizing it for the LO creation process, is another contribution of this research.
- Refining the operationalization of VC principles so that the ID writers find it usable: DBR method having the feature of iterations resulted in this research contribution.
- creating feedback instrument having usability and engagement constructs and validating it. The over all implementation of DBR cycles was helpful in documentation of the process of modifying and refining the IDTs.

Apart from these theoretical contributions, this research also created artifacts which can be used by the creators of eLearning content. These are:

- **ID templates:** The research generated iterated ID templates, which have various levels of VC principles embedded in them. These templates are validated, and found usable by the stakeholders. The softcopy of these templates can be available by contacting the researcher, since all the documents are released in open source.
- **Usability tools:** Variety of data collection tools were used in this research. These tools were based on popular tools in the past. The modified tools with specific constructs addressed were created during the conduct of this research. These tools were validated by following the research processes.
- **Learning objects:** One of the most important artifacts are the interactive learning objects created during this research. During the interviews the SMEs have expressed their wish to use these LOs in their future offerings of the courses. These LOs were created by applying various VC principles and are tested by students for usability and engagement.

All the artifacts created for this research are released under creative commons, and therefore would be free for use. The actual soft copy files can be obtained by contacting the researcher or by downloading them from the website of project OSCAR *Project OSCAR website* (2013).

8.4 Directions for future work

The encouraging results of this research leaves different avenues for conducting future research. Some of the important areas of future research could be as follows:

8.4.1 Testing generalization of templates for different domains

The intervention (IDT) was limited for creating and testing content for the domain of computer science in this research. It would be interesting to study if the same artifact (IDT3) can be used in other domains of science and engineering for creating LOs. It can be interesting to study, whether IDT3 can accommodate the wide range of topics and interactivity requirements from other domains.

8.4.2 Software version of IDT

The current version of IDT3 is created using slide presentation tool. During the informal interviews with the ID writers they expressed a need for an automated software instead of the presentation tool. This would provide more features to the IDT creators to enforce required prompts and feedback.

8.4.3 Creating Design Guidelines Document for animators

As mentioned earlier, the animators come from varied educational backgrounds. The eLearning content creation professionals agree that animators having no academic background for graphic arts is a growing problem. Additionally, most of the animators are unaware of the skill set required to create educational content as compared to entertainment content. The emphasis on the precision, and correctness of the shapes, motion and timing is crucial in the educational domain, which is contradictory to the ‘make-believe’ aspect in the entertainment domain.

These animators are well versed with the software to create the animation, however, not proficient in deciding proper colour schemes or layouts. As a result the Los look ill-designed, unless supervised by a graphic design expert. Again, the availability of the experts is less.

It is therefore desirable to have a formal document which provides objective instructions about the visual aspects especially pertaining to the educational content. This document should be such that animators (from any academic background) should refer it, and create engaging and usable LOs.

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Section II

Review of visual communication principles

A.1 Adaptation of animation principles

Types of contents mentioned in research are facts, concepts, process, procedures, and strategic principles (Clark & Mayer, 2011). Out of these, processes, procedures, and principles have change-over-time and complex visualization requirements. Visualization and interactivity aspects of animation are useful for explaining complex concepts in eLearning (Neo et al., 2004) and (Chang et al., 2002). In order to create effective eLearning content like learning objects (LOs), it is important to know about the production process of animation. Typically, human resource available for animation development, are well versed with traditional animation principles. These principles basically for the entertainment domain. Therefore, it is important to study the feasibility of applying them to create animations for LOs.

This document describes traditional animation principles and their adaptation to eLearning content creation. The rationale for the inclusion and modification of the principles is demonstrated by providing appropriate examples from educational domain. It is found that while all the principles are required for LO creation process, applying them should be based on the topic of the LO.

Genesis of traditional animation principles

Origin of animation is in the form of cell animation, where each frame is hand drawn. This technique was named straight ahead animation, where the animators draw all the required frames chronologically (see section A.1.7). It implies that one person needs to draw the entire sequence alone, because of the dependency on the prior frame. This technique further developed into key frame-in betweening process for scalability, and is known as pose-to-pose technique (see section A.1.8). This technique creates animation faster, as compared to single person drawing all the required frames alone.

Senior animators at Disney studios have documented the animation principles. They present 12 principles for cell animation process in the book titled ‘The illusion of life’ (Thomas et al., 1995). These principles have formalized the process of creating entertainment animation. Animators all over the world, use these principles to create animation. After the invent of computer animation, John Lasseter (Pixar Studios) wrote a paper about adaptation of cell animation principles for computer animation (Lasseter, 1987). He concludes 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 LOs.

The rationale for applying the traditional cell animation principles for creating LOs is given in table A list of 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.

Adaptation of traditional animation principles for LO creation process

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 summarizes the categorization.

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.

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	

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:

A.1.1 Staging

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’ (Lasseter, 1987). 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.

Staging, helps the animator to understand the details of the shot, like position, action, expression, motion and gestures of the character/s.

- *Consequences of using staging principle:* Staging enables the animator to see the whole action (along with the timing information) on a single paper. 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 enables proper communication.
- *Example 1 in cell animation:* Staging is used to show the details of action in a shot (see figure A.1, which shows application of staging principle in animation domain). Observe the position of the character in the first and last frames (frame number 1 and 69). Also, observe, that the action is explained using the key frames and the background is shown for reference.

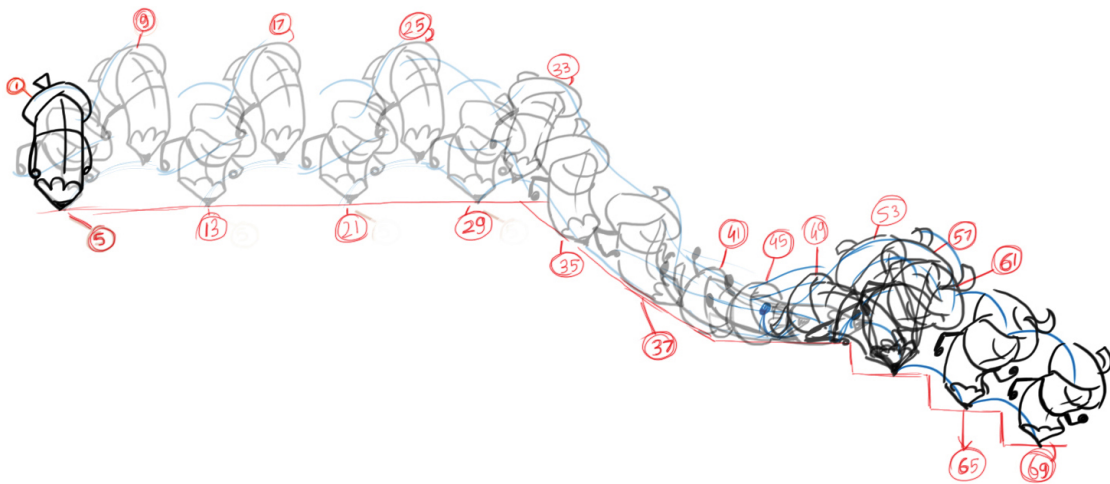


Figure A.1: Staging principle used in cell animation (example 1)

- *Example 2 in cell animation:* Staging also helps in achieving clarity of the message. This implies in creating poses which make it clear to the audience, about the nature of the action, the character is doing. Typically, this is tested by creating silhouettes of the poses. As seen in figure A.2, the poses are presented in silhouettes. The actions of hands are deliberately kept away from the body, as much as possible. This avoids the overlap with the body, and the audience can ‘see’ the action more clearly.

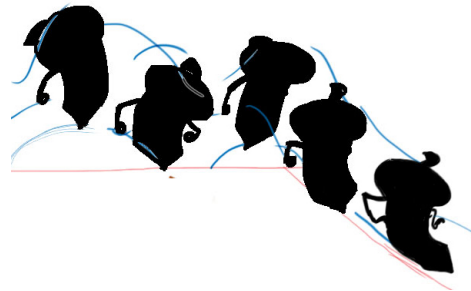


Figure A.2: Staging principle used in cell animation (example 2)

- *Does this apply to LOs? Yes.*
- *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.

- Illustrative example in LO context: Figure A.3 A shows the steps involved in the animation (written by the ID writer). Figure A.3 B 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.

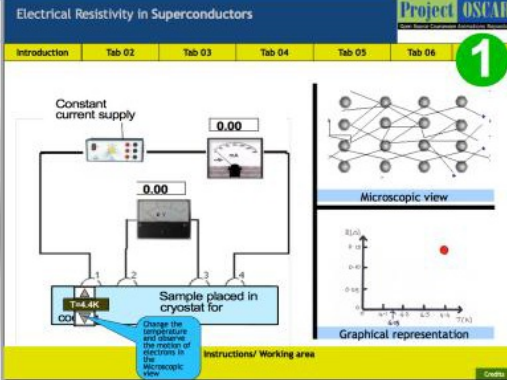
Description of the Action / Interactivity	Audio Narration (if any)	
<ol style="list-style-type: none"> 1. Show the Animation design screen (Slide 7) 2. The temperature meter shows $T = 4.4\text{K}$ as shown. 3. Move the electrons along the path in the 'microscopic view window. Refer to Master Layout 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' <ul style="list-style-type: none"> - 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'. 	<p>Click on these buttons to change the temperature</p>	

Figure A.3: Application of staging principle in ID template

A.1.2 Stretch and squash

The distortion of the object to depict the speed at which it is moving is called 'stretch'. Stretch is also used to show the distortion shown while the object is expanding, lengthening or widening. The distortion caused by the contact/impact/collision with another object is called as 'squash'.

Every object (made up of any material) changes its shape at the time when it collides with other object. This phenomenon is so subtle, that it is not visible to the naked eye for the harder materials like metals, wood, etc. It can be in cases of objects like balloon, rubber ball, soap bubbles etc. Animators from Disney studios have used this principle extensively, to create comic gags.

- *Consequences of using stretch and squash principle:* Applying staging principle makes is easy for the viewers to understand the following aspects regarding the object:
 - Material which is used to make the object.
 - Some additional information about the material used to make the objects near the main object/the objects interacting with the main object. Ex: The ground made up of concrete, and not of stretched 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.

This principle helps the animator to amplify attributes of the object/s like:

- Speed and motion. Ex: Pencil elongates vertically, while in the motion. Note: The elongation happens parallel to the direction of the motion
- Distortion at the time of a collision with other objects. Ex: Pencil flattens against the brick wall at the time of collision. Note: This is mostly parallel to the object of impact. Pencil flattens up against the wall and elongates parallel to the wall.

If the principle of stretch and squash is not used, then, the viewer may have trouble in getting the feeling about the action. The motion shown on screen (without stretch and squash) may lead to a conclusion that the pencil is just colliding with the ground.

- *Example in cell animation:* Figure A.4 shows two frames of a pencil. In the illustration on the left, the pencil has hit the ground, and therefore the longish pencil is flattened after the impact. This is the squash principle applied. It also tells about the surface it was hit upon (like concrete, wood, stone etc. basically a hard surface). The illustration on the right shows the pencil jumping up. The elongation of the pencil shown in the illustration is the stretch.



Figure A.4: Squash and Stretch principle used in traditional animation

- *Does this apply to LOs?* **Yes**, after modification.
- *Rationale for above claim:* This principle is based on exaggeration and distortion of the objects. The main objective of using this principle in the entertainment domain is to create a comic relief, using distortion.

This attribute is not useful in LO creation similar to the entertainment domain, where it is used in exaggerated manner. The objects in the LOs are animated to depict scientific information. Distorting (stretching/squashing) of the imagery is not done for providing comic relief in LOs. This distortion may lead to wrong information and unwanted distraction from the topic.

- *Illustrative example in LO context:* As shown in figure A.5, the drill hits the various layers of the earth and creates a tunnel. If the drill is shown squashed at the time of impact, then it would be difficult for the viewers to believe that the drilling machine is made up of a harder metal as compared to the different earth crusts.

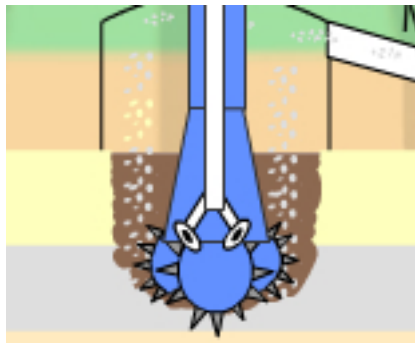


Figure A.5: Example in LO, where squash and stretch principle should not be applied

A.1.3 Timing

Timing in animation is manipulation of the number of frames in order represent different attributes of the object to be animated. More frames are used to show slow movement and less frames are used to show fast movement of the object to be animated.

- *Consequence of using timing principle:* Timing helps in achieving two main effects on the screen, determining the scale (size and weight) and the speed of the object. More number of frames for a given action, make the object look heavier on screen, as the movement is slower. The objects shown with less number of frames for a given action, make the object looks lighter on screen. This successful depiction of attributes like size, scale and weight adds emotion to the character.

If the principle of timing is not used, the objects/characters may not depict their attributes in terms of size, scale, speed etc. It can also hamper the depiction of the emotions of the character. Ex: If the timing is not used then the character which is to depict a pensive mood may look happy.

- *Example in cell animation:* Figure A.6 A, shows the position of the two extreme frames, of an action. This example shows that, the number of in between frames can determine the emotions depicted. In the image A, the two extremes have one of the face on right side of the frame and the other on the left side. With a

variable number of in-between frames, the meaning of the action can change as follows:

- Without an in-between (as shown in frame A): The face is slapped, and the reaction is shown.
- One in-between (as shown in frame B): The character is denying the fact by shaking the head.
- Three in-betweens (as shown in frame C): The character is having a look at the panorama in the front by slowly moving the head from left to right.

This aspect is used by animators to depict various attributes in an animation. These attributes are, physical properties of the object/character or emotions.

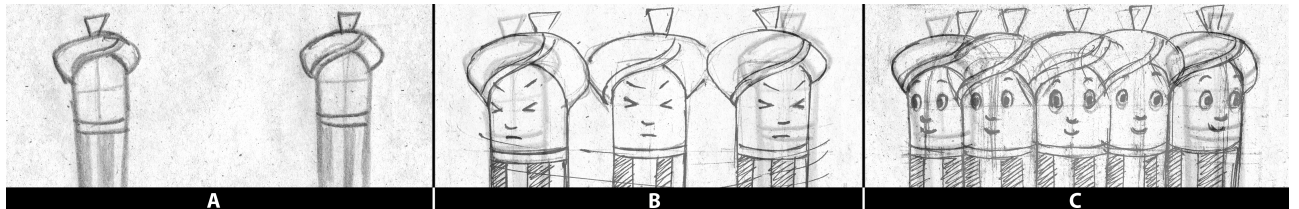


Figure A.6: Timing principle applied in traditional animation

- *Does this apply to LOs? Yes.*
- *Rationale for above claim:* This principle should be used in eLearning at least for its advantage of depicting the scale, size and the speed of the objects. There may not be instances in LOs where there are living characters so the ability of this principle to depict the emotions may be used rarely.
- *Illustrative example in LO context:* The electrons have to move at a stipulated speed in the LO explaining Superconductivity. By using the principle of timing, the animator of the LO can increase the number of frames of the animation to depict expected motion. Ex. Slow moving electrons will require more number of in-between frames as compared to fast moving electrons which require less in-between frames.



Figure A.7: Example of fast timing in traditional animation

A.1.4 Anticipation

Anticipation of the action is the preparation for the main action. It is based on the contraction-expansion phenomenon, where contraction happens before expansion.

Every action can be divided in 3 stages: preparation, actual action, and the aftermath of the action. In traditional cell animation, all the three stages are used effectively. Anticipation is used to show the preparation stage of the action. First it is decided which part of the object moves and in which the direction. The second decision is about the amount of movement, how much does the object moves.

Typically, the part one is easy to plan. The second part depends on few aspects like: type of character being animated, situation in which the character is going to perform the action, location of the action, the relevance based on the connecting shots etc.

- *Consequence of applying anticipation principle:* Applying the anticipation principle in the animation, enhances the effect of the actual action. It also prepares the audience to enjoy the (actual) action which is follows the anticipation.

Anticipation is used to enhance the main action. Every action especially in the traditional cell animation has less dialogues. In this situation, it becomes important to communicate the intentions of the character to the audience. Anticipation is used for this purpose. It also creates a expectation in the audience's minds about the intensity of the action to follow.

When anticipation principle is not used the communication expected from the action loses its importance. In the example above, without anticipation, the actual action of moving out of the frame rapidly, (to the right) may not look fast enough.

Avoiding anticipation in fast paced sequences of chase, fights etc. may fail to communicate the mood of the sequence. Each action (minus anticipation) would be merely 10-12 frames, where the audience will not be able to register what is happening on the screen. Further the actions may look unnatural.

- *Example in cell animation:* In the figure A.8, the pencil is shown shouting at someone. The frame on right side conveys the anger. However, the initial frame is shown on left, where the pencil is accumulating the energy to shout. This is the preparation part of an action. This preparation, makes the final action (on the right) more powerful, and conveys the anger through the action.

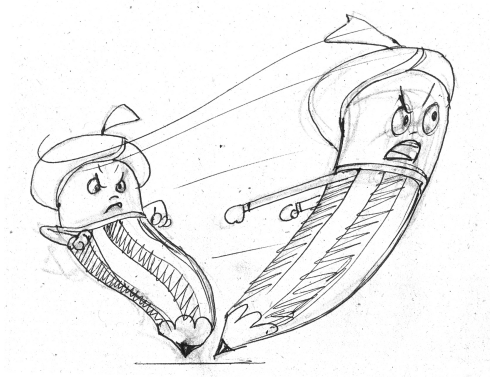


Figure A.8: Example of anticipation principle applied in animation

- *Does this apply to LOs?* **Yes**, but only the first part
- *Rationale for above claim:* Using anticipation in LO creation would be required to make the routine actions look natural. It is also important not to use with exaggeration, as it may be a deterrent factor while depicting scientific concepts in LOs (for details, see the section about exaggeration A.1.11)
- *Illustrative example in LO context:* Given below are two examples where application of anticipation principle has yielded in different results.
 - Example 1: Throwing of a ball in the air: Some amount of anticipation shown in the beginning will make the entire animation look natural. The character moves hand slightly in the opposite direction prior to throwing the ball.
 - Example 2: Car on the road: In this animation if the car is to be shown starting from rest, then it should not go back before moving ahead. This would look unrealistic.
- *Adaptation required to apply this principle in LOs?:* Execution of this principle has two parts. The first part is the theoretical part where it is decided that for every action the anticipation is usually shown in the opposite direction. The second part is the actual rendering of this, where (in traditional animation) exaggeration plays an important role. While considering this principle for LO creation, it is advisable, to adopt first part, but careful thought should be given to the exaggeration part. In the execution, it is important to avoid exaggeration, as it may lead in depicting unrealistic imagery.

