Åbo Akademi University

Master's Thesis

Design and Development of Multimedia E-Textbooks for School Education in Nepal

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"*The teacher is of course an artist, but being an artist does not mean that he or she can make the profile, can shape the students. What an educator does in teaching is to make it possible for the students to become themselves.*"

Paulo Freire

Abstract

The digital form of textbooks as learning resources for school pupils has been analyzed and adopted in various developed countries. But Nepal has a low status of development in education and information and communications technology (ICT) domain compared to developed nations, which poses unique challenges to apply state of the art technology while creating e-textbooks as learning resources for school pupils. Literature has analyzed the use and efficiency of e-textbooks in the context of school education. Research studies have also reviewed multiple factors related to acceptance of the e-textbooks among school teachers and pupils. Even though the interface and functionality of e-textbooks have been discussed widely, well-established design layouts to develop multimedia e-textbooks are not yet available.

This thesis work is early-stage design research to develop a prototype e-textbook system for school education in Nepal. The prototype e-textbook system is a web application to create and render e-textbooks. The rendered e-textbooks, which comprise a digital form of paper textbooks and educational multimedia, can be read via web browsers. While developing the prototype e-textbook system, a design framework on how to sequence, integrate, and display multimedia has been proposed. This framework can provide a way to deal with design issues of e-textbooks, such as making e-textbooks as familiar as paper textbooks and making their interface as self-descriptive as possible.

Keywords: *multimedia e-textbook, school education, Nepal, design research*

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List of Abbreviations

ICT	**I**nformation and **C**ommunications **T**echnologies
SSDP	**S**chool **S**ector **D**evelopment **P**lan
CDC	**C**urriculum **D**evelopment **C**enter
PDF	**P**ortable **D**ocument **F**ormat
EBONI	**E**lectronic **B**ooks **ON**-screen **I**nterface
OER	**O**pen **E**ducational **R**esources
GBL	**G**ame-**b**ased **L**earning
LMS	**L**earning **M**anagement **S**ystem
GDP	**G**ross **D**omestic **P**roduct
IDI	**I**CT **D**evelopment **I**ndex
NRI	**N**etworked **R**eadiness **I**ndex
ITU	**I**nternational **T**elecommunication **U**nion
PHP	**P**HP **H**ypertext **P**reprocessor
HTML	**H**yper**t**ext **M**arkup **L**anguage
CSS	**C**ascading **S**tyle **S**heets
Moodle	**M**odular **o**bject **o**riented **d**ynamic **l**earning **e**nviroment
LMS	**L**earning **M**anagement **S**ystem
GPL	**G**eneral **P**ublic **L**icense
RDBMS	**R**elational **D**atabase **M**anagement **S**ystem
SQL	**S**tructured **Q**uery **L**anguage
XML	E**x**tensible **M**arkup **L**anguage

Dedicated to my parents.

मेरा लागी उच्च शिक्षातर्फको मार्ग सुलभ गर्दिबक्सने मेरा
अभिभावक अम्बिका स्वार रेग्मी र बुद्धि प्रकाश रेग्मीमा समर्पित |

Chapter 1

Introduction

1.1 Background

Prior to the establishment of the Nepal National Education Commission in 1956, access to school education in Nepal was limited and exclusive to the elite and wealthy citizens. The education system plan in 1971 established the foundation for Nepal's modern formal education system. Nepal's new federal constitution, declared in 2015, considers free and compulsory basic education and free secondary education as a fundamental right [1]. The formal school education in Nepal is 12 years long, divided into grades from 1 to 12, with each grade a year-long period. Grades 1 to 8 and grades 9 to 12 have been defined as basic education and secondary education respectively. Nepal has 7.52 million children of age 5 to 16 enrolled in grades 1-12, with no significant difference between genders (50.15 % boys and 49.85 % girls) [1].

The net enrollment rate at the basic education level has increased significantly in the last decade, although a significant number of students drop out before progressing to secondary education, and the low enrollment rate at grades 11 and 12 is still an issue of concern. School education mostly depends on textbooks and teacher-focused classrooms. The school textbooks are considered to be the primary and complete learning material and all teaching is tied to textbooks. Moreover, supplementary materials for students are mostly not available, and a timely printing and distribution of textbooks is still an issue to solve [1]. Use of Information and Communications Technology (ICT) in school education of Nepal is currently at the initial stage. The master plan to implement ICT in school education was launched in 2013 and this has defined four pillars of ICT in education: infrastructure, connectivity, teaching-learning materials, and human

resources. Implementation of this master plan has increased access to computers and the internet in schools, which supports the further use of ICT in school education [1], [2].

The government of Nepal has developed the School Sector Development Plan (SSDP) to be implemented during the period of July 2016 to July 2023. Application of ICT in school education is one of the targets to be achieved by SSDP which aims to improve classroom delivery of learning materials and to increase access to them [1]. At present, the curriculum development center (CDC) maintains the e-library and multimedia learning materials, though the availability of digital learning materials is limited to downloadable school textbooks in portable document format (PDF) and a few audio-visual contents. The SSDP has identified various strategies to improve the use of ICT in school education, which also include the preparation of digital teaching-learning materials and the development of e-libraries [1]. Development and use of e-textbooks in school education of Nepal can provide an integrated and efficient solution, which has not been researched yet within the context of Nepal. This thesis work has been motivated by the broader research question 'How to implement e-textbooks as learning materials for the context of school education in Nepal?'

Although the use of e-textbooks for school education has been investigated with few studies so far, the benefits of e-textbooks compared to their equivalent printed forms have been identified with various research initiatives. Such benefits of e-textbooks come from their digital nature, for example their potential of including multimedia and interactive resources, portability, accessibility, and storage easiness [3]. Therefore, e-textbooks can be considered as the equivalent of the printed textbooks in digital format which can be more advanced compared to their equivalent printed forms. In the global perspective, e-textbooks have been widely known and used across the world. Numerous projects to develop and use a digital form of textbooks, also known as digital textbooks, electronic textbooks, or e-Textbooks, were initiated in the education systems in at least 20 countries [4], [5]. Although e-textbook is not a novice concept, design principles have mostly addressed the interface and technical aspects of e-textbooks. Pedagogical principles for e-textbooks and instructional principles for multimedia contents are still ongoing research topics [6]–[8].

Context is an important factor to consider in the field of learning science to understand the relevance of any educational intervention in its realistic

settings. Educational interventions developed for one context cannot be equally relevant in another context. An educational intervention can be a curriculum, learning process, learning material, ICT application etc and context is defined with a combination of various factors such as available infrastructure, ICT literacy of target users, socio-economic conditions etc. For the domain of educational technology, it is advisable to conduct research aimed at developing an optimal solution for a certain context rather than doing research for comparing available solutions [9], [10].

1.2 Research problem and functions

The formulation of a research-worthy problem is the starting point for any scholarly research. An identified problem is not only required to be research-worthy but also needs to be clearly articulated. A well-defined research problem helps to formulate correct research goals and choose the right research methodology [11], [12]. I followed the framework of problem-based research discussed by [12] to refine the research question within the broader context of the research problem and the research topic. The framework defines research topic, research problem, research question, and research goal as different artifacts of research and details the relationships among them. The research topic is the general domain in which the research problem exists. The research goal is the major intent of the study to address the research problem which is operationalized by one or more research questions. Meaningful research should have a noticeable connection between the answers to the research questions and the research problem [12].

As shown in Figure 1.1, the research topic has been described as 'ICT in school education', which self-evidently describes the topic as interdisciplinary. The research problem has been identified as the inadequacy of design principles for e-textbooks, specifically multimedia e-textbooks. Moreover, the problem has been drawn from the education domain where the context is crucial, so if design principles from other contexts are applied to develop e-textbooks in the context of school education in Nepal, such principles should be validated first with proper research. Insofar, no previous research has been found about developing, validating, or implementing new or existing design principles for school e-textbooks in the context of Nepal. Electronic Books On-screen Interface (EBONI) electronic textbook

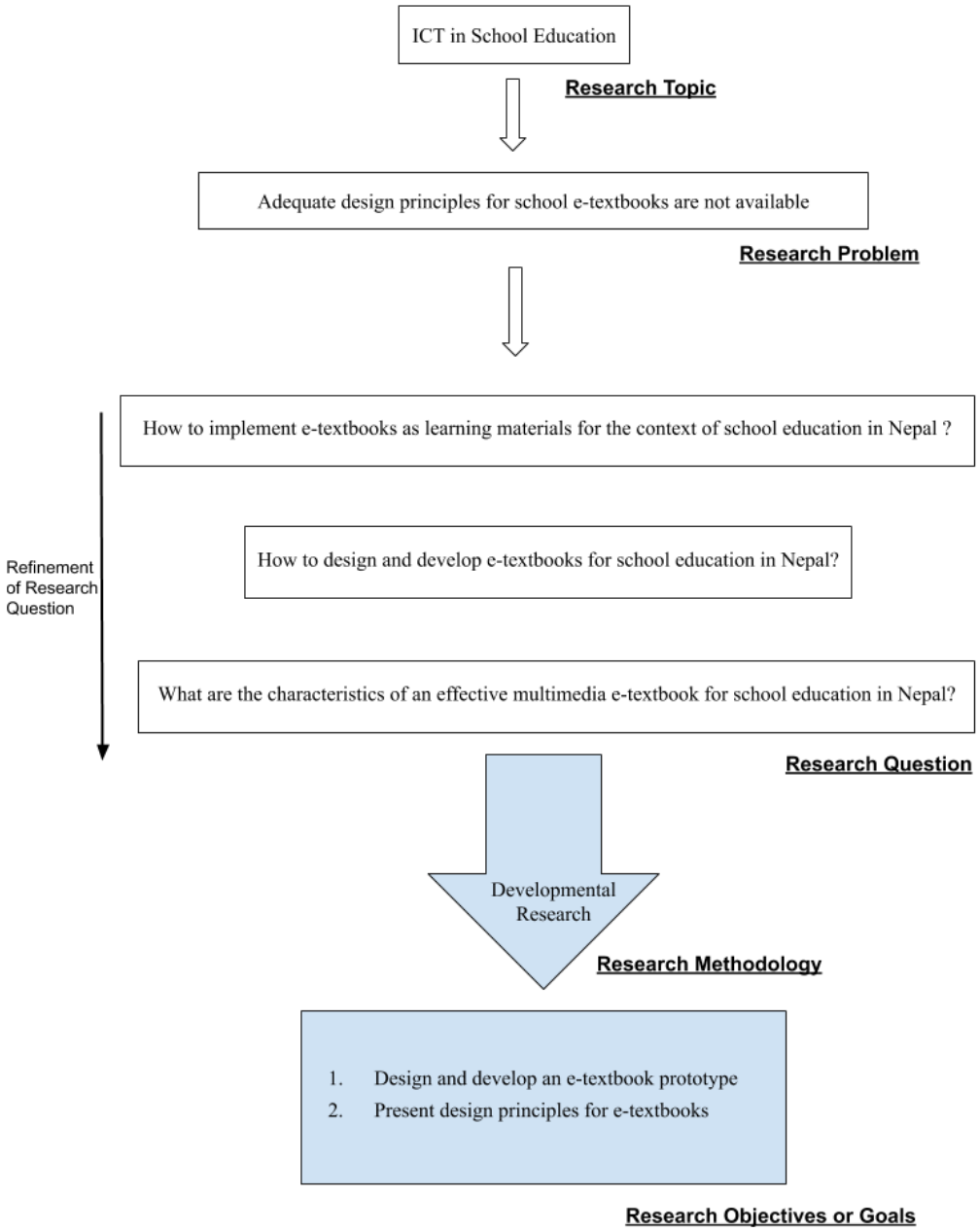


FIGURE 1.1: The research question, methodology, and objectives.