A.1.5 Followthrough

As discussed in the section on anticipation, every action can be split in 3 parts. First is the preparation (anticipation), the second is the actual action and the third part is of coming to rest (after completing the main action) is follow through.

- *Consequence of using follow through principle:* Applying follow through principle will give a appropriate termination to the action. Few actions will come to a sudden stop, most of the actions will have some or the other appendages. These appendages will always continue to be in action little later than the main body stops the action, as they might be placed at different level (in terms of the gravity pull), or may have different material (in terms of weight) etc. Applying this principle gives more realistic effect to the animation.
- *Example in cell animation:* The pencil character swings from left to right. During this motion turban also moves along. However, the open tip of the turban keeps following the action of the turban and pencil. Even after the pencil stops, the tip droops down, after few frames.

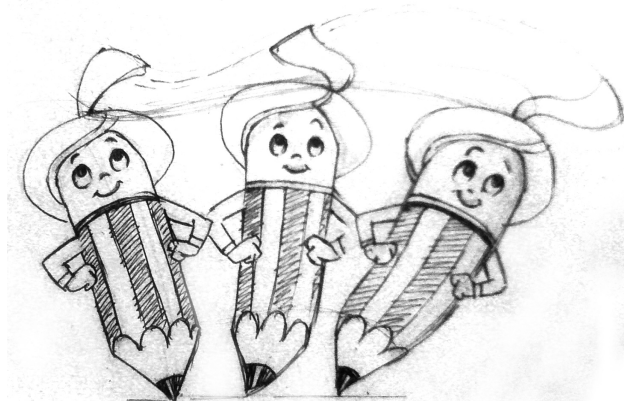


Figure A.9: Example of follow-through principle applied in animation

- *Does this apply to LOs?* **No.** Unless specified
- *Rationale for above claim:* This principle needs to be applied only in cases where the animation demands the follow through motion.

A.1.6 Overlapping action

The action which 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.

- *Consequence of using overlapping action principle:* Principle of overlapping action, acts as a transition action between the follow through of the first action and the anticipation of the second action. This helps in keeping the continuity between the series of actions planned in a particular scene/shot.
- *Example in cell animation:* In the figure A.1, the pencil character is shown jumping on a flat surface. The jumping action is in cyclic motion, and has identical frames (frame numbers 13, 17, 21, 25 and 29). When the character jumps down the slope, the cyclic action changes drastically (see frame number 33). Since this is a continuous action, the character doesn't stop, and then starts the sliding action. In such conditions, overlapping actions are widely used.

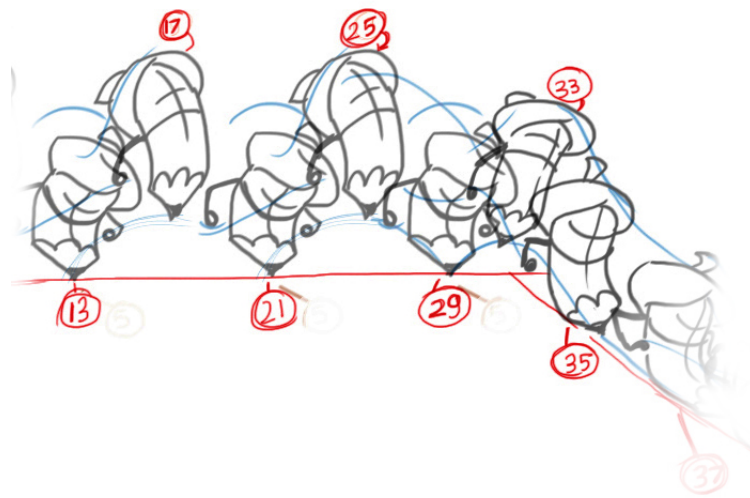


Figure A.10: Example of overlapping action principle applied in animation

- Does this apply to LOs? **No.** Unless specified.
- Rationale for above claim/belief: It is useful in LO creation, because, there would certainly be few situations where the objects change their action from one to another. The in-between action can be created using overlapping action principle.

A.1.7 Straight ahead

Straight ahead action is a method of animation, where the animator creates the frames (of animation) in a linear sequential manner.

- *Consequence of using straight ahead principle:* This method of animation is free form type. The animator has the freedom to continue frame after frame about the idea to be animated. This type of animation creates a spontaneous, zany animation, which is used for depicting a wild, scrambling action.

The animator starts the animation from the frame 1 and goes ahead to continue with the next frames in a sequential manner. There is no detailed plan where the timing allotted to every action in the animation.

No negative results will occur if this principle is not applied. This is because more than a principle this is a method of animation. If the animator does not use this method, then he/she would use some other method. Not using this method may be creating a problem regarding the production time line. As this animation method is based on the frame-by-frame drawing, it cannot be distributed to more animators. Only one animator could be able to work on a shot, as every frame to be created depends on the previous frame. In case where this method is not used where it is best suitable EX: creating a jerky and wild action. The final animation (if not created using straight ahead animation method) will not be able to have the desired effect of the wild/scrambled action (if it is created using other method). It also makes it difficult for the animator to maintain the proportions of the character in the animation.

- *Example in cell animation:* The figure A.11 shows the shot where pencil is jumping. The 5 frames are drawn sequentially, one after the other to create the motion. This style is used for achieving an effect of a wild/scrambled action sequence.

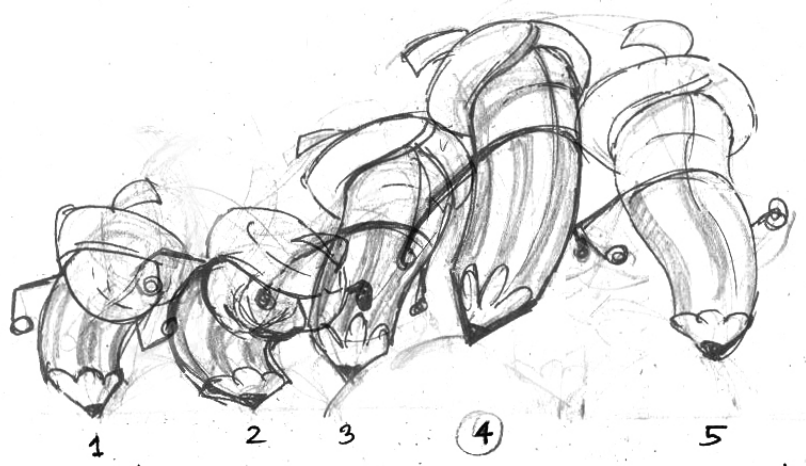


Figure A.11: Straight ahead principle used in traditional animation

- *Does this apply to LOs?* **No**
- *Rationale for above claim:* This method of animation creation is possible in hand drawn, cut out or claymation. It is almost impossible to create computer animation using this method. Computer uses the Pose-to-pose (key frame) method, where the in-between frames follow the interpolation principle.

A.1.8 Pose-to-pose action

Pose-to-pose action is a method of animation, where the animator plans the actions and creates the key frames in the beginning and later fills the gaps with in betweens.

- *Consequence of using pose-to-pose animation principle:* This method of animation is a planned method. The animation can be created quickly, and also more effectively, using this method, as the entire execution of the drawing of the frames is planned in the beginning. This method helps in dividing the animation work to the animator and the in-betweener, 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.

The animator starts the animation by carefully planning the entire shot. He/She first draws the extreme frames of the shot, i.e the first and the last frames. The adds the other frames where there is a change in the size, angle, gesture, emotion etc of the character which are called the key frames. The animator then also writes instructions for the in-between drawings to be created, and then these set of in-betweens are created accordingly by the in-betweener.

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 in-betweener creates the in-betweens. This makes the overall animation process well divided and in turn more effective. It also helps the animator to visualize the complete action on the basis of the key frames. This helps in getting a proper estimation of the timing of the animation.

- *Example in cell animation:* Jumping pencil: As seen in the figure A.12, the pencil starts from frame 1 and hits the ground at frame 7. The frame where the pencil is in air is frame 5. Similarly, in the second jump, the pencil is in air on frame 11, and lands on the ground on frame 13. Here, the animator has carefully planned the action, keeping the gravitational force and the weight of the pencil in mind. The planning of the key-frames based on the time line, is helpful for the in-betweener to create in-betweens and complete the entire animation.

Not using this method may result in an animation which

- would not be scalable, as one animator has to create the entire animation. By creating the key frames the animation process can be sub divided to other stakeholders like assistant animators, and in-betweeners.
- would have problems regarding the maintenance of the proportions of the characters in the animation.

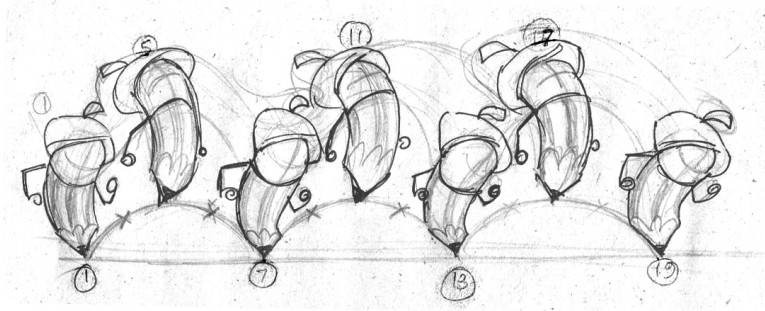


Figure A.12: Pose to pose action principle used in traditional animation

- *Does this apply to LOs? Yes*
- *Rationale for above claim:* LO animations are created using computers. Animation created using computers are where the key frames are created first and then the computers create the in-betweens. It is also important to use this method for LO creation, as the scientific animations have change overs in the actions, where the behavior of the elements in the animation changes. It is possible in this method of animation to identify these key frames and create the in-betweens accordingly.
- *Illustrative example in LO context:* There is no specific example provided for this principle, as most of the modern software are based on key frames. Once the animators creates the key frames, the animation software creates the in-betweens automatically. These in-between frames are placed at equal distance from each other.

A.1.9 Slow in Slow out

The spacing of the in-between frames to achieve subtlety of timing and movement is termed as the slow-in and slow-out principle.

- *Consequence of using slow in slow out principle:* With the pose-to-pose style of creating animation using key frames and in-betweens gives the desired motion. Often in this motion, it is the placement of the key frames which is important in deciding the timing and the speed of the movement. Slow-in and Slow-out is a principle which helps in achieving the subtle timing and movement changes by deciding the placement of the in-betweens.

In traditional animation, the principle of Slow-in and Slow-out helps the animator to slowly come out of a pose or to slowly start a pose by placing the in-betweens nearer to the key frames.

- *Example in cell animation:* In the figure A.13 the pencil character is bowing

down. The extremes are important to be seen by the audience, therefore the animator has marked the in-betweens nearer to the key frames. This way the action slows down near the key frames and speeds up between the two. This gives the desired impact, of showing the key frames to the audience for a longer time.

This principle is used mainly to make the expressions more visible. The motion of the action, can be further enhanced if the slow-in and slow-out principle is added to the animation.

If the principle is not used, then the other principles, (which are used to enhance the expression) may not be useful to achieve the desired impact. Ex: The ball bounce will have the stretch and squash, but the in-betweens will not make it explicit that the ball slows when it gets nearer to the highest point away from the ground. It will also not show that this slowing down has gradual, and smooth transition from its regular speed of bouncing.

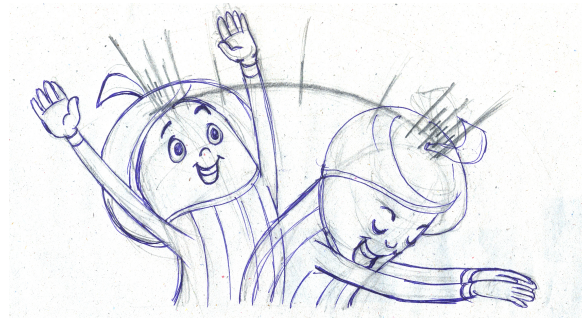


Figure A.13: Applying Slow in and slow out principle in animation

- *Does this apply to LOs? Yes.*
- *Rationale for above claim:* The action in the LO animations are based on the real time movements of various elements. In order to achieve the realistic timing in the animation to be created for these elements it is important to apply this principle in the LO creation process.
- *Illustrative example in LO context:* An example of a car starting from resting position (frame 1) would not run at 50/60 kmph. from the frame 2. The gradual pickup of the speed can be easily animated by applying the principle of slow-in. In the document on Anticipation, we discussed, how for non living objects the action often does not start with anticipation, and the example discussed is a car. The car does not go back before it goes forward, so the principle of Anticipation cannot be applied for the car especially in the LO creation. But the principle of slow-in is necessary for providing the realistic motion to the car.

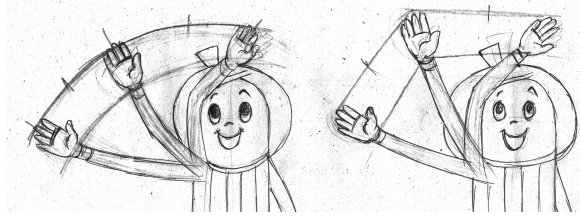


Figure A.14: ARCS principle used in traditional animation

A.1.10 Arcs

Action happens in a gentle curve rather than a straight line. Arcs are the paths which the animator uses as guidelines for placing the character in the animation.

- *Consequence of using arcs principle:* Avoiding a straight line for animating an action makes it look more natural. Once the path (gentle curve) is created, the animators place the positions of the characters or objects in the action along the path. These guidelines (arcs) help the in-betweener to make the action livelier, than the action shown along a straight line.

When the animator gets a shot for animation, he/she uses the staging (section A.1.1). principle to understand the action. Once the action is understood, it has to be created using a number of frames, ex.: a Pose-to-pose method of animation (section A.1.8). While doing this, a line/path is drawn to decide the location of the character performing the action. This line/path is called the trajectory. The trajectory is a line made up of points which are essentially, the centre of gravity points of the character to be animated. The animator uses these points and based on his, sketches various frames keeping the center of gravity of the character on this line.

Using the principle of arcs, the animation created looks natural. It also provides important information to the animator about the path along which the animation has to be created. Not using this principle will make the actions look unnatural, or too mechanical.

- *Example in cell animation:* Figure A.14, shows two variants of the pencil character moving the hand. The pivot point and the extreme positions of the hand are the same. Action A, is shown using curved trajectory, and B is shown using straight trajectory. With all other positions same, the animation will look unnatural for the action shown in B. This is because, our actions always follow an arched trajectory.

- *Does this apply to LOs?* **Yes**
- *Rationale for above claim:* Animation of living organisms look natural if it is

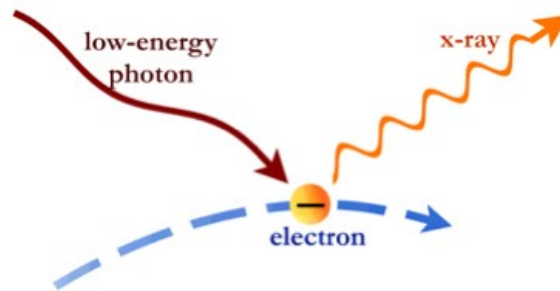


Figure A.15: ARCS principle used in LO

created using arcs. Arcs communicate the action to the animator clearly when provided along with the extreme key frames. In case of the LO animations, since the animator does not have the domain expertise, it is all the more important to use the arcs.

- *Illustrative example in LO context:* The electrons have to move in a certain path, and that is pre defined on the basis of the temperature (see figure A.15). It would be important for the animator to have these paths as the guidelines in order to animate the electrons in a correct manner. The ID writer can show a line which is the path for the animator to animate the electrons.

A.1.11 Exaggeration

Exaggeration is presenting the situation in a wilder/extreme form, but true to reality. In this definition, reality is to be referred as the concept/script/storyline.

- *Consequence of using exaggeration principle:* The perfect depiction of reality sometimes has a possibility of looking dull, so the principle of exaggeration is useful (especially in traditional animation domain), to make it more interesting. This depiction is true to reality (concept/script/storyline), but is presented in a wilder form, which makes the character, situation, or the story more interesting. In actual sense this principle helps in extending the nature of a feature of the character/object. Some actions may look routine (or boring) at times, using the exaggeration principle these actions are made interesting.

For applying this principle, the animator considers the following aspects, which are important in that particular shot/scene:

- a particular emotion in the action
- a specific/unique characteristic of the character to be animated
- a reaction of any other character etc.

In any of the conditions mentioned above, if the animator feels that by creating a realistic animation, the action may look dull and go unnoticed, then he/she takes a call to add exaggeration. He/She picks up one of the aspects mentioned above, for exaggeration. It is made sure that except for the selected action/part of body/unique characteristic of the character, other aspects remain normal. This helps in attention grabbing of the viewers. Ex: In case the laughter is picked to be exaggerate, then the animation of other aspects/body parts is done in a standard basic level. (It is recommended that multiple objects should not be exaggerated in the same shot.) There are various levels in which exaggeration can be applied to a certain action/character/situation, but with a caution that the final output should always be true to reality. As mentioned earlier, exaggeration is about extending the depiction of the action using a wilder or a extreme motion.

Exaggeration is useful in reducing the dullness of the action which is created if shown in a realistic manner. This principle helps the animator in achieving the goal of making the animation more interesting. Further, it is also used because of a fact that these exaggerations are able to depict the actions which are impossible to be created in live action (camera shot) scenes.

If the principle is not applied, there won't be any negative results, as the concept would still be communicated, but would have a chance of becoming dull.

- *Example in cell animation:*
 - Turban and pencil lead coming off : The script mentions that the character was so surprised, that the props come out. When the shot comes for the scene planning stage, the chief animator takes a decision of making the action louder/more effective by exaggerating it. The animator tries to increase the impact of the action by showing the turban falling off and also the pencil lead dropping out. This is a medium type of exaggeration.
 - Dropping of the jaw: The script says that the character was so surprised, that his jaw was open for a longer time. To create the animation for he same, the animator uses exaggeration to make the expression more interesting.
- *Does this apply to LOs? No.*
- *Rationale for above claim:* In the LO animation the concept is to be conveyed in a correct manner. Whether the depiction is creating a dull moment for the users is not the criterion while creating animation. The most important goal in LO animation is to create animation which is 100 percent true to reality. In this condition, the principle of exaggeration, which has a strong base of distorting the imagery for making the depiction interesting, is not suitable.

A.1.12 Secondary action

Secondary action is the action that results from the main action.

- *Consequence of using secondary action principle:* Principle of secondary action, helps in achieving the realistic motion of the overall action. In camera videos, when a particular action is shot, it also captures all other associated actions which occur along with. For example in the action of a walk, the primary action of legs and torso moving ahead is accompanied with the action of the hands, which in fact move exactly in reverse tandem. In a camera shot, this action of the hands would be captured automatically. But in case of animation, it has to be specified by the animator.

Studying the main action and finding out other (secondary) actions which happen because of the primary action becomes an important feature in animation. At this point it is also important to specify the difference between the principle of follow through and secondary action. Follow through (as discussed in Doc 05) is a action which uses the trajectory of the main action. In most cases, it is observed that the follow through action is of the objects which are attached to the main object, or parts of the main objects which are attached to the main object, but have free ends.

Follow through actions are the actions of these parts (with free ends) and the motion which typically continues after the main action. In comparison, secondary action happens along with the primary action of the main object. It is also different in a way, as this action is not based on the trajectory of the main action, but it occurs because of the main action.

To implement the secondary action, the primary action is drawn. Then the animator looks for other parts of the object, which would move because of this action. The trajectory of these movements is studied, and based on that it is decided whether the other actions are secondary or follow through. The parts of object which are attached to the object, but have a substantial size free, OR are lighter in weight (as compared to the main object) mostly follow the similar trajectory of the main object. Important feature to note here is: that they come to rest some time later than that of the primary action. Ex: long hair on the head, or the robe attached to the neck etc.

The actions in which the trajectories are not similar to that of the main action, but the movement is caused by the main action, are then separated as the secondary actions. Ex: Hand movement of the body in a walk cycle motion. For the animator, it is an important step in creation of animation, to spot the secondary

actions. It is difficult to spot them, as it requires keen observation, and imagination on the part of animator. The way this issue is tackled is to first draw key frames of the primary action, only with the parts of the objects involved in the action. This is followed by drawing the other parts, of the main object to these key frames. While drawing these parts, the animator asks a question, ‘would any one part out of these, will move in some other way than mere follow through?’. The answer to this gives pointers towards spotting the secondary actions in the motion.

The primary action is a part of the total motion. There are other movements happening along with the primary action which lend the natural/realistic feel to the overall action. Excluding them and animating only the primary action would make it look unrealistic/unnatural. Ex: Walk cycle without ANY movement of the hands, or head would look unnatural.

- *Example in cell animation:* Figure A.16 shows the primary and the secondary actions of the pencil character. The primary action is the jumping movement of the pencil tip. The hands which are attached to the upper part of the torso, and a significant size of the hands is unattached/free. The hands, in order to balance the overall body (which is touching the ground only at the tip), move in the reverse direction overall motion of the pencil and thereby balancing the entire body.

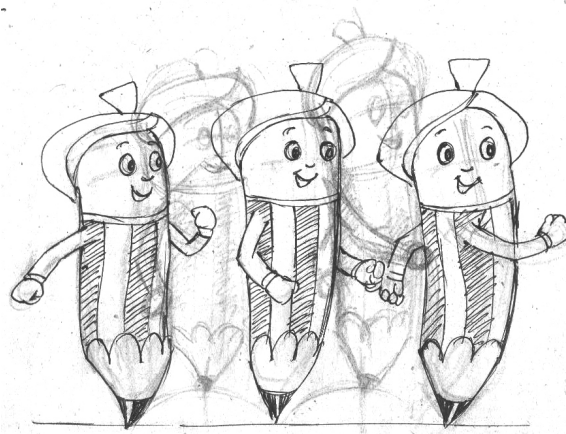


Figure A.16: Example of secondary action from animation domain

- *Does this apply to LOs?* **No.** Unless specified.
- *Rationale for above claim:* Objects in LOs have motion. These objects 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.

- *Illustrative example in LO context:* In the drilling animation, the drill has a rotary motion, when it is drilling down the ground. But the piston to which it is attached also 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. These actions are secondary actions, and need to be defined and thought well along with the primary action of the rotary motion of the drill.

A.1.13 Appeal

Appeal is anything that a person would like to see: a quality of charm, pleasing design, simplicity, communication, or magnetism (Lasseter, 1987). It is a combination of all required attributes in a given object/product in the required proportion. This is achieved by creating solid drawing of the object/character.

- *Consequence of using appeal principle:* In animation domain, the characters need to draw the attention of the viewers towards themselves, and keep it constant as the story telling unfolds. In order to achieve this, the character should be having simplicity, pleasing design, and clarity in it. In comparison with camera shot live action films, the characters which have charisma of their own attract the attention easily. In order to make the animation character enjoy the same privilege, it is seen that the animator uses one or more animation principles in making the poses of the characters (Lasseter, 1987). On using this principle, the character is able to be the center of attraction, and keep holding the attention of the viewers for the narrative that is planned.

As discussed earlier, it is implemented with the help of one or more principles of animation. Exaggeration is used often, to add appeal to the character. Here the exaggeration principle is not used only in terms of the motion, but also can be used in terms of proportions.

- *Example in cell animation:* The character designer has cleverly used the principles of human anatomy while creating this character. Solid drawing showing the anatomy, structure, and the proportions of the character make it appealing for the audiences to see (see figure B, in A.17). Having characters with a weak drawing or design lacks appeal. A design that is complicated or hard to read lacks appeal. Clumsy shapes and awkward moves all have low appeal (see figure A, in A.17). These flaws in the design of the character or its movement results in losing of interest for the viewers. This situation is not advisable for a filmmaker.
- *Does this apply to LOs? Yes.*

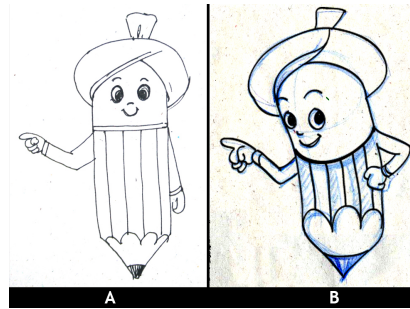


Figure A.17: Example of appeal principle applied in animation domain

- Rationale for above claim:* In eLearning domain, this becomes an important principle. As compared to the entertainment domain, LOs have characters/objects which are less interesting (in terms of the look and feel). The viewers are also drastically different, where the films are seen for entertainment, the LOs are to be seen for education. So in order to keep the viewer interested in what is presented on screen, this principle is required to be incorporated while creating LOs.
- Illustrative example in LO context:* In the figure A.18, the metal slab is shown being cut. The artist has given emphasis to the perspective and angle. The metallic shading is used appropriately to depict the shine of the metal. The warm tones of orange depict the heat generated by the deformation.

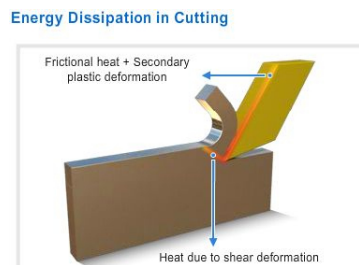


Figure A.18: Appeal principle used in LO

A.2 Adaptation of Graphic design principles

A.2.1 Figure and ground

- *Definition:* Principle of figure and ground is to be able to distinguish between the foreground and background in a visual field. Definitions of the keywords mentioned above are as follows:
 - Foreground: In parlance of the graphic design, foreground is the area in the overall visual which has the objects nearer to the viewer in terms of the visual depth. This will have the components/objects which are the ones the designer feels that the viewers should see at first.
 - Background: Background is the area which has objects which the designer feels that user should see AFTER they have seen the foreground. Objects in the background are placed in such a way that they appear far away to the viewer in terms of the visual depth.
- *Features of this principle:* Motivation of every design is to communicate a certain message. Often, along with the primary message there are other ‘supportive’ messages in a given image. Principle of figure and ground helps the designer in creating a design to make the primary message prominent enough to demand the attention of the viewer. It also makes the background to have the attention at the secondary level, (after the primary level) in order to facilitate the primary message to get across.
- *Implementation of this principle:* In graphic design process, the first step in creating the design is to choose the elements which will convey the message. These are the ‘foreground’ elements or Figure. Next step is to identify the supporting elements which are required along with the ‘main message’. These are the ‘background’ elements or Ground.

Various techniques like, colour, contrast, sizing, placement are applied to create the image which will have a clear demarcation of the elements which the designer feels should demand the attention of the viewer first, and the elements which should get the attention later. The ideal conditions of the figure and ground principle are:

- Ground should not be demanding the attention of the viewer, prior to the figure
- There should be clear demarcation between the figure and the ground.

- Having less/no demarcation will create a image where figure and ground are looking mixed with each other and the viewer is getting confused
- *Example in graphic design:* In the figure A.19, foreground (figure) is the two rectangles placed vertically denoting buildings. The background (ground) is the light blue horizontal rectangles denoting sky and the circle denoting the sun.

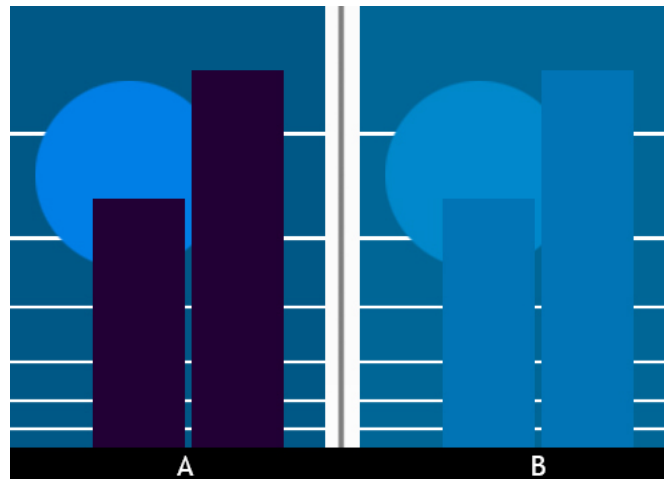


Figure A.19: Figure-ground principle applied in graphic design.

- *Consequences of using this principle:* Use of figure and ground principle helps in achieving correct communication. As shown in the example A (figure A.19), the message to be communicated is the image of the buildings. It is made ‘figure’, by using the dark most colour, making it bigger than other objects, and placing it at the center of the ‘ground’. It demands the attention of the viewer. The ‘ground’ is a pattern of horizontal lines, and a circle. Low contrast of the colours used for these, makes it seem away, or in the background. The vertical rectangles denoting the buildings thus become the nearest graphic and therefore become ‘figure’.
- *Consequences of not using this principle:* See the example B in the figure A.19, having the same images. The principle of figure and ground is not used, by reducing the contrast between the figure and the ground. The graphic does not have the clear demarcation of the background and the foreground elements. The viewer would be unable to decipher the message (which in this case is the buildings) to be communicated by the image.
- *Does this apply to LOs? Yes.*
- *Rationale for above claim:* In LO creation domain, the message is technical content about the topic. However, the screen will have many other elements

apart from the motion graphics of the topic. Figure and ground principle should be applied so that, the main elements would stand out as foreground. All other elements, which have to be presented in a manner, such that, they do not confuse the user, by demanding attention prior to the main elements.

In a nutshell, for an LO, the main concept should be made the foreground, and the other information should be categorized as the background.

- *Example in LO context:* Figure A.20 shows a screen shot of a LO about ‘drilling operation’ concept in metallurgical engineering domain. Animation is created to demonstrate the process. Using figure and ground principle, the designer has made the drilling area prominent, as compared to the background of the topography. The animation area thus demands the attention of the user prior to the background imagery, and other options available on the screen.

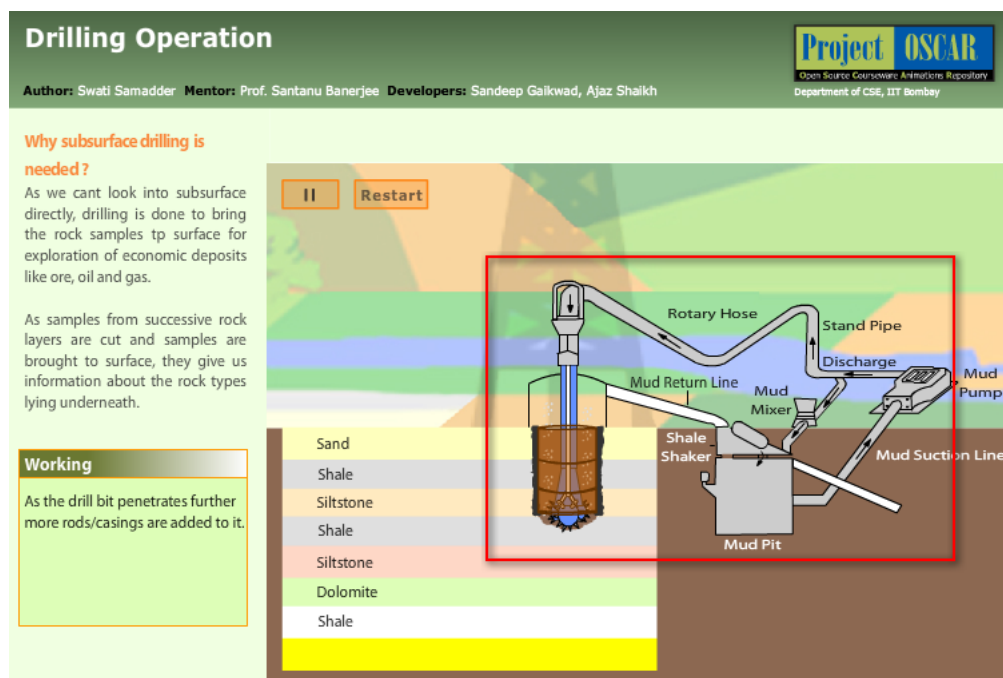


Figure A.20: Figure-ground principle applied in LO design.

- *Adaptation required in this principle to be applied to LO creation:* The demarcation of foreground and background is easy in LO creation. But, as there could be a lot of elements in an LO, placing them in the background is a challenge. Using the principle of similarity to create groups of similar functions and place them accordingly, helps in these situations.

A.2.2 Focal point

- *Definition:* Focal point is an imaginary position in a design, which catches the attention of the viewer first. Typically, focal point is a part of ‘figure’ (explained in section A.2.1).
- *Features of this principle:* Focal point helps the user to locate the point of interest (from the point of view of the designer) in the entire design. The user starts looking at the design from that point, and explores other elements later.
- *Implementation of this principle:* The designer decides the ONE particular element, part of an element, or a point in the design which he/she wants the user to use as the starting point. This point is then placed in the design by applying various alternate methods of making it the most interesting point in the whole design. These methods could be using typography, contrast, colours, scale etc.
- *Example in graphic design:* In the example given above, the red dot is the focal point of the design. The viewer would be starting to look at the design from that point as the colour is strikingly different. The 4 green dots around the red one would be seen prior to all other dots which have same colour.

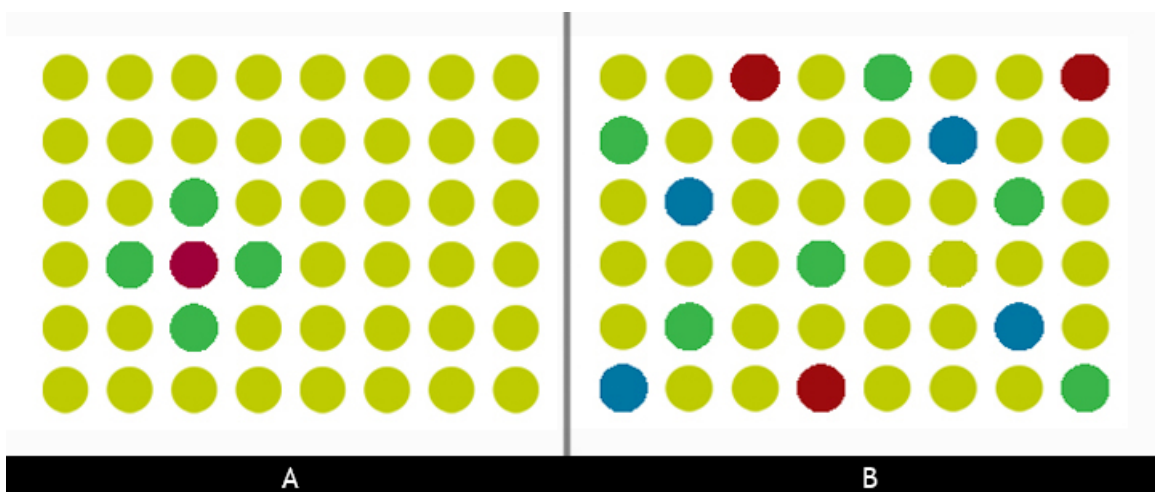


Figure A.21: Focal point principle applied in graphic design.

- *Consequences of using this principle:* Using focal point principle helps the designer to have a flow in the message. The design having a focal point always starts with a point of interest and then takes the viewers to the other parts of the design. This hierarchy in the visuals is decided mainly by the hierarchy of the objectives, the designer sets while designing the image.
- *Consequences of not using this principle:* Absence of a focal point could be analysed in different ways. One situation could be that as there is no specific

focal point marked by the designer, the design has multiple focal points. In a variation of the example shown earlier it can be seen how the image has multiple focal points. In the example below, we see circles having various colours. The users cannot focus on one single point, as almost all the points demand the user's attention. This becomes a problem for the user, and the message (intended to be communicated through this design) is lost.

The other situation could be when all the elements of the design are of same weightage. This makes it uniform image, where the message (which is the most important one) is lost, along with all the other messages/elements in the design.

- *Does this apply to LOs? Yes.*
- *Rationale for above claim:* To explain a complex concept in a LO, it is very important that the explanation starts from a particular point and then has a certain flow. This entire script is thought by the subject matter expert (SME), and an ideal LO delivers it to the expectation of the SME. Focal point principle makes the point of interest clearer to the user, there by setting up starting point for the proceedings to follow.
- *Example in LO creation domain:* The example shows an LO created on the topic of 'Drilling operation' which is a concept from the Petroleum Geosciences (see figure A.22). The main element in this LO is the animation of the drilling action. Along with that there are other elements such as text explaining the action, navigational buttons, and information about the authors. You can see that since the animation of the drilling action is the most important aspect, it is placed in the center, and all the other images (apart from the drilling mechanism) are shown in a low contrast. This enable the viewer to focus on the drilling action, as intended by the subject matter expert/author of this LO. In this example the focal point in the design is created using an animation for the focal point, while other elements are static.
- *Adaptation required in this principle to be applied to LO creation:*

In LO creation processes, apart from placing an element at the focal point, it is important to choose a appropriate medium for the topic to be shown in the LO.

A.2.3 Proximity

- *Definition:* Principle of proximity says that the elements near each other will be considered as together.