design guidelines [13] provide a comprehensive set of design principles which have been applied in the design of e-textbooks by other studies [14], [15]. Even though EBONI guidelines apply to a significant extent while designing e-textbooks, they do not address design issues such as how to sequence, integrate, and display the multimedia while integrating them as a part of e-textbooks, thus the design principles for multimedia e-textbooks can be

seen as only partly available.

The design principles for multimedia e-textbooks are not completely available and the research problem drawn from the educational domain has a context-bound nature, therefore the broader research question of implementing e-textbooks in school education should start with 'How to design and develop e-textbooks for school education in Nepal?'. Thus the primary research function of this thesis work is 'to design and develop'. The nature of this research function requires implementing e-textbooks within the educational domain, which limits the type of research that can be conducted.

The development of an e-textbook as a complete product, its implementation as an educational intervention, and the summative evaluation of the development process, product, and implementation is a broad topic to conduct research under the scope of this Master's thesis. So this research work is limited to developing a prototype e-textbook and carrying out a formative evaluation for the prototype validation.

Aligned with the SSDP's aim to improve the use of ICT in school education, the primary research objective is to develop and evaluate a prototype e-textbook system for school education in Nepal. Such educational interventions are not advisable to be carried out as product development projects [10]. Moreover, design principles for multimedia e-textbooks are still lacking. Hence this research work has followed the developmental research methodology. Figure 1 shows the refinement of the research question, along with the research methodology and research objectives of this thesis work. The refined research question addressed within the scope of this Master's thesis is: what are the characteristics of multimedia e-textbooks for school education in Nepal?

To address the research question "What are the characteristics of multimedia e-textbooks for school education in Nepal?", first a set of characteristics were defined, then a prototype e-textbook was developed, and finally, the prototype was validated with evaluation. In the process of developing the prototype, a set of design principles were formulated.

1.3 Research methods

The research objective of this thesis work requires building a prototype multimedia e-textbook for which sufficient design principles are not available.

E-textbooks are not a novice concept, though they have not been described within the context of school education in Nepal. So the need of the research problem is 'to describe' by 'building or revising' for which the developmental research approach is required [11]. Developmental research aims to build a 'product' to address the problem when there is not a sufficient solution obtainable, and no guidelines or principles are available to build the new solution [11].

Among the various research methods and tools applicable to the different stages of the developmental research, this thesis utilizes document analysis, prototyping, screening, and focus group interviews. Document analysis has been used in the preliminary research phase to better understand the specific needs of school education. Screening and focus group interviews have been used for evaluation at different stages of the development process.

1.3.1 Educational design research

The developmental research approach within the education domain has been discussed under the term 'educational design research' [9], [16]. In educational design research, the process of designing, developing, and evaluating educational interventions is studied systematically. Based on the goals of design research, it can further be divided into three categories: development studies, validation studies, and implementation studies. Development studies within design research do not only discuss the development of a research-based intervention but also provide the reusable design principles for future use [9].

The educational design research encompasses the design and development of 'products' as a solution to an educational problem, in addition to advancing the current knowledge on the process of designing and developing them. Thus, the research problem of developing an e-textbook as a solution to improve the use of ICT in school education is best addressed with educational design research [9], [10], [17]. Apart from the e-textbook prototype, this design research also presents a set of design principles for school e-textbooks.

Developmental research starts with a preliminary research phase to define the first 'design proposal' which is further developed into a global design, a partly detailed product, and a complete product. The output of

each stage, which is in some form of a product prototype, should be evaluated with some formative evaluation method [17]. In this research work, screening and focus group interview methods have been used for formative evaluation within the development process.

Among the four paradigms of educational design research, instrumental, communicative, pragmatic, and artistic, this thesis work has followed the pragmatic paradigm. The pragmatic paradigm of design research is based on a repeated tryout and revision of prototypes. In this design approach, the global outline of the product functions as a prototype that can be utilized to have a better understanding of the design problem, and to optimize the finished product specifications. Such prototypes have to be evaluated to identify design requirements and to determine the usefulness of the product. In the pragmatic design process, design and evaluation activities are intertwined [16].

1.3.2 Formative evaluation of the prototype

The evaluation of the developed product is an important aspect of educational design research. In this thesis work, only a prototype has been developed and this does not have sufficient effectiveness to carry out a summative evaluation. Before carrying out a summative evaluation of a complete product, convincing evidence for the effectiveness and quality should be presented, based on some formative evaluation of the prototype [17].

Studies have proposed various formative evaluation methods such as screening, focus group, walkthrough, micro-evaluation, and tryout. These methods are recommended at the different design stages to check different quality criteria [17]. In this work, the final prototype has been evaluated for relevancy, consistency, practicality, and effectiveness with the focus group interview method. The initial evaluation of the design proposal has been carried out with the screening evaluation methods.

1.4 Thesis structure

The thesis text has 7 chapters. Chapter 1 is the overall introduction of the thesis. This chapter introduces the research question and objectives, as well as the research methods applied. The literature review has been documented in chapter 2 which is divided in three parts. The first part of

the literature review details the various aspects of the e-textbooks including definition, scope, use, appearance, functionalities, and available design principles. The second part of chapter 2 discusses in detail multimedia e-learning contents and their use in e-textbooks. The third part of chapter 2 details and reviews the necessary information and data to define the context of school education in Nepal.

Chapter 3 details the research methodology and methods employed in this thesis work. The chapter discusses the rationale for choosing educational design research for the given research problem. Chapter 4 details the preliminary research phase and chapter 5 documents the development of the partly detailed product as the prototype. Chapter 6 includes the details of the formative evaluation carried out on the prototype. The use of a focus group interview method for prototype evaluation has been documented in this chapter. It also includes the final discussion on design principles which are formulated during the preliminary research in chapter 4 and implemented for the prototype development in chapter 5. The scope and limitations of the research and the conclusion have been documented in chapter 7. Figure 1.2 shows a general overview of the thesis structure.

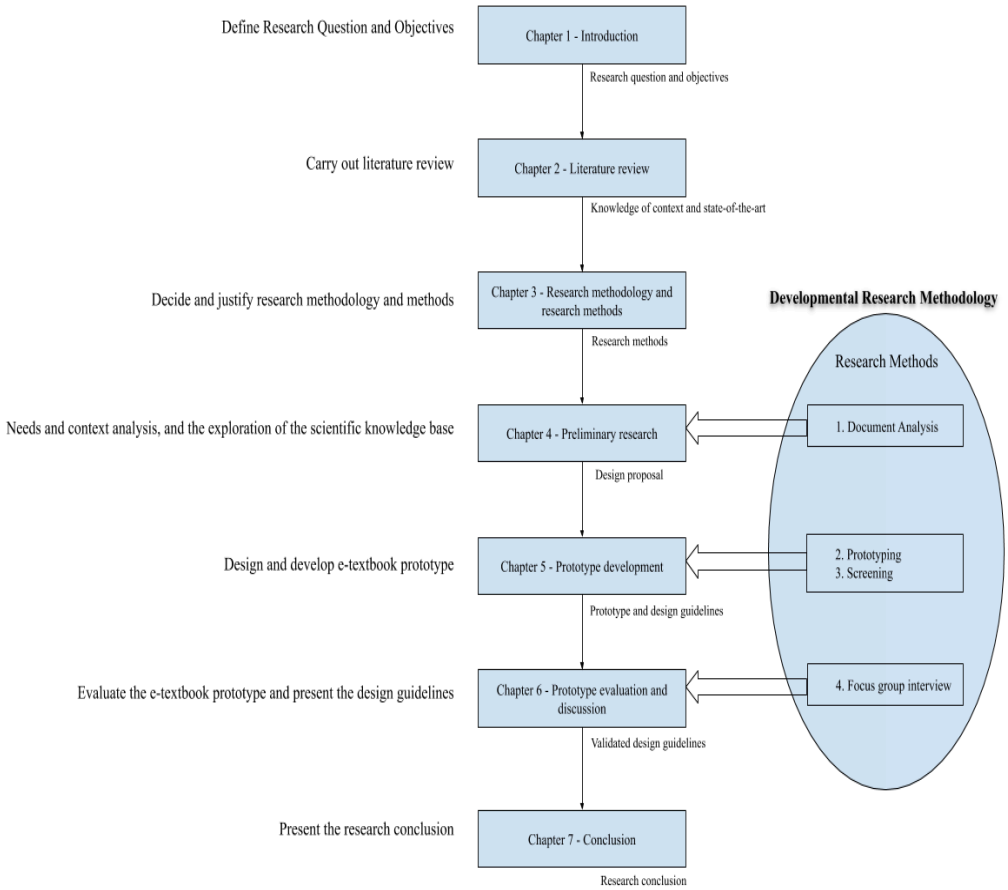


FIGURE 1.2: Thesis Structure.

Chapter 2

Literature review

2.1 E-textbook

2.1.1 Terminology and definition

The term "book" gives a clear picture in mind, which can be defined with its content, the structure of the content, the appearance of the book, and its intended functionality - collectively viewed as the 'book metaphor' [6], [13], [18]. Books written with the intended function of teaching and/or learning can simply be referred to as textbooks [19]. Textbooks are considered a special genre of books due to their content and didactical design. School textbooks have a twofold function - organizing the student's learning process and providing pedagogical interaction between textbook, student, and teacher. The contents provided in a school textbook is predetermined by the school curriculum [20].