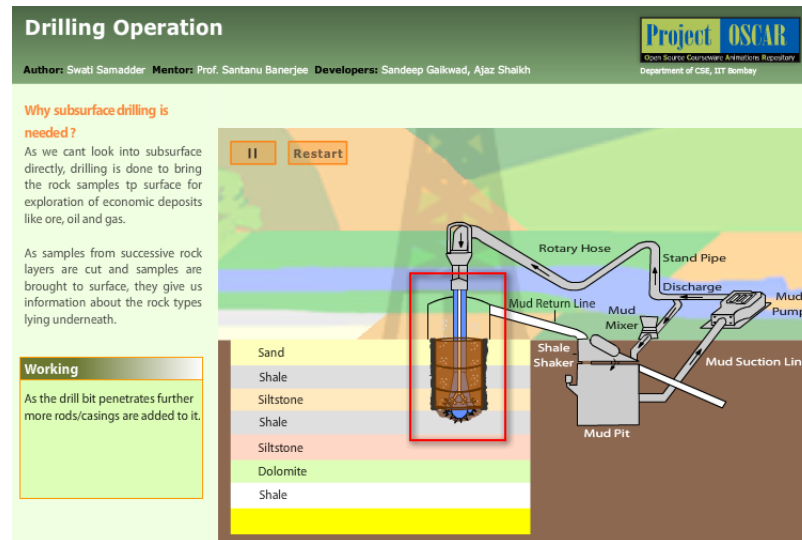


Figure A.22: Focal point principle applied in LO design.

- *Features of this principle:* This principle helps the user to visually organize the information in groups of elements having similar functions or attributes. This facilitates the user to access the required information faster. In short, the user is able to ‘see’ the design in an organized manner, where the related elements are placed near each other to form cohesive groups.
- *Implementation of this principle:* Designer first analyses which elements in the design have similarity in terms of the message to be communicated or the functionality that they provide. Later, the designer creates a group of those elements by placing the elements near each other. This placing is based on chunking theory where the objects with similar attributes are easily accessible if they are placed together.
- *Example in graphic design:* See figure A, in A.23, the coloured dots are scattered. Therefore the user is unable to make connections between the multi coloured dots. This causes chaos, and the information, to be communicated gets lost. See figure B, in A.23, which shows organized lines of similar coloured dots. Applying proximity principle, makes the same information easy for the user to understand. The similar coloured dots in proximity of each other present a connected feel to the user.
- *Consequences of using this principle:* Using the principle of proximity the elements in the design get categorized in chunks with similar functions. This helps the user to get the information which is categorized (based on similarity of functions) in a visual way. This improves the speed of communication of the design.

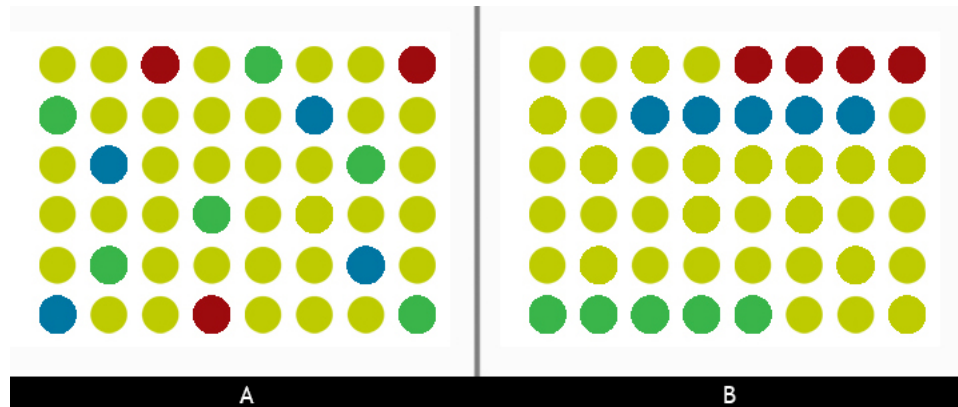


Figure A.23: Proximity principle applied in graphic design

- *Consequences of not using this principle:* Not using the principle of proximity, will have one important negative result: The user would be able to see all the content in the design, but it would be scattered all over the place in the design. It would be the responsibility of the user to go through the entire content, and then categorize it according to its meanings / functions. This will consume time as well as cognitive load on the user.
- *Does this apply to LOs? Yes.*
- *Rationale for above claim:* The users of the LOs are the students, who are expecting to gain more knowledge by interacting with the LO. In this context, it is important to have a design which creates appropriate categories of the elements present in the design.

The design should be able to communicate with the users, in such a way that the information is not presented by the individual elements, but through various categories of the elements having similar functions. It would then be the decision of the user to go through the different categories and get the necessary information. The principle of proximity helps the LO designer to realize this result.

Figure A.24 shows a top panel of an LO. You can see that there are two clear groups shown here. The one on the left is the information group which gives us the details of what is the topic of the LO, what is the domain to which this topic is related to etc. The group on the right has all the sections of this LO aligned together.

This categorization of the elements in the form of groups where the elements are placed in close proximity with each other, provide clear communication to the user about identifying the required information.



Figure A.24: Proximity principle applied in LO design

- *No adaptation is required to apply this principle in LOs.*

A.2.4 Continuation

- *Definition:* Principle of continuation specifies the eye's instinctive action to follow a direction derived from the visual field.
- *Features of this principle:* A design consists of various elements like, shapes, text, colours, images etc. The designer creates the design to communicate a certain message. This message is conveyed correctly, when ALL the elements in the design are aligned in a particular manner or a particular flow of information is followed while placing them. This flow enables the user to read or understand the message in the manner in which designer expects it to be read. The principle of continuation, helps the designer to decide this placement.
- *Implementation of this principle:* The designer first decides the information flow which is required for conveying the message. He/She then uses various options to create this flow in the visual format by placing the appropriate elements. These options are summarized in the table A.1. The details are given after the table.

Details of the type of technique to be used to create continuation	Change applied to an element which the user should see first	Change applied to an element which the user should see last
Using a trajectory or a path as a guideline to place the elements	left most position of the trajectory	rightmost position of the trajectory
Vertical path	Topmost	At the bottom
Scaling	Biggest	Smallest
Colour, contrast	Darkest, Brightest	Lightest, dullest
Combination of trajectory, scale and colour		
Having motion/movement in the elements	More movement within the element	Less/no movement in the element

Table A.1: Options for creating visual flow

- Using a trajectory or a path as a guideline to place the elements Ex: Use an arrow drawn from left end of the design to the right end. Place the elements along the arrow. Place the element which the users have to see first on the left most position of the arrow, and place the element which the users should see the last on the rightmost position of the arrow.
- Vertical trajectory
- Use a hierarchical order of scaling to denote the flow Ex: Make the element to be seen by user first the biggest and make the element which the user should see last, the smallest of all.
- Use a hierarchical order of color intensity to denote the flow Ex: Make the element to be seen by user first the brightest and make the element which the user should see last, the duller of all.
- Combining scale, colour and path together: Movement within the element
- *Example in graphic design:* In the figure A.25, the three straight lines of dots are shown in the right side. The fourth line has the dots arranged in a curve which takes the eye movement to the dark dot. This placing of dots in continuation, makes it easy for the user to reach to the destination which the designer has envisioned.

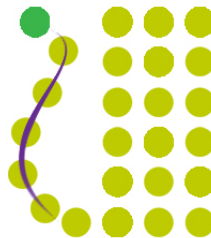


Figure A.25: Continuity principle applied in graphic design

- *Consequences of using this principle:* The goal of every design is to communicate the message as planned by the designer. One important aspect of the message is the flow of information which the designer plans for the design in order to communicate the message in the best possible manner. By applying the principle of continuation, the message is communicated with a flow that the designer has thought of. Application of this principle provides a direction in the visual so that the eye follows it.
- *Consequences of not using this principle:* If the principle of continuation is not used, then the design will have multiple elements which are trying to convey the

message, but a continuity would be missing from it. The message may be read by the user in a staggered manner, which creates a chaos.

- *Does this apply to LOs? Yes.*
- *Rationale for above claim:* The users of the LOs are the students, who are expecting to gain more knowledge by interacting with the LO. In this context, it is important to have a design which has a flow of information which is decided by the designer of the LO. This flow can be achieved by using the principle of continuation.

A.2.5 Unity

- *Definition:* Unity is a measure of how the elements of a page seem to fit together - to belong together. A unified work of art represents first a whole, then the sum of its parts.
- *Features of this principle:* Unity principle gives a visual effect of all the components being from the same family. All the elements in the design communicate one single message. These principles enable individual elements in conveying a collective message, rather than individual messages.
- *Implementation of this principle:* All the elements in the design are perceived not as parts of the design, but one single unit, if they have common attributes. The designer first studies the different attributes of the various components. Then the common attributes are listed, and these attributes are then aligned so that the user can see the similar attributes of the various elements in the design. This gives an effect of harmonious visual.
- *Example in graphic design:* The design has a pattern of squares and circles (see figure A.26). The squares are arranged in a manner that it forms a cross or a plus sign.

The squares are used exactly like the circles. They have the same dimensions, distance between the two, and colour. The unified shape of the all the squares present in the design is conveying a single message, but without standing out too much from the rest. So in short, at a glance the user can see a light green patch with some circles and squares, but after watching carefully, the cross is evident.

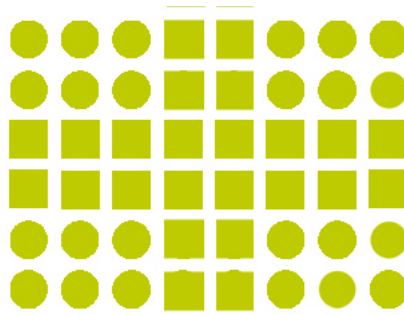


Figure A.26: Unity principle applied in graphic design

- *Consequences of using this principle:* Application of the principle of unity helps in achieving the following goals:
 - Even though the design has different components, they present a unified message.
 - There is a harmony amongst all the components of the design.
 - As the design is able to communicate a unified message, the user is clear as to what is to be seen in the design.
 - It is important, particularly in cases when there is a series of messages planned, with a similar message. The unity in a design can be easily adapted for the subsequent designs to achieve the continuity of the message.
- *Consequences of not using this principle:* Not applying these principles results in a disjointed design. All the elements communicate individual messages, thereby confusing the users. Not using the principle of unity may have a confusion created in the minds of the user. The components of the design may be communicating a different message each, so the user may get confused because of the diversity of the messages.
- *Does this apply to LOs? Yes.*
- *Rationale for above claim:* In a LO design, the user is expecting to get detailed information about a chosen topic with details. While getting this information, the user should be able to focus on the information, and not get disturbed by the other content on the LO screen. Principle of unity, describes the ways in which the content (though diverse) should be conveyed on the screen, so that the user gets the message.
- *Illustrative example in LO context:* The three screen-shots shown in figures A.27, are from two different LOs. The principle of unity is applied in these LO screen designs in multiple ways.

- Tabs for selection as shown in all the screen shots have a colour which is not the same as other colours present in the screen, but is in harmony with them.
- The size of the tabs is different in the all screens, but when we see all the tabs/buttons, we can make out that they ALL are from a same LO/subject domain/repository.
- The second or third level of tabs differs in colour, but still is in harmony with the overall design.

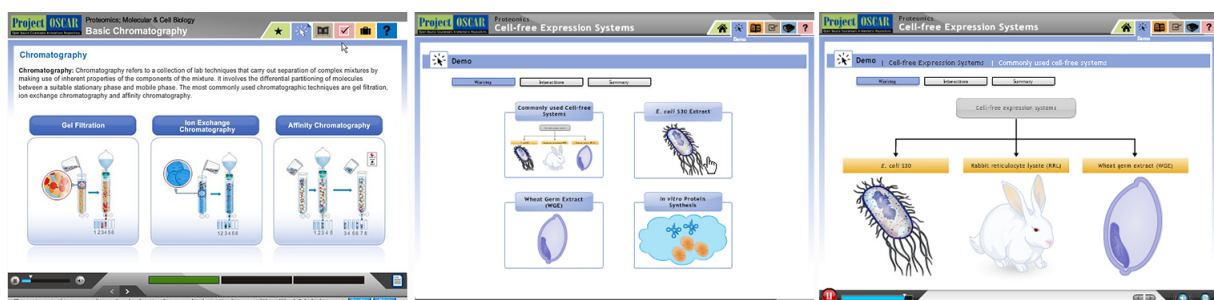


Figure A.27: Unity principle applied in LO design

- *No adaptation is required to apply this principle in LOs.*

A.2.6 Similarity

- *Definition:* Similar objects will be counted as the same group and this technique can be used to draw a viewer's attention.
- *Features of this principle:* This principle is mainly useful in maintaining the uniformity in a series of designs, based on a single topic. Similarity principle applied for these images makes it easy for the user to understand that ALL these images belong to one topic.
- *Implementation of this principle:* The designer first identifies the components with similar attributes from the overall list of the components of the design. These components are given suitable design treatment. Care is taken to have similarity in terms of various elements of the components like shape, colour, texture, etc. This makes the components have an identity, as the similar ones have the same visual treatment.
- *Example in graphic design:* Figure A.28, shows the way in which similarity principle can be applied in graphic design. The one on the top shows similarity applied by shape, and the one below is based on similarity applied using colour. The similar shapes, arranged in a specific order, make the user aware of the

difference in the shapes of the rows quite distinct. In the second image, even if the shapes are the same, the way in which they are arranged has a particular reason, which is the colour. This arrangement, which is based on colour, conveys the message to the user, that there are 4 lines with a similar colour pattern. This pattern could be horizontal or vertical.

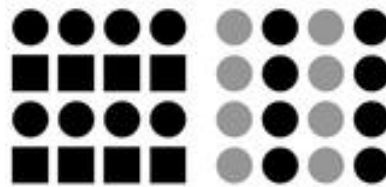


Figure A.28: Similarity principle applied in graphic design

- *Consequences of using this principle:* In a design, the message has multiple elements. It is therefore important to communicate the right message without creating a chaos for the user. In this effort, principle of similarity helps the designer to find the elements with similar attributes, to be displayed in a similar form. This helps in creating a design, which has groups with defined attributes.
- *Consequences of not using this principle:* If similarity principle is not used, then the elements may be having a unique attribute for each. This will create a chaotic image as a whole.
- *Does this apply to LOs? Yes.*
- *Rationale for above claim:* As seen in the options A.29 and A.30 content is of varied type, and is depicted in different forms. The similarity principle is used to display the information in these examples. In option 1 (figure A.29), attributes like volume, weights etc along with their numerical values are to be displayed. The LO designer has a type of visual depiction (a gray box) to display the values, as they are not constant (they can change). The attributes are shown outside, (as plain text) as they are constant. This makes it easy for the user, in case he/she changes the settings and has different values, and then he/she has to only look for the gray boxes for the changed values.

In option 2 (figure A.30), the LO content has mathematical formulas to be displayed. Here again, like option 1, the designer has used a box every time a formula has to be displayed. This helps the user to locate the formulas. The visual treatment given to other components is also similar (if the components are similar).

OUTPUT	Core	Core Print	
Volume	0.000058	0.000192	m ³
	0.000254	0.000201	m ³
Weight	5.78	18.88	N
	24.97	19.73	N
Weight of cores	30.75	38.61	N
Total Weight	69.37		N
Buoyancy force	15.95		N

Net Downward Force	53.41	N
Cross sectional Area	0.001964	m ²
	0.006364	m ²
Net Compressive stress on the mould	27193.32	N/m ²
Check for crushing	Withstands the load	
Safe condition	safe	

Figure A.29: Similarity principle applied in LO design , Option 1

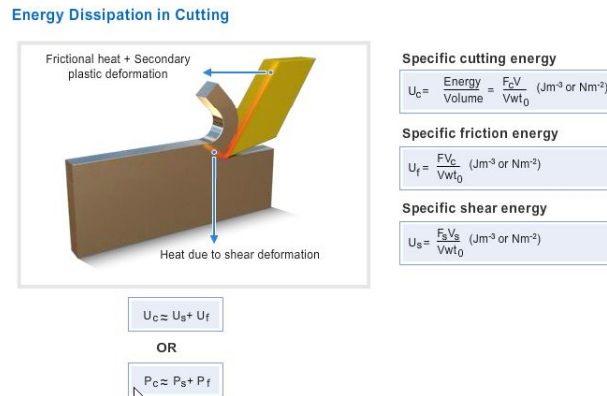


Figure A.30: Similarity principle applied in LO design, Option 2

- *No adaptation is required to apply this principle in LOs.*

A.2.7 Balance and Symmetry

- *Definitions:*

- A visual object will appear as incomplete if the visual object is not balance
- A psychological sense of equilibrium, or balance, is usually achieved when visual ‘weight’ is placed evenly on each side of an axis

- *Features of this principle:* A design is viewed by the user in totality. All the elements placed in a design have visual weights. The design is divided by an imaginary line known as axis. Uneven distribution of the visual weights on both the sides of the axis makes the user unable to get the message the designer is trying to convey. Principle of balance and symmetry enables the designer to analyse the visual weight of each element, create the axis of the design and place the elements in the design. This eventually helps in conveying the message of the designer correctly to the user.

- *Implementation of this principle:* A design has an imaginary line / axis which divide the design in two equal parts. Every element in the design has some visual weight. To achieve balance in a design, the designer places the elements in the

design in a way that the visual weight of the elements on both the sides of the axis should be equal. Some examples of distribution of the visual weight are given below:

- Based on area occupied: Every element in the design occupies certain area. As a thumb rule, the elements covering more area are considered to have more visual weight.
- Based on the colour: Every element in a design has certain colour. Dark colour (like black/blue/violet etc) have more visual weight as compared to lighter colours (white, yellow, orange, etc)
- Based on area occupied and the colour: Combining the two definitions mentioned above there are situations where a large element shown in a light cream may have less weight as compared to an element occupying medium size having a dark colour. There are other attributes which also change this equation like: texture, pattern etc.
- *Example in graphic design:* In the example shown (see figure A.31), sea green or sap green coloured circles are arranged in a specific way. If the graphic is divided in two parts by an axis (shown in red colour) the number of circles (of both the colours) on either side is same. Additionally the placement of the circles is also exactly the same (but in mirrored way). This is called as a balanced or a symmetrical design.

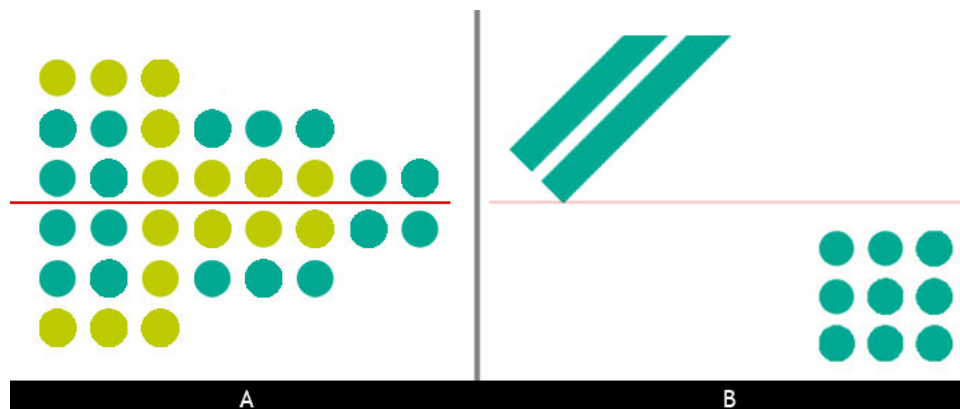


Figure A.31: Balance principle applied in graphic design

In the figure B of A.31), the elements shown on the either sides of the visual axis are different in shapes and sizes, but still the visual weight is managed to be equal.

This is achieved by using size, colour, and empty space around the element. The two horizontal lines are used to balance the 9 circles. To achieve the balance

in these diverse types of elements, the designer has the circles placed in the top right corner, and the lines at the bottom left. The circles are arranged in a uniform pattern equidistant from each other, to form a square. The Lines too are equidistant from each other, on the longer side. The length of the lines is longer than the square formed with the circle, as it has lesser width.

Balance can be achieved in the design using various types of placements, symmetrical or asymmetrical . It can also be achieved using various combinations of colour, contrast and textures for the components used in the design. The two examples given above are representative in nature. Many more variations are possible.

- *Consequences of using this principle:* Use of the principle of balance makes the design evenly distributed along the visual axis. This makes visibility of ALL the elements possible, as there is no single element which stands out in a manner that the user is forced to see ONLY that element and neglect others. It also makes the hierarchy of visuals possible, as the user is forced to look at a component, and then look at the corresponding or complementing component/s.
- *Consequences of not using this principle:* A design, where the principle of balance and symmetry is not used may contain some elements which are placed at such positions in the design that they can be unnoticed by the users. There can also be situations where a part of the design is not seen by the user. This is not a ideal situation, as the designer should create a design where ALL the elements placed in the design should be seen by the user, so that the message is complete.
- *Does this apply to LOs? Yes.*
- *Rationale for above claim:* Balance, lends an important aspect to the LO design, and that is regarding the visual hierarchy. With balance the design has a advantage of guiding the user's eye in a hierarchy as envisaged by the LO designer.
- *Illustrative example in LO context:* In figure A of A.32, the LO design is created mostly using the symmetrical layout. Most of the elements in the design have been placed on the either sides of the axis, such that the visual weight of the two sides is similar. Exact division of the weight is not possible, as the length of the words, number of components etc on the either sides may differ. But the designer has taken enough care to make it almost equal.

For example, the text (which is the title of the process) is blue, and placed in the center, the two graphs are also centralized, and placed below one another. The

text surrounding graphs is also placed in a manner, that it is similar in terms of the visual weight on the either sides.

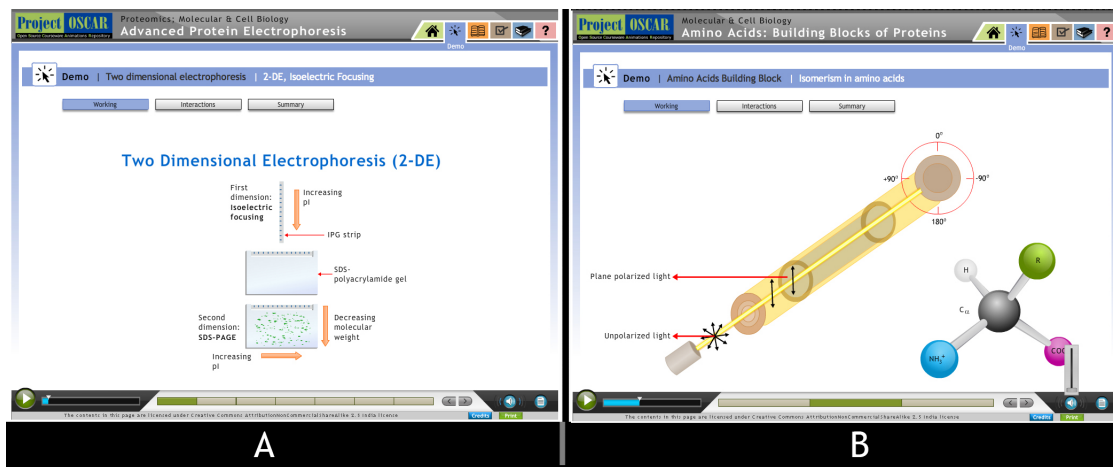


Figure A.32: Balance principle applied in LO design-symmetrical

In figure B of A.32, the LO design has components placed on screen in a asymmetrical manner, but still satisfies the principle of balance. The main (yellow) graphic is placed in the center, but is tilted, to maintain the balance. The text on the left is shown using bold red arrows, to balance the colorful atom structure shown in the right bottom corner.

- *No adaptation is required to apply this principle in LOs.*

A.3 Adaptation of Interaction design principles

For the domain of interaction design (IxD), the notes have been taken from the book titled, 'Interaction design' to list out the principles mentioned in it (Sharp et al., 2003). Most of the principles are in the form of guidelines. Principles are selected for adaptation, which have a role to play in the LO creation process. Justification of the decision to include or leave the principles in the LO creation process is given along with the discussion on each principle.



Figure A.33: Example showing application of Visibility principle for a car dashboard

- *Steps for applying visibility principle:* Make a detailed list of all the controls and options possible to be given to the user. Out of the overall list of the controls:
 - Select the list of controls which 'have to be accessed by the user while performing the primary action'.
 - Position them in such a way, that these controls are easy for the user to find.
 - Keep all the other controls in such a place that they are *not visible* to the user while performing the primary task. The other controls (mentioned above) should be seen, only based on their suitability of the context.
- *Is visibility principle required in LO creation?* **Yes.**
- *Justification for applying visibility principle in LO creation:*
 - Based on the same context of user may use an LO in isolation, it is also important that user 'does not see' the unwanted options (especially in teaching learning scenario, example: hints should not be shown at stage 1).
 - LOs could also be used by the user in isolation, so it is important that the 'possibilities' should be visible to the user, and also accessible.

- *Example of visibility principle applied in LO creation:* The examples shown in Figures A and B of A.34 are about a LO which is low on interactivity. Figure A shows the LO in which has a animation being played. The green strips below are the chunks of video, which would be played in order. In the scenario shown in Figure B, the information displayed on screen is enough for the user to see and interact with the LO. This is an example of good application of the visibility principle.

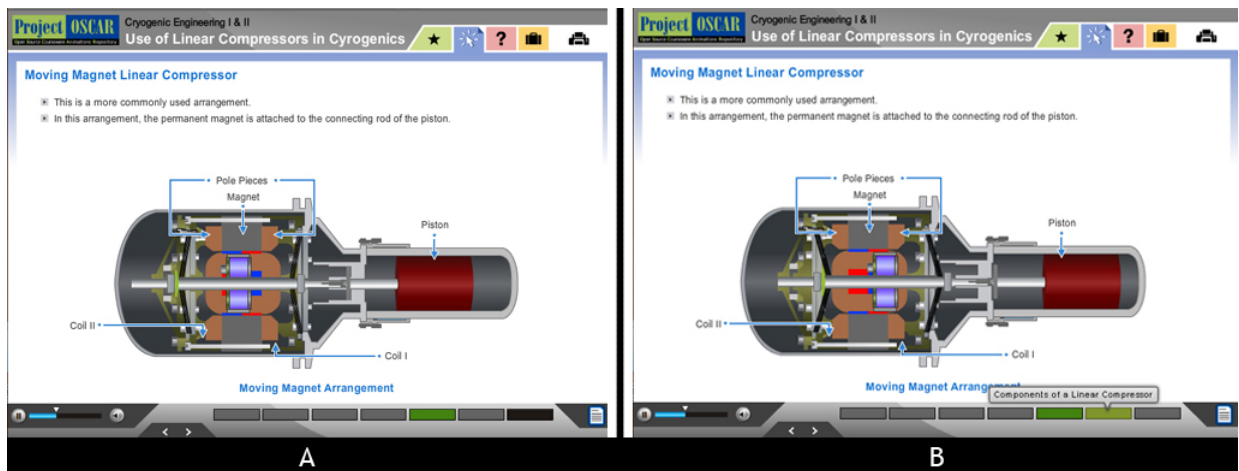


Figure A.34: Example showing application of Visibility principle in LO design

Further, if the viewer is interested or curious to know what is the topic of the next video segment, then this information is also to be provided. But it should be provided only when the user demands it. Information of this nature should not be displayed on the screen all the time and confuse the user. So the designer has used the technology innovation provided in the software to create an option called as: mouse hover action (see figure B of A.34).

This information is visible ONLY when the user ‘hovers’ the mouse over the green strips (video segments). It is NOT shown all the time, as it will be cluttering the screen with a lot of text, which is not ‘required’ at that particular point. Using visibility principle helps the user to get a uncluttered view of the animation running, and an option to access other information, ‘whenever’ it is required.

Steps for applying visibility principle in LO creation The process resembles a lot with the process of applying IxD in any other domain, although some adaptation is done:

- Use the IDD for identifying the controls which are prescribed (by the SME and the ID writer) as ‘necessary’ for the user.
- Place/Display the controls using graphic design principles mentioned in section A.2

- Visibility requirements which are dependent on user interaction can be planned using graphic design, but would require knowledge of technology innovations in order to implement.

A.3.1 Feedback

- *Definition:* Displaying information to the user about what action has been taken, and what has been accomplished for the input he/she provided.
- *Features:* Applying feedback principle will enable the user to take a decision on continuing/changing the strategy of interaction. Note: Using feedback in a right way can also provide the necessary visibility for user interaction.
- *Example of application of the feedback principle:* There are a number of examples in our day-to-day life, about the application of feedback principle. Almost every object we interact with, provides us feedback. Ex. a switch pressed starts the glowing of the corresponding bulb. The feedback enables us to continue or terminate the action we are performing. In cases where there is late or no feedback, the user is not fully confident about continuation of the action. For example, if the bulb does not glow, after pressing the switch, the user re-looks at his/her decisions like: have I pressed the right button, is the filament in the bulb working, is the power supply in the house working? and many other questions.

An example of late and instant feedback is a photography camera (figure A.35). Earlier when camera used celluloid film rolls for taking pictures. The photographer used to see the scene from the viewfinder, and click the button. This transferred the picture on to the film roll inside the camera. The important point is that the user (photographer) is not able to see what he/she clicked unless the roll is given in a lab, and a print is obtained. The time lag was so much, that often the photographer used to miss out on the expected results.

Currently with the digital cameras, the user is able to see the picture he/she has clicked, instantly after clicking it (Figure A.35). This makes photographer take a decision, then and there about re-clicking the image. This is an advantage because of the feedback principle applied in the camera.

- *Steps for implementing feedback principle* In IxD there are types of feedback which are used to communicate the results back to the user. They are: Audio, Tactile, Verbal, Visual, and combination of these. Examples of these could be as follows:



Figure A.35: SLR cameras with and without instant feedback option

- Audio feedback: A beep sound continues till the user shuts all the doors of a car. If a door is open or not closed correctly, the car gives a feedback to the user. The feedback is important from safety point of view, that after all the doors are closed correctly, the beep stops.

Similarly in a software if an incorrect action is performed by the user, the software not only gives a error message on the screen, but also a audio feedback (this can be customised: from a bang sound to a normal beep) to alert the user about the mistake/error.

- Tactile feedback: Continuing with the example of an old SLR camera, a tactile feedback is generated in a scenario of the camera roll getting over. The user is unable to click a new picture, or to forward a frame. No other action can be performed with the camera except for a small button at the base, which can be pressed. This opens the lock and the user is able to rewind the roll in the camera. If the tactile feedback is not applied in the design, the users may keep on clicking the pictures, without getting the feedback that the roll is over.

In a software, in continuation with the error message example discussed in the audio feedback, tactile feedback is also added. The error message displayed in a window has options to select. The software denies access to its other menus, before the user selects one of the options presented in the pop up screen. The screen of other menus of the software can be seen, but cannot be accessed by the user.

The examples discussed above are representative of combination of feedback options like audio, tactile and visual. Apart from these types, one more

option is to use rich visual modeless feedback (RVMF). Details of this are given in the end. Example of this is a alert shown in the in-box of the mail client. Here, without disturbing the work flow of the user the application gives the information that a new message has arrived. The user then can use his/her description to see the message. See figure A.36 showing the screen capture of RVMF.



Figure A.36: Example showing application of rich visual modeless feedback(RVMF)

In order to apply feedback principle in your object/product:

- It is important to know the function of the object/product. This will help in determining the feedback required by the user in order to stop, change or continue the action. Based on this,
 - Provide consistent and clear markings
 - Use animation consciously and sparingly.
- *Is feedback principle required in LO creation? Yes.*
 - *Justification for applying feedback principle in LO creation process:* Based on the pedagogical strategy, feedback would be playing an important role. (ex: constructive or guided discovery strategy of pedagogy would benefit from using appropriately designed feedback, so that the user can easily interact with the LO).
 - *Example of feedback principle applied in a LO:* In a LO, the feedback is required to be given to the user in various sections. The user is expected to use it on his/her own, so feedback becomes really important in order to channelize the exploration of the user. One such example is from the assessment section, where feedback is necessary for the user to know about the correct/incorrect answers. Figure A.37 has a screenshot of a scenario from assessment section. The answer given by the user is incorrect, so along with a audio feedback, there is a visual feedback shown on screen. Colour convention of red for wrong and green for right is used along with the conventional symbols of tick mark and a cross. Along with this, an explanation is also provided in a box below titled feedback. This not

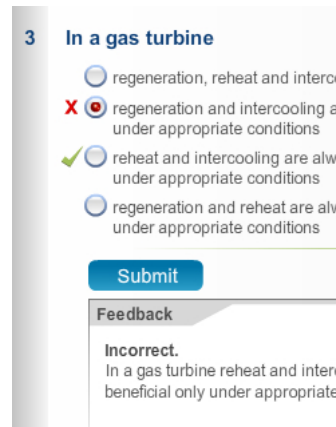


Figure A.37: Example showing of feedback in LO design

only gives the feedback about the answer being correct or incorrect, but also a justification and reason for the right answer.

- *Steps for applying feedback principle in LO creation:* Similar as explained earlier. For applying the RVMF, consider the following steps:
 - Use the same visual design principles when considering RVMF as with other forms of interface design.
 - Use visual hierarchy to insure that the critical RVMF data stands out on the screen.
 - Use more than just color as a vector to represent RVMF.
 - Use color consistently and meaningfully to represent status and create a learnable color system (the Yahoo! Finance example utilizes commonly accepted color codes to represent direction).

A.3.2 Constraints

- *Definition:* Determining the ways of restricting the kind of user interaction that can take place at a given moment. There are three types of constraints. They are:
 - Physical: Inserting a USB disc drive (only one way to insert)
 - Logical: Menu items which cannot be accessed even if they can be seen (greyed out), and
 - Cultural: Red colour for danger, Smiley icon for happiness etc.
- *Features:* Principle of constraints helps the user to use the product in a way that he/she is planning to use. This principle, blocks the other (or undesired) options

of the product, so that the user gets the message, and uses it in the desired way only.

- *Example of application of the constraints principle* In the example given below, a VGA connector used for connecting displays is shown in Figure A.38. The design of the connector is done in such a way that it can fit in to its counterpart only in one way...The 15 pins present will be inserted in the 15 holes available..but that will coincide, only if the outer rim matches.



Figure A.38: Example showing constraints principle in product design

In the example 2 (see figure A.39), even though the sockets look the same, and the connector which can be inserted inside is also the same, they are meant for separate purposes. Please note that the same connector can go inside all the three. The basis of the classification is the use of coloured rings around the socket. These rings help the user identify the correct socket, to insert the appropriate connector.

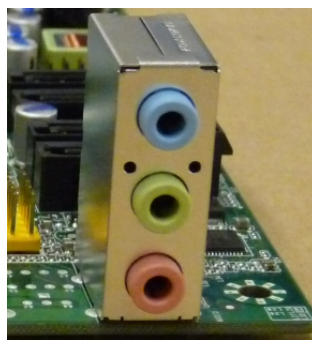


Figure A.39: Example showing constraints principle not applied in product design

- *Steps for implementing the principle of constraints* Specific way in which the types of constraints are applied:
 - Physical: Constrained by the shape and size, so that inserting is possible only in one way.

- Logical: Users understanding of a particular thing works. Depends on the common sense of the user.
 - Cultural: Rely on learned conventions.
- *Is constraints principle required in LO creation? Yes.*
 - *Justification for applying feedback principle in LO creation process:*
 - Physical: Not required in eLearning, as it is mainly based on the size and shape of the product. In terms of LOs we are referring to, the content would be mainly in the form of a computer based application so this would not apply.
 - Logical: Required in eLearning. Disabling menu items is a good way from managing the flow of events of the user.
 - Cultural: Not required in eLearning, as the LOs created would be based on some of the universal conventions, and not specifically about the local/regional conventions.
 - *Example of constraints principle applied in a LO:* Out of the three types of constraints mentioned earlier, logical constraints are most useful in LO design. Figure A.40 shows disabling of menu items which are not required at a particular stage. Some options are shown in grey colour, and the user is unable to select them. These options are the ones which cannot be performed at that particular instance in the work flow of the software.

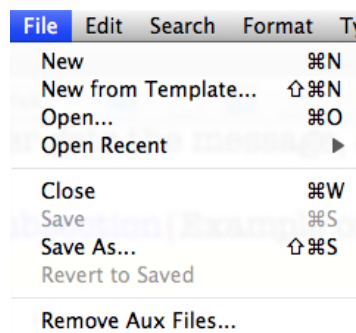


Figure A.40: Example showing logical constraints principle applied in LO design

These are shown grey in colour or disabled. This is done in such a way that the user can see it (as a consistency principle) but will not be able to perform that action, as it is not possible at the particular instance.

- *Steps for applying mapping principle in LO creation:* Common practice in screen design is to deactivate certain (which are not to be used by the user at

that given point of time) menu options by shading them. These options are not hidden (unlike the principle of visibility) but are shown in a way that the user feels that they are inactive. This restricts the user to perform the actions, only which are active.

A.3.3 Mapping

- *Definitions:* Relationship between controls and their effects in the world.
- *Features:* Placing buttons based on the common convention (Left to Right, Right to Left and Top to Bottom) of the sequence of buttons, where the configuration maps directly to the directionality of the actions
- *Example of application of the mapping principle:* The example given is of the volume control buttons of a mobile phone. These buttons are typically placed on the sides of the mobile. There are two buttons, one for increasing the volume and the other for reducing it. The designers use the convention of 'up' for increase and 'down' for decrease. In this manner, even if the user never looks at the button (if they have an engraving of '+' and '-') but can operate them and get the desired results. This happens due to the correct mapping of the convention in the design.