Conventionally books are published in print media (paper) and bound to include only printable contents (text/graphics). The history of e-publishing can be traced back to 1971 when Michael Hart started the Project Gutenberg [21], [22], which currently provides 59000 free ebooks to read online or to download. The integration of the book metaphor into the electronic environment can be referred to as an e-book [6], [13], [18]. An e-book is a digital object which represents the familiar concept of the book in the electronic environment and can thus include non-printable contents (audio, video, etc) and provide functions otherwise not possible in the paper book (text search, hyperlink, etc) due to its digital/electronic nature [21]. The three main components of an e-book are hardware, software, and an e-book file. The e-book file is the digital object which is realized as an e-book within the electronic environment provided with a combination of hardware and

software [14], [21], [22]. More than 30 different formats are available for e-book files, the most used ones are: TEXT, HTML, CHM, PDF, and EPUB [4].

Studies have used different terms, such as electronic textbook, digital textbook, or e-textbook to represent a similar concept [4], [5], [23]. An e-textbook has been expected to be useful in education because of its flexibility, accessibility, interactivity, and extensibility [4]. E-textbooks can be replicas of traditional print products or could add non-traditional content like online assessments, games, and animations. In all cases, an e-textbook includes a finite content and/or activity set for a given area of study which is delivered to faculty and pupils digitally and is consumed on screens [5]. An e-textbook is not merely an electronic format of the paper textbook. It is expected to include collaborative, interactive, and other features which are possible due to its digital nature [24].

In the context of school (k-12) education, an e-textbook is considered as a special kind of e-book developed according to the curriculum standard which presents its contents similarly to the paper textbook style. It is an e-book integrated with classroom instruction which meets the pupil's reading habits and facilitates organizing learning activities [3], [7]. Metaphorically, e-textbooks in the digital learning device can be compared to the paper textbooks in the school bag, where a digital learning device can be a handheld, laptop, or desktop computer and metaphorically compared to the schoolbag [4].

Apart from the basic advantages of the e-textbook, such as high storage capacity, ease of transporting, access, update, and backup, it also offers the possibility to incorporate multimedia and interactive content such as interactive tests, games, and simulations [14], [22], [25], [26]. With the advancement in handheld computing devices and internet connectivity, digital textbooks started to be used in education more rapidly [4], [5]. Currently, over 20 countries are using e-textbooks in education [4].

2.1.2 Types of e-textbooks

Based on how much of the book metaphor has been implemented into the electronic version, e-books have been categorized into six types: the page-turner, scrolling, portable, multimedia, hypermedia, and cyberbooks. The content of the page-turner, scrolling, and portable e-books is limited to

printable content, which supposedly derives from the printed version of the book. The contents of multimedia and hypermedia e-books are a mix of printable content and multimedia, and the conceptual structure of a book is used to organize and present the contents. Multimedia e-books embed the multimedia content as part of the e-book file, whereas the hypermedia e-books hyperlink the multimedia content which can be a different file stored internally or can be an external resource in the Internet. The content of a cyberbook is mostly multimedia and hypermedia free from the conceptual dependence on the book metaphor [6].

The page-turner e-book, also known as "page-fidelity" or "print-fidelity" [5], is screen rendering of the print book and presents contents in page-turning style, whereas the scrolling e-book presents a print book on-screen in a web-page style [6]. The majority of e-textbooks are derived from a print product and are therefore a rigid or semi-rigid representations of the print book, which can be further supplemented with media-rich and interactive content [5].

Based on how e-textbook content is manifested, it can be classified into three types: applications, open online books, and e-books. Applications (or apps) are the manifestation of e-textbooks as a web application to present textbook content, multimedia content, and other functionalities via a web browser. Open online e-textbooks are collaboratively developed by teachers, education institutions, and national agencies to contribute to the global open educational resources (OER). The contents of these free e-textbooks are freely accessible web pages that teachers and pupils can utilize. Digitizing existing printed books as replacement textbooks is the easiest and widely recognized method to develop e-textbooks. This kind of e-textbook digitizes printed books without adding interactive and/or multimedia content [4].

Based on their accessibility and usability, e-textbooks can be categorized into three types: web-based, reading software-based, and device-based. The web-based e-textbook uses the HTML as file format, web-browser as reading software, and can be read on various devices with a web-browser. Reading software-based e-textbooks are software dependent due to their specific file format. For example, an e-textbook file in EPUB format requires an EPUB reader to read it. A device-based e-textbook is a device dependent e-textbook which is developed for certain devices, for example, Ebooks developed for Amazon Kindle [4], [21], [27].

2.1.3 Use in school education

E-textbooks have some perceived advantages over print textbooks such as cheaper cost of production and delivery, and the possibility of incorporating better contents otherwise not possible in print medium [4], [5], [22]. They can provide useful features such as note-taking, annotation, bookmarking, highlighting, and searching [4], [5], [7]. For teachers, the use of e-textbooks can provide easier methods to access, monitor, categorize, and document the pupils' learning activities [22]. Texts presented on an electronic screen and in print have no meaningful difference in learning performance so e-textbooks are at least comparable to print textbooks in terms of learning effectiveness [4].

The use of hyperlinks and multimedia has been discussed as one of the advantages of using e-textbooks over paper textbooks [7], [14], [26], though some researchers [8] argue that excessive connectivity and the enormous amount of data can result in cognitive overload and decline in the ability of pupils to concentrate. Studying with linear text is useful for understanding core concepts and remembering important facts, so hypertexts are not always useful and their effectiveness should be carefully interpreted [8]. The hyperlinking facility creates a new potential to navigate the content not possible in paper textbooks, though pupils also have a strong need for a guiding structure to provide navigation support. In traditional textbooks, the guiding structure is provided with the division of content into chapters, subchapters, and paragraphs. Therefore, finding an optimal combination of hyperlink-based navigation and guiding structure is an important issue to consider while using multimedia and hypermedia [28]. Studies have indicated the need for more research to define the pedagogical design of e-textbooks and to study the cognitive overload of using e-textbooks in school education [4].

In the context of school education, textbooks are daily-use technology and they are adopted in a top-down fashion. Due to this frequency of use and adaptation process, e-textbooks have a greater impact on in-service teachers unlike other technologies such as learning management systems (LMS) and presentation software [24]. Teachers' computer self-efficacy and anxiety toward using technology play a significant role in the adaptation of e-textbooks. Furthermore, technological factors such as the reliability of the devices are also a key issue for teachers to use e-textbooks in the classroom

[3], [24]. Even though e-textbooks have the potential to supplement print textbooks to expand their use, replacing the print textbooks entirely with e-textbooks is still premature [4].

2.1.4 Available design guidelines

Reliability, compatibility, usability, accessibility, and maintainability are the five main characteristics relevant to successful e-textbook design. A well-designed e-textbook is less prone to service failures (reliable) and can be used on multiple devices (compatible). It should be easy and effective to use for the given purpose (usable), easy to access and transport (accessible), and easy to troubleshoot and update (maintainable) [27].

One of the complete sets of guidelines for designing electronic books has emerged from the EBONI projects which have given more than 20 design guidelines under three broader categories [13]. As shown in Table 2.1, the first set of guidelines has been produced from the appearance and functionality of the paper book, such as the inclusion of a table of contents and index page. The second set of guidelines deals with integrating features possible in the electronic environment and the third set of guidelines talks about the guidelines for an e-textbook reader device.

TABLE 2.1: EBONI design guidelines, adapted from [13]

Adhering to the book metaphor	Cover your book. Include a table of contents. Include an index. Treat the book as a closed environment. Provide bookmarking and annotation functions. Provide orientation clues.
Adapting to the electronic medium	Provide a search tool. Use hyperlinks for navigation and cross-referencing. Use multimedia and interactive elements. Enable customization.
Hardware design guidelines	Employ high-quality display technology. Balance portability against legibility. Design devices for comfort.

Studies to define the appearance and functionality of e-textbooks for school education have also validated the effectiveness of adhering to the book metaphor in e-textbook design. They concluded that users want features of paper books to be transferred to e-textbooks and suggested that e-textbooks should use a similar structure and layout as paper books such as page flip effects and navigation [4], [7], [14].

Although the main function of e-textbooks is to show textbook content and other teaching materials, other common functions expected to be provided by e-textbooks are note-taking, annotating, searching, and highlighting. Multimedia presentations, scaffolds for the learning process, and automated evaluation of student work are believed to improve student learning, hence are advised to be included in school e-textbooks [7], [14], [22], [26].

Even though the interface and functionality of e-textbooks have been discussed widely, well-established design layouts and instructional principles to develop e-textbooks are not yet available [4], [14]. Studies about the design and development of e-textbooks and their use as learning materials in the school classroom are still at an initial stage [4], [22].

2.2 Multimedia e-textbook

2.2.1 Use of multimedia in education

Three basic forms of learning materials are printed materials (text, drawings, pictures, etc), analog audiovisual material (slides, film, radio, television, etc), and digital materials (CD-ROM, computer programs, web resources, etc) [28]. Multimedia technology is a core part of e-learning technologies which broadly refers to the use of various types of media such as text, audio, images, animations, and videos to enhance content visualization and user interaction [29]. Studies have suggested that educational technologies such as voice, video, and computer-based assessment can be effective tools for teaching and learning [30]. Replacement of hand-graded homework by computer-based assessment can be an effective instructional approach to improve student learning by saving time and economic resources [31].

Video and animation can present pre-generated learning content in multimodal forms which are helpful to increase a learner's engagement in active learning [29], [32]. Videos can also provide dynamic displays of reality by distorting it in various ways, such as slow-motion or time-lapse videos [32]. Use of video and interactive content in education enables teachers to encourage authentic learning and allow students to control the learning pace, facilitating the student-centered learning process [29], [33].

Media differs not only due to the type of its content (verbal, pictorial, static, moving, etc) but also due to the difference in perspective of learner

engagement. Five pedagogical categories have been suggested to classify educational media - narrative, interactive, adaptive, communicative, and productive [34]. This classification has been used by other studies also to define appropriate media types for different learning activities [35]. Table 2.2 details the five media types along with expected learning engagement and possible examples.