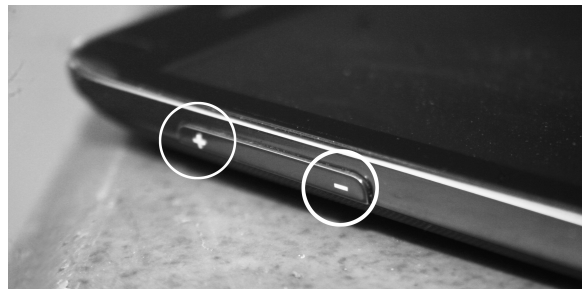


Figure A.41: Mapping principle applied for creating volume controls in a mobile phone

- *Steps for applying the mapping principle:*
 - Study the IDD, and see if there is a mapping (directional or logical) required in any of the elements.
 - Then apply the conventions (as per the regional/cultural background) create the controls.
- *Is mapping principle required in the LO creation? Yes.*

- *Justification for applying mapping principle in LO creation:* Principle of mapping is required in LO creation process, because especially in eLearning, the user (who is mostly the student using the LO in isolation) should not be wasting their time in finding out the relationship between the controls and the results. The intuitiveness of this relationship would make the user navigate and use the LO with ease. This will help reduction of the cognitive load for the user, and then the student can concentrate on learning of the concept.

A.3.4 Affordance

- *Definitions:* Here are two definitions of affordance:
 - Definition by Paul Seys: ‘Affordance is the quality of an object that allows an individual to perform an action’
 - ‘Affordance is a term used to refer to an attribute of an object that allows people to know how to use it’, (Sharp et al., 2003).

In short the physical properties and the appearance of an object should suggest and in some cases compel the user to use it in exactly the manner it has to be. In the context of user interfaces, affordance can be achieved by simulating ‘physical world’ affordances e.g. buttons or switches. Here the user relates to the action of click/press to use it. The other options are derived by the user interface elements like underlined texts (as links) or default button styles.

- *Features:* Principle of affordance, if applied correctly, compels to user to use the product for the reason it is designed for. For example a switch which is designed to be pressed, and in turn it starts the bulb, or a ceiling fan which speeds up if the regulator is turned clockwise. It also helps the user to differentiate between the various psycho-motor skills for getting respective outcomes.
- *Example of application of the affordance principle:* Figure A.42 shows various affordances. The handle of the cupboard expects us to use the entire palm. A pair of scissors having handles of unequal sizes suggest the use of the thumb (which requires lesser space) and other fingers (which require more space) so the user can use it. Other scissors expect one finger each to be used for the two handles. Any other combination of the fingers may not allow the user to perform and produce best possible results.
- *Is affordance principle required in the LO creation? Yes.*

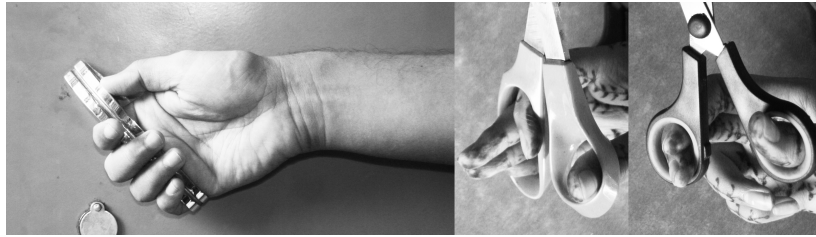


Figure A.42: Affordance principle used in product designing

- *Justification for applying affordance principle in LO creation:* In LO design, the user is expected to use it without the support of anybody else. This means that the elements in the LO design should suggest the exact action, as expected by the designer+SME. In order to fulfill this, the affordance principle is useful in LO design. I would like to elaborate this using an example.
- *Example of affordance principle in LO design:* The figures A.43 and A.44 show examples of 2 types of buttons. Figure A.43 shows a button which looks like a flat (2D) plain box with an outline and a symbol of 'Pause' on it. Figure A.44 shows a round button (3D) with the similar symbol.



Figure A.43: Affordance principle applied in the design of a button



Figure A.44: Affordance principle applied in the design of a button for an LO

Out of the two, the second one suggests the user to 'click' more convincingly as compared to the first one. This is application of affordance, where the design suggests the user to perform the action, which is expected.

A.4 Adaptation of Multimedia principles

Multimedia principles have been researched by various authors. They include, Ruth Clark (Clark & Mayer, 2011), Brown and Voltz (Brown & Voltz, 2005), (Mayer, 2005) and others.

In the book by Clark and Mayer, the authors have given multiple case studies, where the principles are applied and the user tests are conducted. Every principle is studied in detail, by having a good sample size and applying it in multiple scenarios.

These principles and the details of the studies reported in the book are explained below. Summary of these experiments is given at the end of this section in table shown at the end of this appendix.

A.4.1 Multimedia principle

- *Definition: People learn better from words and pictures than from words alone.* In other words, the principle recommends using words and graphics rather than words alone.
- *Brief outline of studies conducted:* The studies are conducted for two types of content, one which has only narration and other where animation is supported by narration.
- *Case study:* Post test results show that samples using animation + narration score better than the group which use the intervention having narration only. The study documents 11 different experiments. In all the experiments, the scores of the animation + narration group are found more than the group using just narration by 89%. The results are significant, since the effect size reported is 1.50.

A.4.2 Contiguity principle

- *Definition: Students understand an explanation better when corresponding words and pictures are presented at the same time than when they are separated in time.*
- *Brief outline of studies conducted:* The researchers conducted studies for this principle for two separate cases. Few studies are done for printed material, while few more are conducted for video content.
 1. *Case study 1:* In this study, experiments are conducted on two groups. One having content with integrated text and graphics and the other group had

content where text and graphics separated. Post test results of five such experiments, reveal that Integrated group scored better than the group which had text and graphics separated. These results are found significant with an effect size of 1.12.

2. *Case study 2:* In another study, the two groups have audio-video content. One has asynchronous audio for the graphics presented on screen and the other has synchronous audio for the same graphics presented. Post test results reveal that the group having synchronous audio score better than the group having asynchronous audio. Four such experiments are conducted and the results have an effect size of 1.00.

A.4.3 Modality principle

- *Definition:* Words should be presented in an audio format rather than typed text, wherever possible. Present words as speech, rather than text.
- *Brief outline of studies conducted:* The studies for this principle are conducted for two types of content. One type had the print medium with printed text and graphics, while other has multimedia graphics with supportive narration.
- *Case studies:* In these studies, the groups using content with printed text + Graphics scored better than other group having the content with narration + graphics. Post test results (of twenty one such studies) reveal that the group having synchronous audio score better than the groups having asynchronous audio. The results are found significant with an effect size of 0.97.

A.4.4 Redundancy principle

- *Definition:* People learn better from animation and narration than from animation, narration, and on on-screen text. In short the principle suggests to explain visuals with words in audio or text, NOT in both. Avoid repetition of communication (in different mediums) to avoid confusion of the users.
- *Brief outline of studies conducted:* The studies for this principle are based on the content with and without redundant text on screen. The two groups have two types of content. One with required animation and corresponding narration. The other group gets content having redundant animation and the corresponding narration.

- *Case studies:* Post test results (of three such studies) reveal that the group having non-redundant animation and narration scored better than the group which had redundant animation and narration. The results (for the three experiments) are significant with an effect size of 1.00, 0.80 and 1.00.

A.4.5 Coherence principle

- *Definition:* People learn better when extraneous words, pictures, and sounds are excluded rather than included. In short, the principle suggests that adding extraneous material (of any type) can hurt learning.
- *Brief outline of studies conducted* The studies for this principle were conducted for two types of content. One type had content without any extra elements, except the necessary ones. The other was the content having extraneous images, graphics, sounds or music.
- *Case studies:* Post test results (of three such studies) reveal that the group not having extraneous elements score better than the groups which has the extraneous elements. The group having no extraneous music and sound shows an increase of 105%, as compared to the results of the group having extraneous elements. The results are significant, with an effect size of 1.66, 0.86 and 1.00 respectively (for the three experiments).

Multimedia principles and the studies conducted (Mayer and Clark)

Name of the principle	Details	Brief outline of the research study	Groups	Results	Number of experiments / tests conducted (if available)	Performance score (range)	Median of the score (more performance by a group)	Effect size
Multimedia principle People learn better from words and pictures than from words alone. Use words and graphics rather than words alone			Animation + Narration	Animation + Narration group scored better	11	55-121	89% Animation + Narration group	1.50
		Changing static visuals to animation	Computer group	Paper group scored better	--		32% Paper group	0.55
		Changing static visuals to animation	Computer group	Paper group scored better	4		--	0.57
Contiguity principle Students better understand an explanation when corresponding words and pictures are presented at the same time than when they are separated in time								
	Part 1: Place printed words near corresponding text	Text is placed near the corresponding image	Integrated group Text+Graphics separated	Integrated group scored better	5	43-89	68% Integrated group	1.12
	Part 2: Presenting speech and graphics at the same time		Asynchronous audio	Integrated group scored better	4	--	50% Integrated group	1.00
Modality principle Present words as speech, rather than text		Explanation. Interactive games, Virtual reality based training			8		60% Integrated group	1.30
			Printed text + Graphics	Narration + Graphics group scored better	4	--	20%	1.00
					21	--	--	0.97
					43	--	--	0.72

Name of the principle	Details	Brief outline of the research study	Groups	Results	Number of experiments / tests conducted (if available)	Performance score (range)	Median of the score performance by a group)	Effect size
Redundancy principle: People learn better from animation and narration than from animation, narration, and on-screen text. Explain visuals with words in audio or text...NOT in both		Omitting redundant on screen text	Non-redundant Animation + Narration Redundant Animation + Narration + Text	Non-redundant group scored better	3	43-69		1.00
					1			0.80
		Text after narration			1			1.00
		Including redundant on screen text	Spoken words + text	--- group scored better	3		3 times more	0.80
			Spoken words + animation	--- group scored better			79% Spoken text + animation	
Coherence principle: People learn better when extraneous words, pictures, and sounds are excluded rather than included. Adding extraneous material can hurt learning	Adding extraneous music	Process of lightening formation, Hydraulic brakes				20-69		
	Adding extraneous environmental sounds							
	Removing both extraneous music and sounds					61-149	105% Removed music and sound	1.66
	Adding extraneous graphics		Animation + extraneous video	Animation only group scored better			30% Animation only	0.86
			Text + Illustrations + Other related colour photos	Text + Illustrations group scored better			52% Text + Illustrations	1.00

Appendices

Appendix A

Sample instructional template (IDT3)

INSTRUCTIONS SLIDE: DO NO EDIT

ID template 3.0

for creating learning objects

Created by OSCAR team



October 2011

INSTRUCTIONS SLIDE: DO NO EDIT


Welcome

This is a document to explain the chosen concept to the animator.

Since the animator may not be aware of the subject matter, write elaborately and provide images wherever possible

This document has sections which will provide the necessary details to the animator before starting the animation.

The slides with yellow background (like this one) are the 'Instruction slides'. Read these slides to understand the section.

The slides having Blue background  (like the one shown) are the 'Guidelines slides' These slides would be helpful in writing the sections.

INSTRUCTIONS SLIDE: DO NO EDIT

Information section

Next few slides are about the necessary information regarding the concept.

Write the information by clicking on the headings provided in the slides.

You can add more slides, incase the information is not fitting in the given slide.

Avoid changing fonts, colours and font sizes, unless it is really critical (ex: make text bold if you want the readers to pay attention to that word)



Title of the animation

Brief description of the animation (1 or 2 sentences)

Related LOs:

- Prior Viewing:
- Future Viewing:

Course Name:

Level(UG/PG):

Author(s) :

Mentor(s):



Learning objectives

- After interacting with this Learning Object, the learner will be able to:
 - (objective 1)
 - (objective 2)

INSTRUCTIONS SLIDE: DO NO EDIT

Assembly Diagram providing visual information

It is important for the animator to get a visual idea about the components in the LO. Therefore, provide visuals of ALL the components in the concept.

This section has two important aspects:

- information about visuals in the LO
 - placement information of those visuals
- Create visuals in the slides titled 'Diagrams' wherein show a detailed images of the components (See example slide). Number the diagrams
 - Use **BOLD lines** in the diagram (minimum 2pts.). In the images, identify and label different parts of the components.
 - Illustrate the basic flow of action using arrows.
 - In the slide after that, provide the definitions of **ALL** the labels used in the diagram. (See the example)
 - You may have multiple diagrams. In this case, number them as Assembly Diagram 1, 2, 3...Create multiple slides for these

Guidelines slide

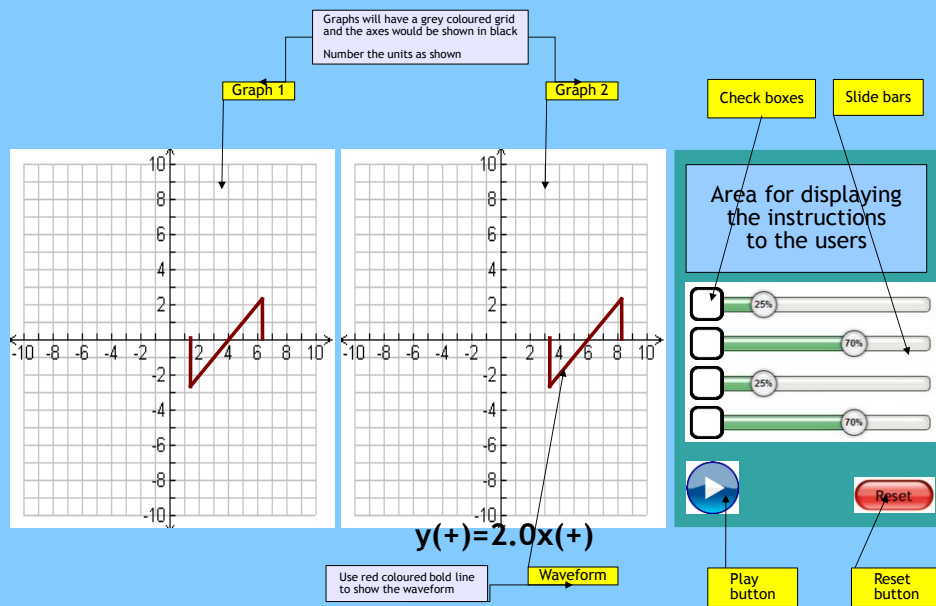
Creating a diagram

- Create a schematic diagram of the assembly used in the experiment
- Initially, use shapes to denote the components in case you don't have the actual images.
- Instruct the animator to recreate the images, if you haven't provided, or if the ones you have used are copyrighted. Provide suggestive links/hand drawn sketches of the images
- Show the flow of action using bold and coloured arrows.
- Make new diagram, every time the components change
- Add unique labels to each component, and place the label near it. Use an arrow to show the association between the component and the label
- Be consistent in the labels used. Do not change the label names for the same component in various diagrams
- Provide definitions for ALL the labels used in the diagram in the slide after the diagram

GUIDELINES FOR AUTHORS OF LEARNING OBJECTS
RACHEL S. SMITH

Example of Diagram slide

Assembly Diagram 1: Single transformation



GUIDELINES FOR AUTHORS OF LEARNING OBJECTS
RACHEL S. SMITH

Example of Definitions of the labels

Diagram 1: Graph

Definitions of the labels used in Diagram 1:

Graph: Graph is a diagram showing the relation between the two quantities, typically of two variables, each measured along one of a pair of axes at right angles

Waveform: It is a curve showing the shape of a wave at a given time

Check boxes:

Slide bars:

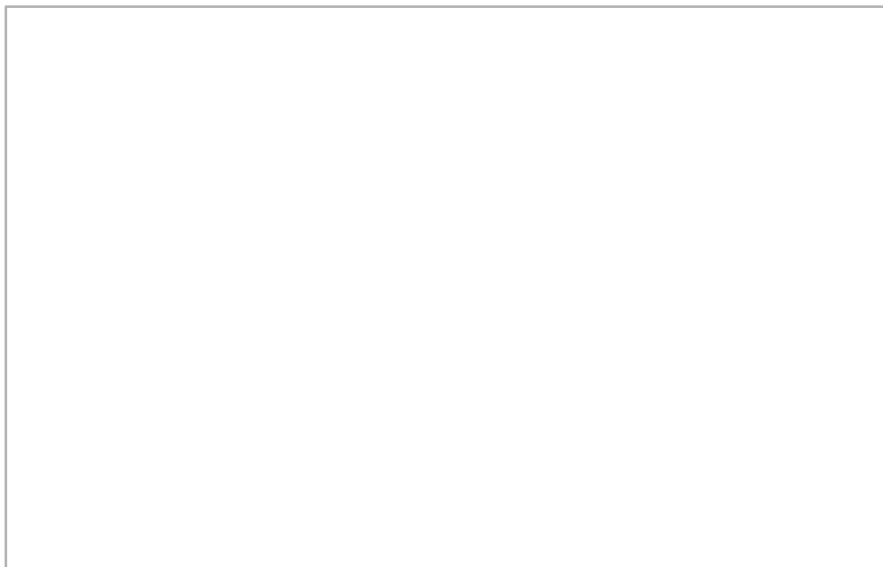
Play button:

Reset button:

Area for textual display:

GUIDELINES FOR AUTHORS OF LEARNING OBJECTS
RACHEL S. SMITH

Diagram 1





Definitions of the labels in Diagram 1

1

2

3

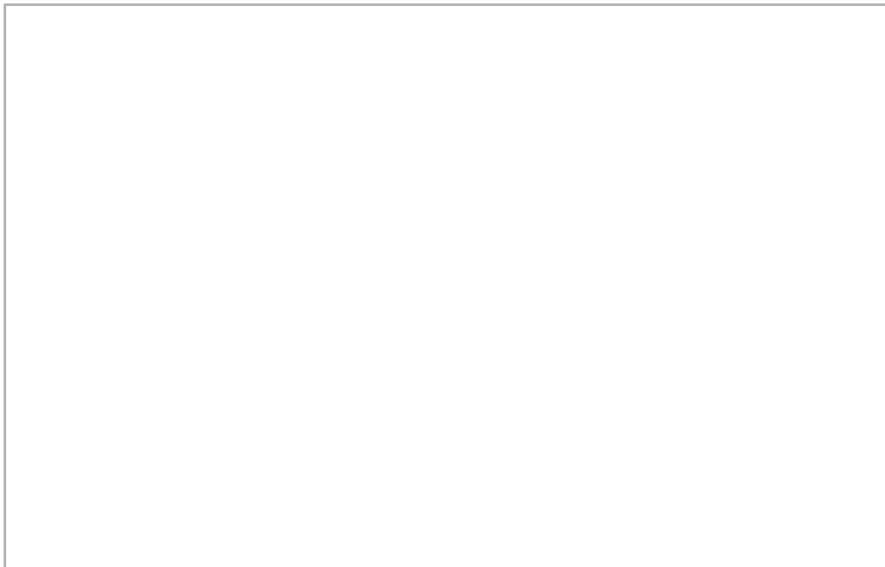
4...

- Add more slides if required



Diagram 2

Add more diagrams if required





Definitions of the labels in Diagram 2

1

2

3

4...

- Add more slides if required



Add more slides to create diagrams if required

INSTRUCTIONS SLIDE: DO NO EDIT

Animation design

- Use the template given (next slide) to show the placement of the elements.
- This is a sample template, and you are free to change as per your design requirements.
- Try and add / rename / move the tabs / buttons / sections / subsections as required.

Slide 3

- Use 'callouts' as shown above to explain the source of content. Ex: If the call out is placed at the Tab 01, and you want the content to be taken from slide 3 of this presentation, then place this callout on the Tab 01, and write 'Slide 3' inside the callout.

Slide 3

Introduction Tab 02 Tab 03 Tab 04 Tab 05 Tab 06 Tab 07

Name of the section/stage

Animation area

Interactivity area

Button 01

Button 02

Button 03

Instructions/ Working area

Credits

INSTRUCTIONS SLIDE: DO NO EDIT

Stepwise description of process

- The goal of the document is to provide instructions to an animator (who is not an expert).
- You have to describe what steps the animator should take to make your concept come alive as a (moving) visualization.
- Refer to the pedagogy and interaction design guidelines (next two slides after this) before creating the LO, these will give an idea of various options to be used for creating LOs.
- Use one slide per step. This will ensure clarity of the explanation.
- Add a image of the step in the box, and the details in the table below the box.

- You can use any images for reference, but mention about it's copyright status. If required, the animator will have to re-draw/re-create the drawings

Add more slides as per the requirement of the animation

Guidelines: Refer before creating sections

General pedagogy guidelines

- Invite access to content via multiple modalities of learning (visual, auditory, kinesthetic).
- Provide opportunities for learners to make choices, make decisions, or manipulate elements.
- When learners are able to make choices, ensure that the choices are meaningful.
- Give learners a chance to interact with the content. Use interactive tools where users can manipulate abstract concepts, test their own assumptions about them and see the consequences of their own actions.
- Provide feedback for every action done by the user

INSTRUCTIONS SLIDE: DO NO EDIT

Guidelines on adding interactivity

- Some of the ways in which Interactivity can be added are:
 - Simple navigation: back and next, or play and pause buttons
 - Allowing selection to the user: radio buttons, check boxes
 - Providing options for specific inputs: text/numeric boxes
 - Providing regulatory controls: slider bars, regulators
 - Providing active participation: drag and drop, move / rearrange

Use interactivity to decide the flow of communication in the LO.



Step 1: T1: Title of the step, to appear as heading of the screen (if any)

Image/graphic for the step

Description of the action/ interactivity	Audio Narration (if any)	Text to be displayed (if any) (DT)

Interactivity option 1: Step No: 1

Image/graphic for explaining the interactivity options

Interactivity type	Instruction to the learner	Boundary limits	Instructions for the animator	Results and Output

INSTRUCTIONS SLIDE: DO NO EDIT

Self- Assessment Questionnaire for Learners

- Please provide a set of questions that a user can answer based on the LO. They can be of the following types:
 - These questions **should be 5 in number** and can be of objective type (like MCQ, Match the columns, Yes or No, Sequencing, Odd One Out).
 - The questions can also be open-ended. The user would be asked to think about the question. The author is requested to provide hints if possible, but a full answer is not necessary.
 - One can include questions, for which the user will need to interact with the LO (with certain parameters) in order to answer it.
 - It is better to avoid questions based purely on recall.



Questionnaire: Add more slides if required

Use appropriate formatting for the questions

INSTRUCTIONS SLIDE: DO NO EDIT

Links for further reading

- In the next slide, provide some reference reading material for the users.
- It could be books, reference publications, or website URLs.



Links for further reading

- Reference websites:

- Books:

- Research papers:

INSTRUCTIONS SLIDE: DO NO EDIT

Summary

- Please provide points to remember to understand the concept/ key terms of the animation, in the next slide.
- The summary will help the user in the quick review of the concept.



Summary

Appendix B

Sample instructional design documents

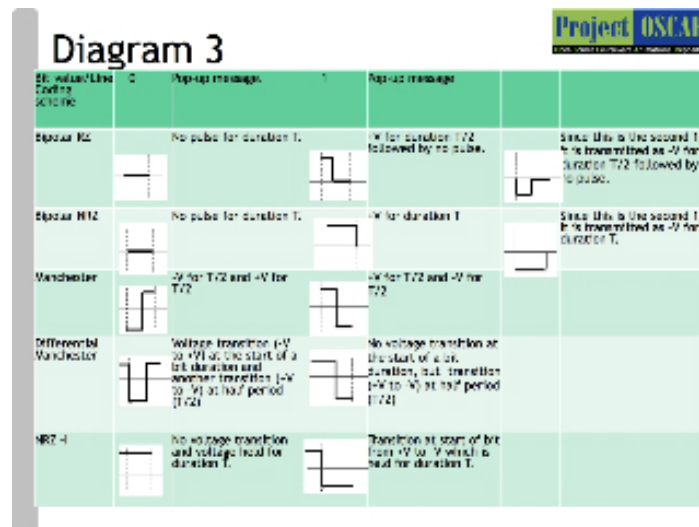


Figure B.1: Sample screens from IDD3 for the topic of line coding

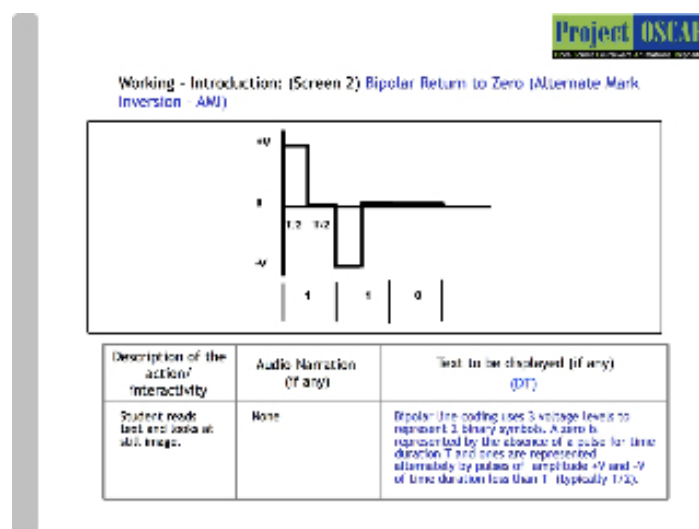



Figure B.2: Sample screens from IDD3 for the topic of line coding

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Step 3: Interaction




Description of the action/ interactivity	Audio Narration (if any)	Text to be displayed (if any) (DT)
Use mouse to slide bar on the histogram and observe the effect of threshold value on the final image.		Move the slider bar and observe where the threshold lies in the histogram. Also observe the effect in the final image.

Figure B.3: Sample screens from IDD3 for the topic of image thresholding

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Open Source Content Authoring for Research Assistants

Interactivity option 1: Step 3



Interactivity type	Instruction on the screen	Accessibility links	Instructions for the animator	Results and Output
Buttons	Select one value	Permit user to select one value only (dot.) allow the user to select more than one value.	Create 3 buttons with numbers 150, 170 and 200 written next to them.	When the user selects 170 display file eg1_histy.jpg in the image histogram box and file eg1_thimgy.jpg in the final image box.


Figure B.4: Sample screens from IDD3 for the topic of image thresholding

Appendix C

Sample learning objects

Project OSCAR
Image Thresholding
Electrical Engineering > Digital Image Processing

Click on the Icons on the top right corner to go to the relevant section of the learning object(LO).




Thresholding is the simplest method of image segmentation. From a grayscale image, thresholding can be used to create binary images.

Learning Objectives


After interacting with this Learning Object, the learner will be able to:

- Explain how the thresholding of an image is done.

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Credits


Project OSCAR
Image Thresholding
Electrical Engineering > Digital Image Processing

Image Thresholding

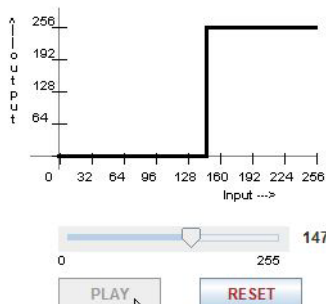
Before Thresholding



After Thresholding




Transformation Graph



Explanation

- The left image is the original image
- The right image is the resulting image when the threshold value is 147

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Credits



Open Source Courseware Animations Repository

Image Thresholding

Electrical Engineering > Digital Image Processing






Image Thresholding

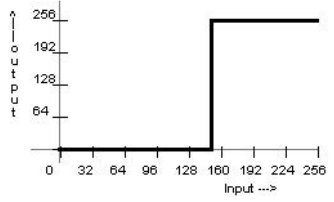
Before Thresholding



After Thresholding



Transformation Graph



151

0 255


[Go back](#)

Explanation

- The left image is the original image
- The right image is the resulting image when the threshold value is 151

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Credits



Open Source Courseware Animations Repository

Image Thresholding

Electrical Engineering > Digital Image Processing





Check your understanding : 1 2

Click buttons 1,2 to view questions


1. If the threshold value is 200, what is the output of the given image

Note: Gray colour value is 150.







a)



b)



c)




d)

1. a
 2. b
 3. c
 4. d

Answer Wrong

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Credits



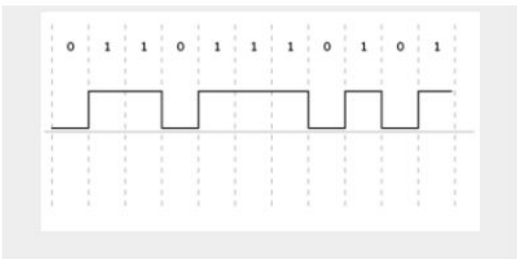
Project OSCAR
Open Source Courseware Animations Repository

Line Coding Schemes

Electrical Engineering > Data Communications



Click on the Icons on the top right corner to go to the relevant section of the learning object(LO).




Line coding is the process of converting binary data, a sequence of bits to a digital signal.

Learning Objectives


After interacting with this Learning Object, the learner will be able to:

- Convert the sequence of binary digits into a digital signal.


Sponsored by :



Developed by :




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Project OSCAR
Open Source Courseware Animations Repository

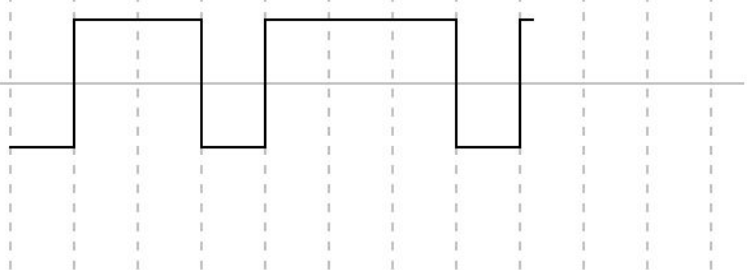
Line Coding Schemes

Electrical Engineering > Data Communications

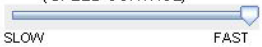


Polar Non Return to Zero(NRZ) Scheme

Bits: 0 1 1 0 1 1 1 0 1 0 1

Signal: 

(SPEED CONTROL)




Explanation

Polar NRZ: Polar Non Return to Zero








- Bit 0 is mapped to a negative amplitude
- Bit 1 is mapped to a positive amplitude

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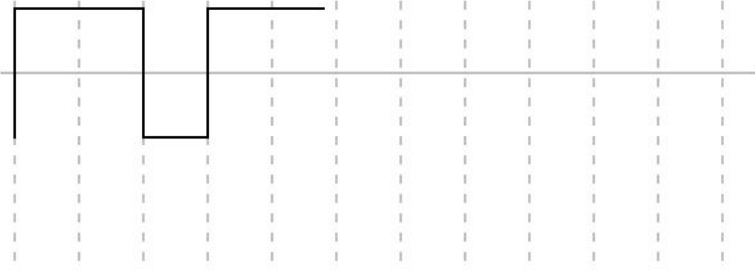
Line Coding Schemes

Electrical Engineering > Data Communications

Polar Non Return to Zero(NRZ) Scheme

Bits: 1 1 0 1 1 0 0 0 1 1 1



Press 1 or 0 button to input

(SPEED CONTROL)


Explanation

Polar NRZ: Polar Non Return to Zero

- Bit 0 is mapped to a negative amplitude
- Bit 1 is mapped to a positive amplitude








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Line Coding Schemes

Electrical Engineering > Data Communications

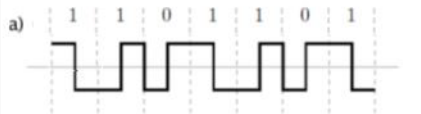








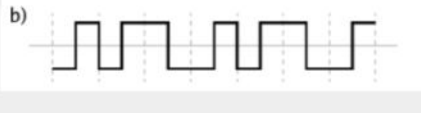
Check your understanding : 1 2

Click buttons 1,2 to view questions

1. What is the Differential Manchester waveform corresponding to the bit string 1101101 ?

Note: The signal level before the first bit is assumed to be high.

a)


b)


1. a
 2. b

Answer

Wrong

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Credits

Project OSCAR Electronics Engineering
Open Source Courseware Animations Repository **Image Thresholding**

Home

Home





Image Thresholding


This animation describes thresholding of grayscale images and the effect of threshold value on the image.


Learning Objectives:

After interacting with this learning object, the learner will be able to:

- Explain how thresholding of a grayscale image is performed.
- Describe the effect of threshold value on the resulting image.
- Determine a suitable threshold value from the histogram of an image.

Sponsored by:  MHRD

Developed by:  IIT BOMBAY

Click "Start" to begin > 

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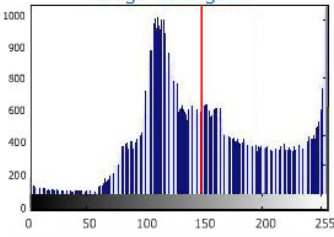

Project OSCAR Electronics Engineering
Open Source Courseware Animations Repository **Image Thresholding**

Demo

Demo | Working | Interactive demo

Working Interactions Summary

Original image Image histogram Thresholding image

Observe
Location of the threshold value in the histogram

Low 100 Medium 170 High 200

Threshold values

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Project OSCAR Electronics Engineering
Open Source Courseware Animations Repository Image Thresholding

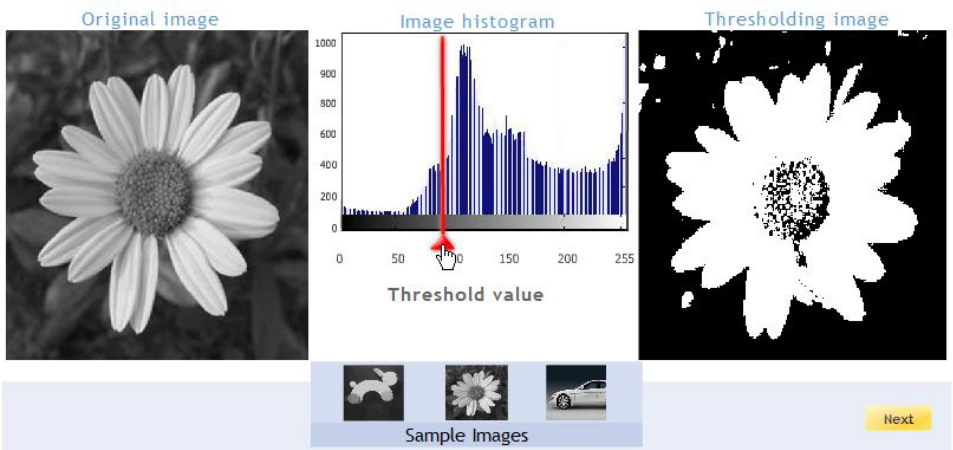
Demo

Demo | Interaction | Interaction 1

Working Interactions Summary

Move the slider bar and observe the changes in the histogram and thresholding image.

Original image Image histogram Thresholding image



Sample Images

Next

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Project OSCAR Electronics Engineering
Open Source Courseware Animations Repository Image Thresholding

Quiz

Question: 1 2 3 4 5

Consider the image shown below (same as that in question 4). The grey in the star is of value 100 and the grey in the lightning is 150. If you choose a threshold of 175 what happens to the image and why?



The entire image is white.

The entire image is black.

Both the star and lightning will be white.

Only the lightning will be white and the rest of the image will be black.

Feedback

Right answer! When the threshold is 175, all pixels of value less than 175 will be blacked out. So the star and the lightning will both be blacked out and we will get an image which is entirely black.

Back Next

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Communication
Line Coding Schemes

Home

Line Coding Schemes

Line coding is the process of converting binary data, a sequence of bits to a digital signal.

Learning Objectives:

After interacting with this learning object, the learner will be able to:

- Explain how to encode a string of bits using Bipolar RZ, Bipolar NRZ, Manchester, NRZI and differential Manchester coding schemes.
- Apply using Bipolar RZ, Bipolar NRZ, Manchester, NRZI and differential Manchester coding schemes to encode a given string of bits.
- Given a coding scheme from among Bipolar RZ, Bipolar NRZ, Manchester, NRZI and differential Manchester coding, analyse a waveform and decode the string of bits from it.

v+
T/2
T/2
v-
| 1 | 1 | 0 |

Click "Start" to begin >>

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MHRD

Developed by:

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Communication
Line Coding Schemes

Home

Line Coding Schemes

Demo

Working | Compare Coding Schemes

Working

Interactions

Summary

Definitions of different coding schemes

Bipolar RZ	0		<p>+V for duration T/2 followed by no pulse.</p>	1
Bipolar NRZ		No pulse for duration T.		1
Manchester			-V for T/2 and +V for T/2	1
Differential Manchester	0		No voltage transition at the start of a bit duration, but transition (+V to -V) at half period (T/2)	1
NRZ I	0	1		1

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Project OSCAR Communication Line Coding Schemes

Open Source Courseware Animations Repository

Home Demo

Demo | Interaction | Interaction 1

Working Interactions Summary

Compare the coding schemes

1 0 0 0 1 1 0 Reset

Manchester

Select two other coding schemes to see the comparison

Bipolar RZ Bipolar NRZ Manchester Differential Manchester NRZ I

Compare

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Project OSCAR Communication Line Coding Schemes

Open Source Courseware Animations Repository

Home Quiz

Quiz

Question: 1 2 3 4 5

A set of bits 1101 are encoded using Bipolar NRZ (B-NRZ) and NRZ-I schemes. Which of the waveforms will have more +V to -V or -V to +V transitions. Assume any initial level for NRZ-I.

A) NRZ-I irrespective of initial level

B) Assuming high initial level, NRZ-I ✗

C) B-NRZ

D) Both are equal

Feedback

✗ No

B-NRZ 1 transition

NRZ I 3 transitions assuming initial level low

NRZ I 3 transitions assuming initial level high

Back Next

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Credits Print

Appendix D

Tools used in the research

This section has various instruments used in this research.