TABLE 2.2: Types of media, adapted from [34], [35]

Media type	**Learning engagement**	**Example**
Narrative	Attending	Text, image, audio, video
Adaptive	Experimenting	Simulation, educational game
Communicative	Discussing	Email, discussion forum
Productive	Expressing	Spreadsheet, modeling

Use of multimedia content in classrooms in the form of compact disks started in mid-1990 when personal computers began to show up in classrooms. Although it provided learning advantages, the development costs were high, and it was difficult to update multimedia materials along with printed textbooks [4], [5]. The time and effort required to develop multimedia content are significantly high compared to textual content, therefore finding effective ways to use multimedia content in education is still an important research topic [29].

In recent years, OER has been recognized as a tool to improve the quality of education which can provide an effective way to develop, use, and re-use educational multimedia resources. OER are licensed open source materials for teaching, learning, and research which include slides, lectures, videos, animations, homework, tests, podcasts, e-books, etc and are freely available to re-use [31], [36]. A majority of the OER allows users to edit and adapt the original content in various ways. Three common ways to adapt OER are mixing, adaptation, and asset extraction. Mixing is the way when OER are mixed with additional content to create a new resource, adaptation occurs when a single OER is adapted in multiple ways for multiple contexts, and asset extraction is applied when a part of OER is extracted and used in a completely different context [31].

2.2.2 Multimedia approaches for the learning process

Multimedia information is a collective set of various types of media, such as text, audio, images, animations, videos and games [29], [37]. The use of multimedia information and communication technologies to enhance content visualization and user interaction is becoming a core part of e-learning technologies [29]. It has been suggested that learning with multimedia allows greater use of learner's effective working memory capacity because multimedia presentations can include visual and auditory information at the same time [37]. Similarly, game-based learning (GBL) can help students to gain a deeper understanding by turning the learning process into a combination of entertainment and interaction-based tasks [29].

Videos

Videos are important tools for learning and instruction because they contain both verbal and nonverbal information, thus utilizing both hemispheres of the brain, the left hemisphere to process the verbal input and the right hemisphere to process the nonverbal input [33]. Moreover, the dual-code theory suggests information communicated in both verbal and pictorial form provides a double track for the processing, encoding, and retrieval of given information [38].

Web-based video distribution services like YouTube are an innovative technology tool for education [39], [40]. The launch of YouTube in 2005 and the ever-increasing Internet bandwidth have given a new possibility of using video podcasts in education [39]. Although use of video lectures by educational organizations has already started, conventional standards to create video lectures or guidelines about the presentation style of video lectures are not available [41].

Studies have categorized educational videos in various ways. Depending upon the purpose, video podcasts have been broadly categorized into lecture-based, enhanced, supplementary, and worked examples [39]. Based on the production technology and media richness [41] presents three types of video lectures: lecture capture, picture-in-picture, and voice-over presentation. Table 2.3 makes a side-by-side comparison of the video types presented by [39] and [41] with examples.

TABLE 2.3: Different types of video lectures, adapted from [39], [41]

Type by [39]	**Type by [41]**	**Example**
Lecture-based	Lecture-captured	Recordings of a lecture using a digital video camera
Enhanced	Voice-over presentation	PowerPoint slides supplemented with an audio explanation
	Picture-in-picture	Instructor's recorded image and voice, PowerPoint slides, subtitles, and animation
Supplementary		included administrative support, summaries, other materials
Worked examples		video explanations of problems that students may need to solve

Animations

Animations are a useful medium to present in a simpler form, inherently dynamic complex concepts which are otherwise not easily observable. Dynamic concepts such as biological processes and chemical reactions, when presented as animations, can help to draw students' attention and motivate them towards learning [30], [38]. Animations can be entirely generated by the computer, they can be developed by recording video from a real scene, or can be produced as a mixture of recorded video and computer-generated animation [38].

According to the types of media provided by [34], animations can act as narrative, interactive, or adaptive media. Narrative animations are computer-controlled, whereas in interactive and adaptive animations the user can provide inputs and control the pace or events. Simulations are adaptive animations which provide a high degree of interactive learning experience in a discovery-learning approach [38].

Games

To reduce anxiety and increase enjoyment in the learning process, especially for subjects like mathematics and science, educational games can be an effective tool in school education [42]. Games are more beneficial for learning when they are used as part of a package of instructional activities rather than as a stand-alone activity [40].

Researchers have discussed six key learning functions which can be assisted by games in school education. These six functions are: activate prior learning, teach the relationship between knowledge and context, provide feedback and assessment, encourage to apply gained knowledge, accommodate experiential learners, and foster sharing of knowledge [42].

2.2.3 Multimedia in e-textbook

E-textbooks are considered more advanced than print textbooks, especially because they can accommodate multimedia contents and integrate interactive functions [4]. Even though researchers have classified ebooks based upon whether they contain multimedia or not [6], e-textbooks as an educational tool are inherently considered as containing some form of multimedia and interactive features [27].

Studies have suggested a wide range of multimedia and interactive media for school textbooks, such as mixed composing of text and other media, short clips of audio and video, graphics, and animations [7]. A survey of school pupils has concluded that pupils need to see both still and moving images in e-textbooks, and animations and videos are a popular way of information dissemination [14]. A comparative study to find common features of e-textbooks used in school education in Japan and South Korea has found that video clips and diagram animation in Japanese e-textbooks and Flash Movies, Media Player, and 3D shapes in South Korean e-textbooks are common ways of showing non-printable teaching materials [26].

The design of multimedia e-textbook requires extra attention to decide how to integrate and display multimedia contents [6]. Such contents are integrated mainly in two ways: embedding multimedia as part of the e-textbook file, and storing multimedia as a separate file, then linking it to the e-textbook file with a hyperlink [5]. In paper textbooks, the orientation of a learner is guided by dividing the content into chapters, by providing orientation clues such as page numbers, etc. In an educational system, the orientation of a learner is expected to be guided by the underlying curriculum [43]. Therefore, to display the multimedia content, it is necessary to define a conceptual place for its display so that the orientation problem and the risk of confusing users with too much information can be mitigated [6]. Multimedia development is not an easy process because it includes a wide variety of content requiring different methods to produce, and different data

representations to store and render, which is difficult for regular teachers to manage [29].

Compared to text and images, videos have an excessive file size which requires significantly larger storage capacity and download speed for offline or online use [39], therefore video poses technical problems for its frequent use in e-textbooks. About the use of videos in education, basic pedagogical questions, such as 'What is the optimum length for videos?' and 'Are summaries more effective than full lecture videos?', also need further research exploration [39].

2.3 Context of school education in Nepal

2.3.1 Socio-economic background

Area	147,181 sq km
World rank	96
Population	29,717,587 (July 2018 est.)
World rank	47
GDP	US$79.19 billion (2017 est.)
World rank	95

Image file from the Wikimedia Commons, https://upload.wikimedia.org/wikipedia/commons/thumb/d/d4/Nepal_%28orthographic_projection%29.svg/553px-Nepal_%28orthographic_projection%29.svg.png

FIGURE 2.1: Nepal (colored green) in the globe with some facts [44].

Nepal is located in Southern Asia, between China and India. It is a landlocked country, with a total area of 147,181 square kilometers [44]. As per 2011 national census record, Nepal has a population of 26.5 million [1], (July 2018 estimated 29.7 million [44]). It is one of the least developed countries with a per capita annual income of USD 762 [1] and gross domestic product (GDP) of USD 79.19 billion (2017 estimation) [44]. Figure 2.1

shows the geographical location of Nepal in orthographic projection map along with some key facts.

Agriculture and remittance have been identified as Nepal's largest source of income, accounting for 34 % and 21 % of GDP in 2012 respectively. Agriculture employs 70 % of the population at home and a significant portion of the youth population is in foreign countries for employment. About 2.2 million labor permits were issued over the six-year period 2008/9 to 2013/14 for foreign employment, which represents about 8 % of Nepal's total population. [1], [45].

2.3.2 Status of ICT

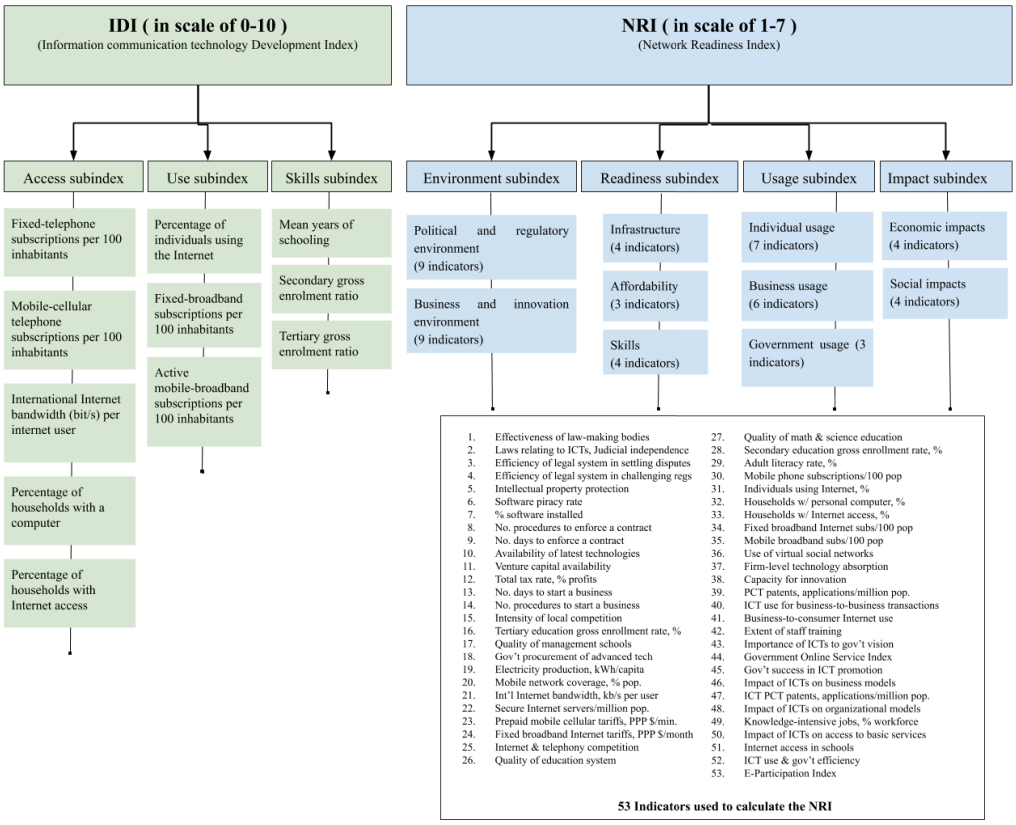


FIGURE 2.2: IDI and NRI, sub-indexes and indicators, adapted from [46] (p. 27) and [47] (p. 35).

There is a severe lack of national statistics in Nepal to assess the status of ICT, thus policymakers have to depend solely on global ICT related statistics and indexes [48]. I have used the ICT Development Index (IDI) and Network Readiness Index (NRI) to assess and compare the context of

Nepal with five other countries: United Kingdom (UK), South (S) Korea, Japan, Malaysia, and China. These have been selected for context comparison because most of the studies reviewed so far are within the context of specific countries. For example, [18] and [6] (UK), [4] and [8] (S Korea), [26] (Japan), [22] (Malaysia), and [7] and [3] (China) are, entirely or partially, within the context of countries given within the parenthesis.

Launched by the International Telecommunication Union (ITU) in 2008, the IDI is a composite index comprising 11 indicators into one measure [46]. The NRI is also another composite indicator developed by the World Economic Forum in 2001. It combines four main categories further distributed across 10 subcategories with 53 individual indicators [47]. The IDI and NRI scores are used to assess the level of ICT development and the state of networked readiness in countries across the world [46], [47]. As shown in Figure 2.2, the IDI is calculated based on the values of 11 indicators like fixed-telephone subscriptions per 100 inhabitants, percentage of individuals using the Internet, mean years of schooling, etc. Similarly, NRI is calculated based on 53 indicators, including effectiveness of law-making bodies, availability of latest technologies, electricity production, Internet and telephony competition, etc. The 53 indicators of NRI are categorized into 10 categories, such as political and regulatory environment, infrastructure, individual usage, economic impacts, etc.

TABLE 2.4: Values of IDI and constituent sub-indexes [46]

	S Korea	UK	Japan	Malaysia	China	Nepal
IDI score for 2017 (0-10)	8.85	8.65	8.43	6.38	5.60	2.88
IDI rank (176 countries ranked)	2	5	10	63	80	140
IDI access sub-index (0-10)	8.85	9.15	8.80	6.93	5.58	3.62
IDI use sub-index (0-10)	8.71	8.38	8.15	6.17	5.27	1.73
IDI skills sub-index (0-10)	9.15	8.17	8.22	5.70	6.28	3.73

Table 2.4 shows the value of IDI and Table 2.5 shows the value of NRI for Nepal and the other five countries. The IDI values are on a scale of

0 to 10, where 10 represents the best. Looking at the values for IDI and its subindexes, it is evident that the access and use of ICT services, as well as the skills required to develop, use and maintain ICT infrastructures, show significantly lower status compared to other countries given in the table. For example, the value of IDI use sub-index for Nepal is only 1.73, in comparison, it ranges from 5.27 to 8.71 for the other five countries.

Table 2.5 shows values for some of the indicators used to measure NRI, such as mobile network coverage, households with a personal computer, households with Internet access, etc. In Nepal, only 8.2 % of households have personal computers and only 5.6 % of households have Internet access, which is significantly lower than the other countries used for comparison. For instance, in S. Korea 98.5 % of households have Internet access and in the UK 90.8 % of households have personal computers.

TABLE 2.5: NRI and some of the indicators [47]

	S Korea	UK	Japan	Malaysia	China	Nepal
NRI score for 2016 (1-7)	5.7	5.6	5.6	4.9	4.2	3.2
NRI Rank (139 countries ranked)	8	10	13	31	59	118
Mobile network coverage, %	99.7	99.9	99.9	95.4	99.5	80.0
Households with personal computer, %	90.8	83.3	78.3	66.5	46.7	8.2
Households with Internet access, %	89.9	97.5	98.5	65.5	47.4	5.6
Quality of education (1-7)	4.7	4.5	3.7	5.4	3.9	3.7
Secondary gross enrolment rate, %	124.4	101.9	97.7	71.1	96.2	67.2

Nepal has a total of 5,716,419 Internet users as per July 2016 estimation, which is 19.7 % of the population. Estimated number of fixed broadband

subscriptions by July 2016 is 224,184 which is equivalent to about one subscription per 100 inhabitants [44]. Studies have also found that access to the Internet is low and mostly city-centric, the quality is substandard, and the price is not affordable for the majority of the population [48].

2.3.3 Status of education

Prior to the establishment of the Nepal National Education Commission in 1956, access to school education in Nepal was limited and exclusive to the elite and wealthy populations. The education system plan in 1971 established the foundation for Nepal's modern formal education system. Nepal's new federal constitution, declared in 2015, considers free and compulsory basic education and free secondary education as a fundamental right. The formal school education in Nepal is 12 years long, divided into grades from 1 to 12, with each grade a year-long period. Grades 1 to 8 and grades 9 to 12 have been defined as basic education and secondary education respectively. Nepal has 7.52 million children of age 5 to 16 enrolled in grades 1-12, with no significant difference between genders (50.15 % boys and 49.85 % girls) [1].

After the democratic revolution of 1990, the education policy focused on increasing access, equity, and inclusiveness of the basic education. It made significant progress, especially in the girls' enrollment which grew by 65 % in eight years [49]. Nepal has 312,687 teachers (36.3 % female, 63.7 % male) in 35,222 schools among which 29,207 schools are community/public and 6,015 schools are private/institutional [50]. About 74.6 % of the pupils who enroll in basic education reach grade 8, which signifies a severe issue of dropout rate in school education of Nepal [1].

As shown in Figure 2.3, 53.6 % of the population have education attainment between grade 1 to 8 [50] whereas the percentage of the population with age 5-14 years is only 25.2 % [51]. If the usual age of a pupil to pass grade 8 is considered to be 14 years, the data indicates that almost 30 % of the population who have primary or lower secondary education in Nepal are over 14 years of age and might have dropped out of the education system already. The percentage of the population with age 25+ years is 45.1 % [51] but the percentage of graduates and postgraduates combined makes only 3.4 % of the population [50], which signifies a severe lack of human resources with a university education or similar qualification.

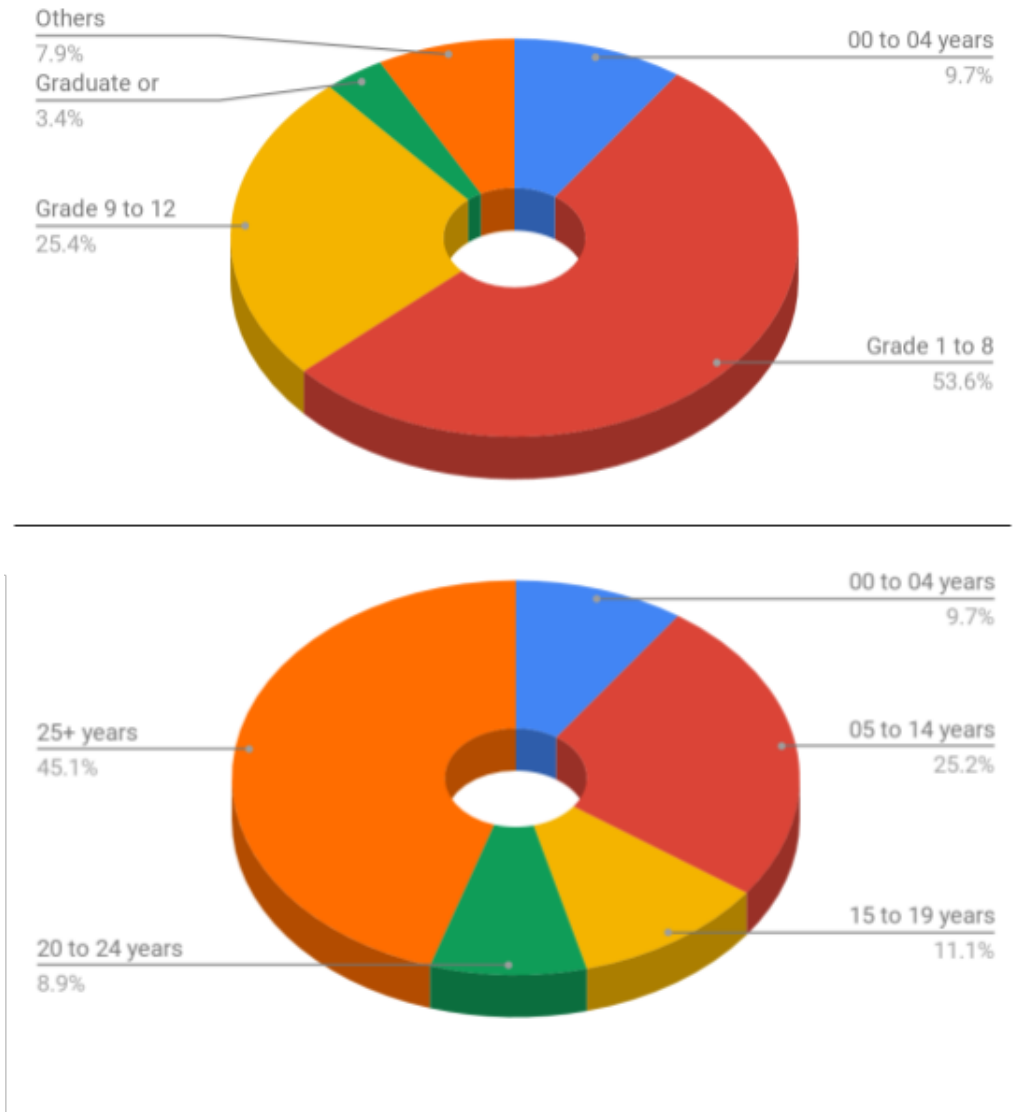


FIGURE 2.3: Comparing the distribution of educational attainment and the distribution of age group, adapted from [50], [51].

School education in Nepal mostly depends on textbooks and teacher-focused classrooms. The school textbooks are considered to be the primary and complete learning material and all teaching is tied to textbooks. Moreover, supplementary materials for students are mostly not available and timely printing and distribution of textbooks is still an issue to solve [1].