Student feedback form

20th April 2013 | DJ Sanghavi College of Engineering | Mumbai University

<http://oscar.iitb.ac.in/onsiteDocumentsDirectory/LineCoding/LineCoding/index.html>

Project OSCAR Line Coding Schemes
Electrical Engineering > Data Communications

Click on the icons on the top right corner to go to the relevant section of the learning object(LO).

Line coding is the process of converting binary data, a sequence of bits to a digital signal.

Learning Objectives
After interacting with this Learning Object, the learner will be able to:
Convert the sequence of binary digits into a digital signal.

Sponsored by: Developed by:

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Later, see the questionnaire below, and give feedback by selecting your option for each of the animation. Place a tick mark in front of the option of your choice.

Note: Read the explanation of the options: 'Disagree, Neutral and Agree', before selecting your choice.

Your name

1. Image thresholding concept is presented in an interesting manner in the animation

Disagree: Interactions are rudimentary (simple). They are not presented in interesting way	
Neutral: Few interactions are interesting, others can be better	
Agree: Interactions are interesting. Playing with the parameters is enjoyable	

2. Interaction design features like sliders, buttons, drop downs and other options in the animation are easy to use

Disagree: Most of the buttons are difficult to use, in terms of their working, placement and behavior	
Neutral: It is bit difficult at times. Some buttons are easy to use, however, some are not	
Agree: They are easy. I can easily decide when to press, drag, and click to see the desired results	

3. Interaction design features like buttons, tabs and other options help navigation through the animation

Disagree: Features don't help at all, I navigated on my own	
Neutral: Some screens have these features, while some don't	
Agree: Features prompt the movement from every screen/section to other	

4. Features like sliders, buttons, drop downs and others display the output as expected after using them

Disagree: Outputs don't match to the actions performed	
Neutral: Some outputs displayed are as expected, however some are unexpected	
Agree: Outputs displayed are as per my expectation	

5. Feedback of the response features like, pop-ups, explanation instructional text and others help in interacting with the animation

Disagree: Sparse feedback creates problems. It becomes difficult to interact with the animation	
Neutral: Some feedback is useful to select appropriate options, while absence of feedback in some places, leads to confusion	
Agree: Presence of feedback for the interaction done with the animation helps in selecting appropriate options	

6. Animation provides sufficient examples to understand the concept

Disagree: Inadequate samples/examples are provided	
Neutral: Few samples are provided, more would have been better	
Agree: Multiple samples provided, make understanding easy	

7. Select one of the statements below

- Animation is usable
- Animation is partly usable
- Animation is not usable

Provide justification (using one example) for your choice above:

.....

.....

.....

.....

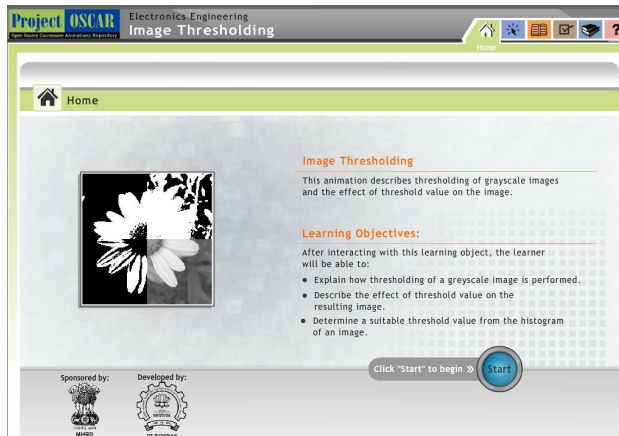
.....

Thank you for your time!

Student feedback form

30th March 2013 | DJ Sanghavi College of Engineering | Mumbai University

http://oscar.iitb.ac.in/ee/Image_Thresholding_V8/index.html



Later, see the questionnaire below, and give feedback by selecting your option for each of the animation. Place a tick mark in front of the option of your choice for BOTH the animations.

Note: Read the explanation of the options 'Disagree, Neutral and Agree', before selecting your choice.

Your name (Optional)

1. Image thresholding concept is presented in an interesting manner in the animation

Disagree: Interactions are rudimentary (simple). They are not presented in interesting way	
Neutral: Few interactions are interesting, others can be better	
Agree: Interactions are interesting. Playing with the parameters is enjoyable	

2. Interaction design features like sliders, buttons, drop downs and other options in the animation are easy to use

Disagree: Most of the buttons are difficult to use, in terms of their working, placement and behavior	
Neutral: It is bit difficult at times. Some buttons are easy to use, however, some are not	
Agree: They are easy. I can easily decide when to press, drag, and click to see the desired results	

3. Interaction design features like buttons, tabs and other options help navigation through the animation

Disagree: Features don't help at all, I navigated on my own	
Neutral: Some screens have these features, while some don't	
Agree: Features prompt the movement from every screen/section to other	

4. Features like sliders, buttons, drop downs and others display the output as expected after using them

Disagree: Outputs don't match to the actions performed	
Neutral: Some outputs displayed are as expected, however some are unexpected	
Agree: Outputs displayed are as per my expectation	

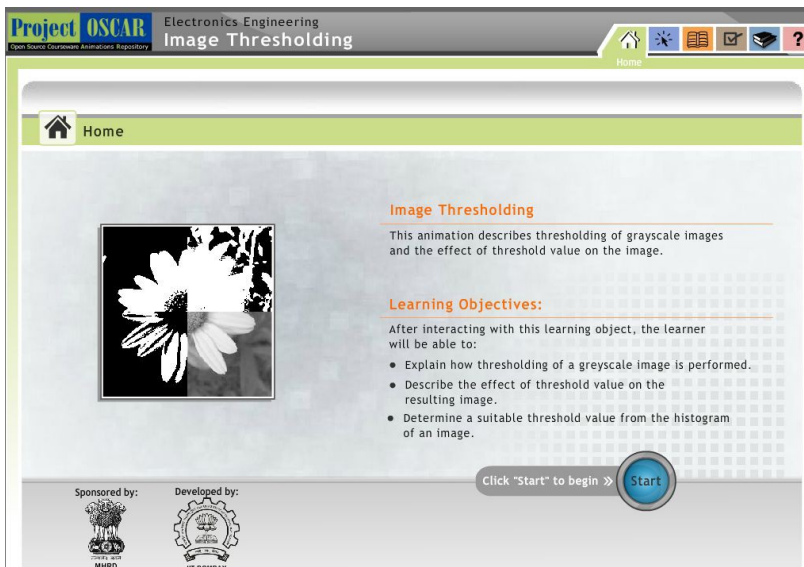
5. Feedback of the response features like, pop-ups, explanation instructional text and others help in interacting with the animation

Disagree: Sparse feedback creates problems. It becomes difficult to interact with the animation	
Neutral: Some feedback is useful to select appropriate options, while absence of feedback in some places, leads to confusion	
Agree: Presence of feedback for the interaction done with the animation helps in selecting appropriate options	

6. Animation provides sufficient examples to understand the concept

Disagree: Inadequate samples/examples are provided	
Neutral: Few samples are provided, more would have been better	
Agree: Multiple samples provided, make understanding easy	

7. Select one of the statements below



- Animation is usable
- Animation is partly usable
- Animation is not usable

Provide justification (using one example) for your choice above:

.....

.....

.....

.....

Thank you for your time!

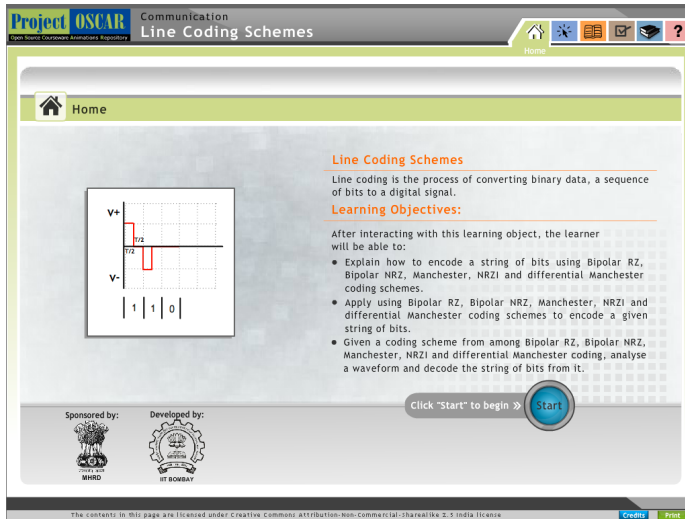
Feedback for Line coding learning object 1 (LCLO1)

Please click on the link below and open the learning object.
Interact with it for some time, and after studying all the sections, fill up the questionnaire in this form.

Link:
<http://oscar.iitb.ac.in/ee/lcs/index.html>

* Required

Screenshot of the LO1 for Image thresholding topic (given for reference).



1. **1. I liked the look and feel of the LO1 ***

Mark only one oval.

1 2 3

Agree Disagree

2. **2. Look and feel of the LO1 helped me in learning. ***

Mark only one oval.

1 2 3

Agree Disagree

3. **3. I found LO1 to be engaging ***

Mark only one oval.

1 2 3

Agree Disagree

4. **4. Working with the LO1 helped me learn ***

Mark only one oval.

1 2 3

Agree Disagree

5. **What I liked about LO1?**

.....

.....

.....

.....

.....

6. **What I disliked about LO1?**

.....

.....

.....

.....

.....



Faculty questionnaire for Image thresholding (VCLOs and AVCLOs)

1. Students will be able to learn the concept using this LO			
	AVCLO	VCLO	
a. Strongly agree			
b. Agree			
c. Neutral			
d. Disagree			
e. Strongly disagree			

2. LO reinforces concepts progressively			
	AVCLO	VCLO	
a. Strongly agree			
b. Agree			
c. Neutral			
d. Disagree			
e. Strongly disagree			

3. LO is interactive			
	AVCLO	VCLO	
a. No interactivity provided			
b. Limited interactivity provided			
c. Fair amount of interactivity provided			
d. Interactivity is adequate and engaging			
e. Many interesting and innovative forms of interactivity provided (e.g. Simulation and game-based learning etc.)			

4. Use of media is appropriate			
	AVCLO	VCLO	
a. Animation/Simulation not necessary for this topic			
b. Use of Animation/Simulation is appropriate for this topic			
c. Use of Simulation would be more appropriate for this topic			
d. Visualization and combination of audio/text explanation is appropriate			
e. Visualization and combination of audio/text explanation is appropriate & engaging			

5. Clear instructions are available on how to use content			
	AVCLO	VCLO	
a. There are no instructions available. The content is very difficult to use			S1000brains
b. kau23samThere are some instructions available.			
c. Most instructions to use the content are available			
d. All necessary instructions to use the content are available			
e. All necessary instructions to use the content are available, with additional help tools			

6. The interface is user-friendly			
	AVCLO	VCLO	
a. Interface is not user-friendly (i.e. user need to use manual extensively or require many hours of training)			
b. Some parts of interface are user-friendly			
c. Many parts of interface are user-friendly			
d. Interface is user-friendly and visually appealing			
e. Interface is very user-friendly, visually appealing			

7. Use of fonts and colors are appropriate			
	AVCLO	VCLO	
a. Text is not readable.			
b. Text is readable but fonts & colour are not appropriate			
c. Text is readable and fonts & colour are appropriate for the target learner			
d. Text is readable and font & colour reflect information hierarchy			
e. Text is readable; font & colour reflect information hierarchy and are creatively used.			

	AVCLO	VCLO
What I liked?		
What I disliked?		

Concept Selection Form

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Goal: Objective is to guide the Subject Matter expert (SME) to choose a concept that requires visualization

Need Analysis: You feel there is a gap in student understanding of this particular topic & visualization is the answer. The steps below will help you to choose the type of visualization

Please Note: PowerPoint is a powerful visualization resource for teaching. But, in PowerPoint animations, learners are not able to manipulate variables or see different bond angles in a molecule

Let us explore if we can go beyond PowerPoint for your chosen content topic

Step 1: Choosing content category

Q.1 Write the concept (from the list above), which you feel can be explained better using animation. *

Q.2 Choose the appropriate content category from the table below:

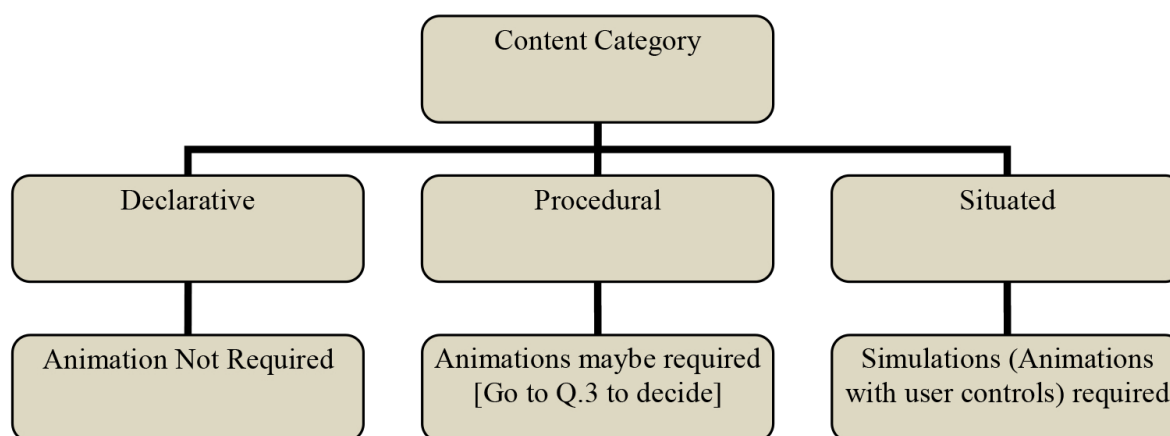
Table 1: Content Taxonomy Models for e-learning

Categories of e-learning content	Content type
Declarative (knowing what)	Concepts & facts
Procedural (knowing how)	Procedure & processes
Situated (knowing when & why)	Principles

(Chyung, 2007)

Therefore, my animation/simulation content comes under _____ category.

Step 2: Choosing animations/simulations as a medium



Q.3. Please tick any one of the options (Yes/No) for the following questions

For content category = Procedural

- (i) Are there images with motion like a movie? Yes No
- (ii) Is there a trajectory to be shown? Yes No
- (ii) Will the learner manipulate a variable? Yes No

If you have ticked Yes, to either (i), (ii) or (iii) APPENDIX D. TOOLS USED IN THE RESEARCH
Animation/Simulation is the preferable visualization medium to choose.

Else
(iii) Are there separate static images/videos for each & every step? Yes No

If you have ticked Yes to (iv),
PowerPoint is the visualization medium to choose
Else
Animation is not necessary. Instead use representational graphics (good diagrams)

Endif
Endif

Therefore, my content comes under _____ category and requires _____ type of visualization.

Step 3: Content creation form

Q.4 a) Please select the availability of the teaching material used for the concept selected.

- Textual mediums
Slides Notes Papers Other documents
- Static graphic mediums
Diagrams Illustrations Photographs
- Motion graphic mediums
Any other Video shown during the lecture Animation
- Interactive audio/visual medium like
Simulation
- Websites
(Do you know any sites which has animation for the above mentioned concept)
- Other _____
(If you have any file/teaching material related to the concept please copy the material after this form as appendix with proper numbering of the concept)

b) Explain which part of this concept is worth animating? *

c) Explain why you feel it is important to animate this concept? *

Appendix E

Publications

E.1 Related to this research

E.1.1 Journal

1. Sahasrabudhe, S., Murthy, S., & Iyer, S. (2013). Applying Design Based Research to create Instructional Design templates for Learning Objects. In *New Frontiers in Education* (Jan-Mar 2013) ISSN: 0047-9705
2. Sahasrabudhe, S., Murthy, S., & Iyer, S. (2012). Applying traditional animation principles for creating learning objects. In *New Frontiers in Education* (Jul-Sep 2012) ISSN: 0047-9705
3. Sahasrabudhe, S., Murthy, S., & Iyer, S. (*In writing*) Embedding visual communication principles in instructional design template using design based research method. For *British Journal of Education Technology*

E.1.2 Conference

1. Sahasrabudhe, S., Murthy, S. & Iyer, S. (2012). Embedding visual communication principles in Instructional Design phase of Learning Object creation process. In *proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications (EdMedia) 2012* (pp. 1189-1198). Chesapeake, VA: AACE

E.2 Publications on other research areas

E.2.1 Conference

1. Sahasrabudhe, S., Bhawar, P., Ayer, N., (2014). Netra3D: Android application having affordances of tablet computers. In T4E 2014, Kollam, India. IEEE
2. Majumdar, R., Bhawar, P., Sahasrabudhe, S., & Dinesan, P. (2014). HasTA: Hasta Training Application Learning Theory Based Design of Bharatanatyam Hand Gestures Tutor. In Advanced Learning Technologies (ICALT), 2014 IEEE 14th International Conference on (pp. 642-643). IEEE.
3. Kadam, K., Sahasrabudhe, S., Iyer, S., & Kamat, V., (2013). Integration of Blender 3D in Basic Computer Graphics Course, 21st International Conference on Computers in Education 2013
4. Bhawar, P., Ayer, N., & Sahasrabudhe, S., (2013). Methodology to create optimized 3D models using Blender for Android devices. Fifth International Conference on Technology for Education (T4E) 2013, Kharagpur, India: IEEE
5. Sahasrabudhe, S., Shah, A., Thakkar, M., Thakkar, V., & Iyer, S. (2012). Math-Mazing: 3D gesture recognition exergame for arithmetic skills. In Proceedings of 20th International Conference on Computers in Education (ICCE) 2012 (pp. 11-17). Singapore: APSCE
6. Kadam, K., Sahasrabudhe, S., & Iyer, S., (2012). Improvement of Mental Rotation Ability Using Blender 3-D, In proceedings of Fourth International Conference on Technology for Education (T4E) 2012, (pp. 60-66). Hyderabad, India: IEEE
7. Dere, S., Sahasrabudhe, S., Iyer, S., (2010). Creating open source repository of 3D models of laboratory equipments using Blender. In proceedings of International Conference on Technology for Education (T4E), 2010. (pp.149-156). Mumbai, India: IEEE
8. Sahasrabudhe, S., & Iyer, S., (2009). Creating 3D animations of laboratory experiments using open source tools. In proceedings of the International Conference on E Learning (ICEL) 2009. (pp. 440-449). Toronto, Canada: ACL
9. Krithivasan S., Baru M., & Sahasrabudhe S., (2005), Achieving stability on VSAT networks, Case Study: Distance Education Program at IIT Bombay, at International Conference on Distance Education (ICDE), New Delhi, India, 2005.

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