2.3.4 ICT in education

Use of ICT in school education of Nepal is still at a very primitive stage. The learner-to-computer ratio at the primary education is more than 500:1 and more than half of the available computers in schools are primarily used for administrative tasks. Reallocating the computers from administrative tasks to teaching and learning is also challenging due to the lack of basic infrastructure, such as electricity. In Nepal, only 1 % of primary schools and 6 % of secondary schools are connected to the Internet, and only 0.5 % of primary and secondary schools combined have computer-aided instruction available. The popular global initiative One Laptop Per Child program, which provides developing countries with specifically designed low cost laptop computers to promote one-to-one computing, had given 6000 units to Nepal by June 2013, which accounted for more than one-third to one-half of all the computers then available in schools for similar purposes [52].

The master plan to implement ICT in school education, started in 2013, defined four pillars of ICT in education: infrastructure, connectivity, teaching-learning materials, and human resources. The implementation of this master plan has increased access to computers and the internet in schools, which may promote further use of ICT in school education [2], [50]. The master plan was implemented in a span of five years, from 2013 to 2017. It invested 5,477,971,000 Nepalese Rupee (Approx. USD 50 million) to the four main components: development of ICT infrastructure, development of human resources, development of digital learning materials, and enhancement of education system [2].

2.3.5 Prospective use of e-textbooks

At present, the CDC maintains the e-library and multimedia learning materials [53], though the availability of digital learning materials is limited to downloadable school textbooks in PDF and a few audio-visual contents. The SSDP has identified various strategies to improve the use of ICT in school education, which also includes the preparation of digital teaching-learning materials and the development of e-libraries [1]. Development and use of e-textbooks might provide an integrated, efficient, and feasible solution for overall use of ICT in school education of Nepal.

Chapter 3

Research methodology and research methods

3.1 Educational design research

A logical sequence of research starts with the identification of the primary research problem which then leads to intended research functions followed by the choice of research design [11]. Various research functions have been discussed in literature, such as to describe, to compare, to evaluate, to explain, and to design and develop. To address a particular research function, one or many research designs/approaches can be used [9]. Based on the nature and stage of the research problem a wide variety of research approaches can be used in the domain of information systems. As shown in Table 3.1, these approaches are: experimental, causal-comparative, historical, developmental, correlational, case study, grounded theory, ethnography, and action research. Overall these approaches aim either to theory building, theory testing, or theory revising [11].

Table 3.1: Key categories of research, taken from [11]

Stage of problem	**Categories of theory**	**Approach**
Evaluation	Testing or revising	Experimental
Evaluation	Testing or revising	Causal-comparative
Description	Testing or revising	Historical
Description	Building or revising	Developmental
Description	Testing	Correlational
Exploration	Building or revising	Case-study
Exploration	Building	Grounded theory
Descriptive	Building	Ethnography
Applied exploration	Building or revising	Action research

In causal-comparative research, the researcher does not control the independent variable like in experimental research, but rather observes and measures its performance on the dependent variable in naturally-occurring research setting. Correlational studies are carried out to determine if a predictive relationship exists between an independent and dependent variable so that knowing the value of one can be used to predict the value of another. Therefore, at a practical level, no distinction is required between independent and dependent variables in correlational studies. An empirical investigation of a contemporary phenomenon within its natural setting is a case study research where evidence is usually qualitative and multiple sources are used for the evidence. Historical research mainly relies on the interpretation of qualitative data to explain the causes of change in history. Ethnographic research is best used to explain various issues within a group of individuals that have been together for a considerable length of time and thus share a common culture. Action research is a type of research that focuses on finding a solution to a local problem in a local setting and the researcher himself or herself is part of the practitioners' group that faces the problem. Grounded theory is used when current theories in the literature fail to explain an observed phenomenon due to flaws in their fundamental assumptions, and research to establish a new theory is required from scratch [11].

Developmental research can be viewed as the process of answering 'How can researchers build a thing to address the given research problem?' It is generally applicable when the primary research function is to build or revise products or solutions, although not all development processes require following the development research approach. It is suitable when the following two criteria are fulfilled: there is a lack of solutions to even test for efficacy, and the process of building the solution is also not known. The three main phases of developmental research are establishing criteria for the product, developing the product, and evaluating the product as to whether it satisfies the criteria [11]. The developmental research approach is also referred to as design research and within the educational domain has been discussed under the term educational design research [9], [16].

In educational design research, the process of designing, developing, and evaluating educational interventions is studied systematically. It is an appropriate research design to develop research-based solutions to address educational problems. Apart from product development, design research

is also applicable to develop or validate theories about learning processes, environments, etc. As shown in Table 3.2, based on the research goals, design research can be categorized into three types: development studies, validation studies, and implementation studies [9].

TABLE 3.2: Three types of design research [9]

Type of design research	**Research goal**	**twofold yield**
Development studies	Development of intervention	1. A research-based intervention as a solution to a complex problem, and 2. (Re-usable) design principles.
Validation studies	Theory development and/or validation	1. Validated educational intervention, and 2. Theories about learning and learning environments, and/or validated design principles.
Implementation studies	Implementation or up-scaling	1. Implementation of educational intervention, and 2. Strategy and conditions under which implementation can happen (design principles).

The development studies type of design research encompasses the design and development of products as a solution to an educational problem with the additional aim of advancing knowledge about the process of designing and developing them [9], [16]. The aim of an early-stage design research is not the theoretical yield, rather it provides a foundation for theoretical yields from later randomized clinical trials or other laboratory tests [10]. Development studies within design research not only develop research-based interventions but also provide reusable design principles for future use. The two types of design principles anticipated from development studies are the procedural design principles that reflect the characteristics of the design approach and the substantive design principles that reflect the characteristics of the design (product) itself [9], [54].

The validation studies type of educational design research has the primary purpose of developing or validating theories and it is carried out with a systematic study of educational interventions in their naturalistic settings such as a school classroom. Such educational interventions can be learning processes, learning environments, or learning technologies and the purpose

of the study is to develop or validate theories about the use of interventions and/or their design process. The implementation studies type of design research focuses on the implementation or scaling-up of the developed and validated interventions, and while doing so details the strategies and conditions optimal for similar implementations [9].

The three main phases of design research as development studies are preliminary research, development or prototyping, and assessment. The preliminary research is carried out to get insights into an existing problem situation and to propose the desired outcomes and characteristics for the product in question. The development or prototyping phase consists of multiple prototyping, each followed by formative evaluation. Two common evaluation methods described for educational design research are formative and summative. Formative evaluation is carried out to improve the prototype whereas summative evaluation is performed to proof the product. In the early stages of design research, the development phase usually provides a partially completed product as an output. Based on the stage of the product developed (completed/partially completed), summative or semi-summative evaluation is performed in the assessment phase. The term semi-summative evaluation is used to indicate the evaluation carried out on a partially completed product. The evaluation of a partially completed product is done to improve the product while advancing it as a completed product, as well as to proof the design guidelines established so far on the design process. These dual objectives make the evaluation performed on partially completed products both formative and summative in nature, thus termed as semi-summative evaluation [9], [17].

Literature has proposed four quality criteria to assess the overall quality of developed educational intervention: relevancy (content validity), consistency (construct validity), practicality (expected and actual), and effectiveness (expected and actual). An intervention is considered relevant when there is a need for the intervention and its design has followed the state-of-the-art scientific knowledge. Consistency or construct validity is achieved by ensuring that the intervention is logically designed and consistent with the identified needs and context. The practicality of an educational intervention is determined by how easy and usable the end-users find it whereas the effectiveness is the capability of the intervention to produce the desired outcomes [9], [17].

Various research methods have been suggested to carry out formative

evaluations on the intermediate prototypes during the development phase, such as screening, focus group interview, walkthrough, tryout, etc. Screening is a self-evaluation method of formative evaluation in which the product developer/s evaluate/s the intermediate design by using a checklist of criteria expected to be realized in the product design [17]. As shown in Table 3.3, the selection of the research method for evaluation is determined by the design stage and quality criteria needing to be assessed. The quality criteria such as actual practicality and actual effectiveness should only be measured when the end-users can have practical experience to the product in a target setting [9]. The grey background of the cells in Table 3.3 indicates the quality criteria on focus and the suitable evaluation methods preferable at a particular design stage. For example, the quality criteria on focus at design proposal stage are relevancy and consistency which are best evaluated with screening and/or focus group interview. When a design advances from design proposal to global design, partly detailed product, and completed product, the quality criteria on focus shift from relevancy and consistency to practicality and effectiveness thus the more suitable evaluation methods such as walkthrough, micro-evaluation, and try-out should be used.

TABLE 3.3: Formative evaluation methods, grey indicates that with a shift in focus more suitable evaluation methods also come into play [17]

Quality criteria	**Design proposal**	**Global design**	**Partly detailed product**	**Completed product**
Relevancy	Screening, focus group	Screening, focus group	Screening, focus group	Screening, focus group
Consistency	Screening, focus group	Screening, focus group	Screening, focus group	Screening, focus group
Practicality-expected	Screening, focus group	Screening, focus group	Focus group, walkthrough	Focus group, walkthrough
Practicality-actual			Micro-evaluation	Micro-evaluation, tryout
Effectiveness-expected	Screening, focus group	Screening, focus group	Focus group	Focus group
Effectiveness-actual			Micro-evaluation	Micro-evaluation, tryout

3.2 Suitability of the educational design research

About the inappropriateness of design research [10] states, "If the problem has a known or standard solution, and there is general agreement on when to apply the solution, and the solution has been regularly successfully applied in various settings, design research is probably a poor use of resources." Therefore the justification for the choice of research design is to argue that the research problem does not have a standard solution, and/or if a solution exists, it has not been validated in a similar context in question.

Some basic looking questions, such as how to structure subject matter, and in what order to present it etc, require definitive answers in the design of digital learning materials which have not yet been decomposed in a comprehensible manner [55]. This has also been reflected by the literature review as a lack of design guidelines about how to integrate and display multimedia content within an e-textbook environment. If e-textbook content is limited to the printable content derived from the paper textbook then the need to define structure and order for the content is not necessary because it is already determined by the school curriculum. Multimedia content is usually not a part of the print textbook and thus adds the requirement of defining structure and order while integrating these as an e-textbook content.

A design process is the generation and evaluation of specifications for artifacts whose form and functions are expected to achieve objectives and satisfy specified constraints. A design process starts with a situation involving a perceived problem or opportunity and ends with a developed artifact which will have to function within a context [55]. The context is an important factor to consider in the field of learning science to understand the relevance of any educational intervention in its realistic settings. Educational interventions developed for one context cannot be equally relevant in another context. An educational intervention can be a curriculum, learning process, learning material, ICT application, etc, and context is defined with a combination of various factors such as available infrastructure, ICT literacy of target users, socio-economic conditions, etc. For the domain of educational technology, it is advisable to conduct research aimed at developing an optimal solution for a certain context rather than doing research for comparing available solutions that were developed for rather different

contexts [9], [10]. Design principles for multimedia e-textbooks have not been defined in their entirety and the research problem is drawn from the context of school education in Nepal which differs significantly compared to other contexts within which similar studies have been conducted. This significant difference in context is essentially due to the difference in available ICT infrastructure and skills, and their overall use in school education.

3.3 Implementation of the educational design research

Development of an e-textbook as a complete product, its implementation as an educational intervention in realistic settings, and the summative evaluation of the development process, product, and implementation is a broad topic to conduct research under within the scope of this Master's thesis. Such design research in its entirety would require all three types of studies development, validation, and implementation, at some stage. One sequence can be development studies to develop the product as an educational intervention, followed by validation studies to validate the use of the intervention as an effective educational tool, and finally implementation studies to adopt and adapt the intervention within the naturalistic educational settings. Therefore as a first step, this research work has followed the developmental studies type of design research, and it is limited to developing a prototype of e-textbook system and carrying out a semi-summative evaluation for the prototype assessment. The prototype of the e-textbook system and a set of design guidelines are the outcomes of this thesis work. The prototype can be developed into a complete product or used as a reference for new developments. A set of design guidelines will be presented on how to design multimedia e-textbooks, which is expected to be useful in the process of designing and developing e-textbooks in school education of Nepal and similar contexts.

One of the formats to present design principles is given by [54], which has been discussed in other literature [9] too. The format is: "If you want to design <intervention X> for the <purpose/function Y> in <context Z>, then you are best advised to give <that intervention> the <characteristics A, B, and C> [substantive emphasis], and to do that via <procedures K, L, and M> [procedural emphasis], because of <arguments P, Q, and R>."

I have used this format to present the research questions and their answers at various stages of the design research as shown in Figure 3.1. Essentially the objectives of design research can be viewed as defining each variable given in the above-mentioned format of presenting design principles. Such variables are X as the intervention, Y as the purpose of the intervention, Z as the context within which the intervention is planned, A, B, and C as the characteristics of the intervention, K, L, and M as the procedures to follow while designing the intervention, and P, Q, and R as the arguments for following the procedures.

As shown in Figure 3.1, the preliminary research not only defines the intervention, context, and function but also establishes the characteristics of intervention and proposes the procedures to achieve those characteristics. The developmental phase is an iterative process consisting of designing and revising the intervention to achieve its proposed characteristics. The assessment phase ascertains that the developed intervention is as per the criteria established in the preliminary research phase.

3.3.1 Preliminary research phase

Two important activities performed in preliminary research are needs and context analysis, and an investigation of the scientific knowledge base. The needs analysis looks into the perceptions of stakeholders on the current situation and the context analysis is aimed at exploring the problem environment and scope for the innovation. Investigation of the scientific knowledge base helps to make relevant and valid design decisions by providing insight into the state-of-the-art knowledge. Research methods commonly used for needs and context analysis are focus group interviews, lesson observations, document analysis, and case studies. The exploration of the scientific knowledge base is achieved via various methods such as a literature review, expert appraisal, and analysis and evaluation of existing projects. This phase results in the first blueprint for the intervention, with the main emphasis on content validity [9], [17].

A low-cost way to obtain empirical data is document analysis which involves skimming, reading, and interpretation of documents. The documents to be analysed are usually among the documents selected during the literature review, but not limited to this and can include any documents if felt necessary and justified by the researcher. Documents to be analysed

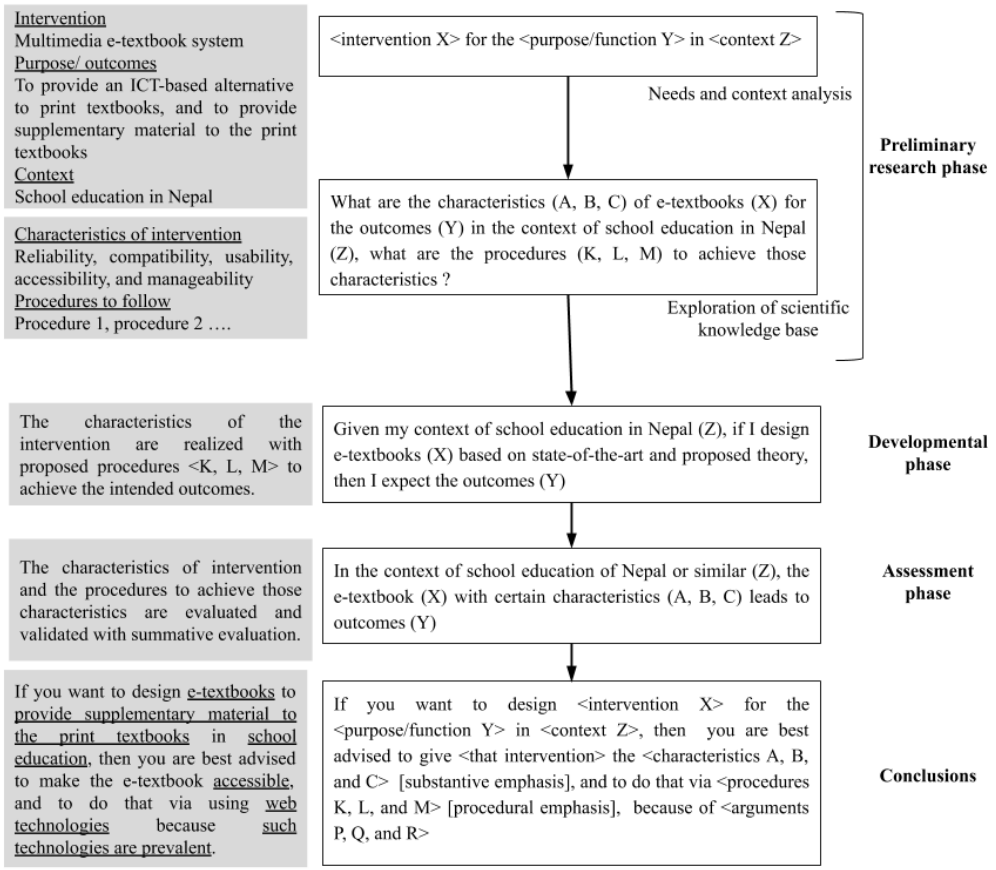


FIGURE 3.1: Overview of research questions in different stages of design research, adapted from [9].

for a preliminary study should be carefully selected so that the necessary information can be targeted efficiently. It is often combined with data from interviews and observation to minimize bias and establish credibility. Document analysis is an iterative process combining elements of content analysis and thematic analysis. Content analysis is a process of organizing information into categories and thematic analysis is a form of pattern recognition within the data to identify themes [56]. The focus group is a variation of the group interview which is used by researchers to collect data and discover the perceptions of participants around a focused topic [57]. According to [58], focus group interview is "a technique involving the use of in-depth group interviews in which participants are selected because they are purposive, although not necessarily representative, sampling of a specific population, this group being 'focused' on a given topic."

Even though a combination of various methods is ideal for the needs and

context analysis to minimize bias, in this research only the document analysis method has been used, primarily due to the time constraint that arose from the research limitations. The exploration of the scientific knowledge base has been carried out with a thorough review of literature which provides insight into the state-of-the-art about design, development, and use of e-textbooks. The state-of-the-art provides some design guidelines but not all, especially to address the multimedia part of e-textbooks. Therefore I have proposed a framework to define, integrate, and display multimedia content as part of an e-textbook. The understanding of context, scientific knowledge base, and the proposed framework collectively provides a foundation to define the required characteristics of the intervention and proposes the procedures to achieve those characteristics.

As shown in Figure 3.1, the preliminary research phase defines the intervention (X), context (Z), and functions of the intervention (Y). It also details the expected characteristics of intervention (A, B, C) and proposes the procedures via which the characteristics can be realized (K, L, M). These definitions all together serve as a design blueprint of the e-textbook system.

3.3.2 Development phase

Instrumental, communicative, pragmatic, and artistic are four different development approaches on educational design, each of which can be the most adequate for certain design situations due to their specific usefulness [16]. Among these four paradigms of educational design research, this thesis work has followed the pragmatic paradigm. The formulation of the objectives is central in the instrumental paradigm so it can be viewed as a planning-by-objectives approach where great emphasis is on preliminary data collection and analysis which guides the overall development process. Communication with stakeholders to reach consensus is of primary importance in the communicative paradigm where regular communication between developers and other stakeholders is required throughout the development process. The artistic paradigm can be seen as an approach to create products based on the connoisseurship of the developer/s [16].

The pragmatic paradigm of design research is based on a repeated tryout and revision of prototypes which serve as essential means for identifying the requirements of the product [16]. Prototyping is a process of creating an early version of the final product to get a better understanding of the

design problems and to create the final product specifications. It creates possibilities to incorporate the user more explicitly in the design process by providing the users with a working example of the proposed system. Such prototypes are evaluated to identify design requirements and to determine the usefulness of the product [16], [28].

The development phase consists of multiple prototypes, each followed by a formative evaluation to improve and refine the product. Four main stages of this phase can be identified: the development of a design proposal, global design, partly detailed product, and completed product [9], [17]. In this thesis work, only the first two stages are completed within the development phase. So the final output of this development phase is a global design of the e-textbook system which is passed to the assessment phase. The design proposal is the only intermediate prototype which has been evaluated in a formative way with the screening method, whereas the global design has been treated as the final prototype and forwarded for the semi-summative evaluation to the assessment phase.

Design proposal

The design proposal is the first prototype which consists of a general description of the product with a focus on its substantive parts. This proposal is written based on the results of the preliminary research phase [17]. I have presented the design proposal as a combination of multiple software design artifacts such as use case diagrams, data-flow diagrams, sequence diagrams, component diagrams, and user interface mock-ups. As shown in Table 3.4, this design proposal is evaluated for consistency and relevancy with the screening method. Screening is a self-evaluation method of formative evaluation which is performed by the members of the design research using a checklist of important characteristics or design specifications. It has low resistance to revision and is usually limited to finding obvious errors only [9], [17].

TABLE 3.4: Formative evaluation of the design proposal

Relevancy	Consistency	Expected Practicality	Actual Practicality	Expected Effectiveness	Actual Effectiveness
Screening	Screening	Not evaluated	Not evaluated	Not evaluated	Not evaluated

Global design

The second stage of the development phase consists of developing a global design which is a working prototype of the e-textbook system in its primitive stage. The prototype e-textbook system is a web application that can be deployed on web servers and used via web browsers. The prototype serves as the final output of the development phase that is ready for the final assessment. It has realized the proposed characteristics (A, B, C) which are expected to lead it to the intended outcomes (Y). At this point, the research question can be rephrased as, given my context of school education in Nepal (Z), if I design e-textbooks (X) based on state-of-the-art and proposed theory, then I expect the outcomes (Y).

3.3.3 Assessment phase

The assessment phase is necessary to evaluate whether the product from the development phase meets the intended requirements. In design research in its entirety, a product ready for implementation is usually the output from the development phase which requires a summative evaluation. Carrying out complete educational design research was not possible within the scope of this Master's thesis. Thus the development phase of this design research is limited to providing a prototype product that has been evaluated semi-summatively in this assessment phase.

Summative evaluations are costly, time-consuming, and need to meet criteria that are hard to meet in educational settings. For example, a quasi-experimental research design is required to reveal cause-effect relationships such as the effect of an intervention in learner results. Criteria that need to be taken into consideration while applying quasi-experimental research designs are often difficult to meet in educational settings, for example, it is often not possible to randomly assign respondents to groups, it may take a long time before learning effects can be measured, etc. Therefore a summative evaluation should not be performed until the intervention has sufficient potential effectiveness while used in realistic settings [17].

The assessment phase of early design research is usually a semi-summative evaluation with two-fold objectives: concluding whether the product meets specifications determined at the preliminary research phase, and collecting recommendations for improvement [9]. The aim of a summative evaluation is to proof which primarily deals with validating

that the product meets the specifications. Formative evaluation is usually carried out to improve the product by collecting recommendations [17]. So with both aims, evaluation carried out on the prototype e-textbook system at the assessment phase is a semi-summative evaluation. The main quality criteria to evaluate at the assessment phase are practicality and effectiveness of the prototype e-textbook system. The prototype is not a completed product and lacks the required functionalities to evaluate whether target users can work with the product in a realistic setting. In such instances, it is not advisable to evaluate actual practicality and actual effectiveness and the methods, such as expert appraisals or group discussions, should only be limited to access the expected practicality and expected effectiveness [9]. As shown in Table 3.5, only four quality criteria have been evaluated for the prototype e-textbook system with a focus group interview.

TABLE 3.5: Semi-summative evaluation of the global design

Relevancy	Consistency	Expected Practicality	Actual Practicality	Expected Effectiveness	Actual Effectiveness
Focus Group	Focus Group	Focus Group	Not evaluated	Focus Group	Not evaluated

The semi-summative evaluation has been carried out with a focus group interview for four quality criteria: consistency, relevancy, expected practicality, and expected effectiveness. Sixteen respondents were selected from Kathmandu, Nepal to represent the four main perspectives of stakeholders: students, teachers, policymakers, and developers. In the focus group interview, a group of respondents reacts to the prototype and data is collected via interviews. Four students of grades 9 and 10, four in-service teachers, four school administrators, and four ICT service developers were the respondents of this focus group interview. All participants were active in Kathmandu, Nepal at the time of the interview, and thus represent the stakeholders from actual context. After the assessment phase with its positive findings on the prototype quality, the research question can be transformed as the answer: in the context of school education of Nepal or similar (Z), the e-textbooks (X) with certain characteristics (A, B, C) lead to outcomes (Y).

The screening method is used for a formative evaluation of the design proposal at the development phase, whereas the focus group interview is

used for a semi-summative evaluation of the global design at the assessment phase. Due to the combination of only two evaluation methods, evaluation and revision were possible only on some important aspects of the prototype e-textbook system such as content, design, and technical quality. As shown in Figure 3.2, four horizontal layers of evaluation can be visualized where the self-evaluation is at the bottom-most layer and field test is at the top-most. Evaluations based on expert reviews and one-to-one methods are kept in the same layer and are considered less resistant to revision compared to evaluations based on small groups. Evaluation with a screening method has a low resistance to revision because it is a self-evaluation method and is efficient to find obvious errors only. Evaluation with a focus group interview is a type of expert review and has high resistance to revision compared to the evaluation done with screening method [9]. Even though evaluations with small groups and field tests have not been done within this research work, such evaluations should be carried out when the prototype progresses towards a completed product.

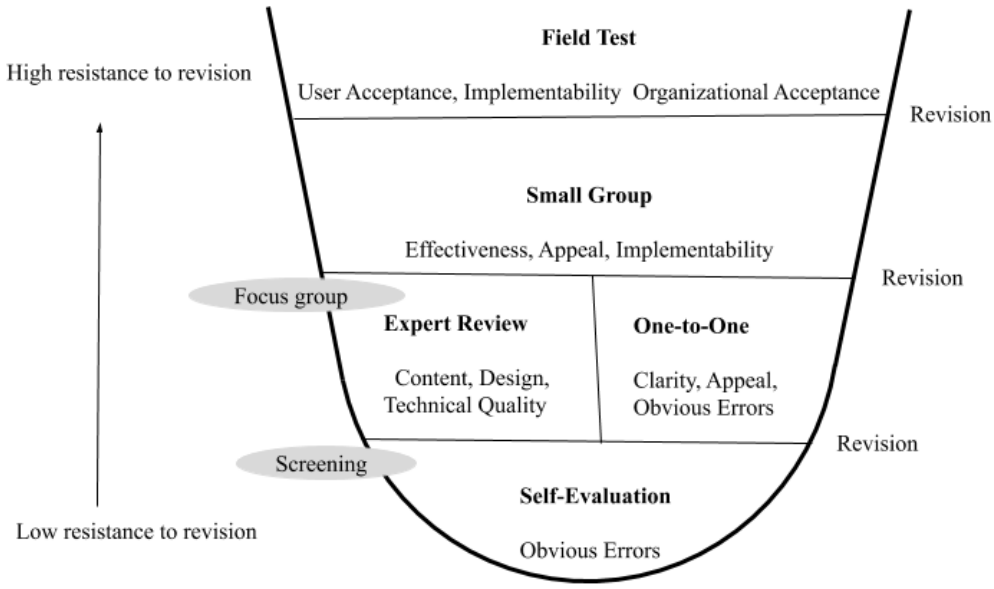


FIGURE 3.2: The layers of formative evaluation and the positioning of the two evaluation methods [9].

Chapter 4

Preliminary research

4.1 Overview

The preliminary research phase deals with the opening research question of the educational design process. The question can be phrased as, what are the characteristics (A, B, C) of <intervention X> for the <purpose/-function Y> in <context Z>? The first part of the preliminary research is a needs and context analysis which defines the intervention, its intended functions, and the context within which the intervention is being developed. The second part of the preliminary research includes the exploration of the scientific knowledge base which defines the characteristics of the intervention and a set of methods/procedures to achieve those characteristics. The output of the preliminary research phase is a design blueprint that provides a detailed overview of the intervention and the context. It also defines the functions and characteristics of the intervention, as well as proposes the procedures to develop the intervention. This design blueprint is used in the subsequent design phases to design and develop the e-textbook system.

4.2 Needs and context analysis

The definition and scope of the e-textbook as an educational intervention in the context of school education in Nepal and its intended functions are defined based on a needs and context analysis. This need and context analysis is primarily based on the conclusions drawn from the document analysis of [1], [2], [46], [47], [50], and [59]. Even though the status of ICT and its use in education are in a very primitive stage in Nepal compared to other developed countries [46], [47], the government programs to develop the ICT infrastructure and deliver ICT based education in school level have

been manifested in the policies [1], [2], [50]. Preparation of digital teaching-learning materials and the development of e-libraries have been discussed in the SSDP [1], although the lack of a strategic plan to produce skillful teachers and to develop ICT infrastructure indicates that the ICT in education policy is fragile [59].

Based on the literature review carried out in the previous chapter (see 2.1.2), e-textbooks can be divided in three broad categories: basic e-textbooks, multimedia e-textbooks, and application e-textbooks. A digital copy of the print textbook displayed on a computer screen can be viewed as a basic e-textbook. A basic e-textbook supplemented with multimedia contents are multimedia e-textbooks whereas a multimedia e-textbook further supplemented with organizing, management, and analytic functions can be termed as an application e-textbook. In countries like S. Korea, Japan, and China, the application e-textbooks are being implemented as a daily-use classroom technology.

Considering the lack of enough empirical evidence to ensure the availability of ICT infrastructure and human resources in the context of school education in Nepal [59], all possible functions of e-textbooks as per the state-of-the-art should not be realized at once. E-textbooks should be developed as a possible alternative and not as a replacement of print textbooks. The current status of school e-textbooks in Nepal is the availability of school textbooks in PDF which are free to download via the website of the CDC. Thus, I have proposed only two intended functions that are feasible to implement within the context of school education in Nepal. These two intended functions are to provide an ICT-based alternative to print textbooks, and to provide supplementary materials to the print textbooks for teaching and learning.

A digital copy of the print textbook distributed in the form of e-textbook can provide a possible alternative when print textbooks are not available. Such a basic form of e-textbooks can integrate the searching and note-taking functions that are not possible otherwise in print textbooks. Furthermore, multimedia e-textbooks are efficient tools to provide supplementary materials to print textbooks because multimedia e-textbooks can include media and interactive content that can not be presented in printed form. Now the research question can be rephrased as, what are the characteristics (A, B, C) of e-textbooks (intervention X) to provide an ICT-based alternative to print textbooks, and to provide supplementary teaching/learning materials

(purpose/function Y) in the context of school education in Nepal (context Z).

4.3 Exploration of the scientific knowledge base

The needs and context analysis defined the e-textbooks as the educational intervention and school education in Nepal as the context. It also detailed the two intended outcomes from the interventions when implemented in the given context. Now the exploration of the scientific knowledge base is carried out to identify the expected characteristics of the e-textbooks and to describe the procedures to achieve those identified characteristics. The expected characteristics of e-textbooks are proposed based on the scientific knowledge base.

The migration of paper-based textbooks to e-textbooks requires overcoming a wide range of technical, social, cultural, and budget issues. These issues can be broadly kept in eight categories, providing a lower price, standardizing the format of content, improving service reliability, improving quality and accuracy of content, increasing the life of ownership, reducing health risk and visual fatigue, improving readability, and protecting copyright [25]. These issues can also be categorized based on five main characteristics pertinent to the successful use of e-textbooks in the education system: reliability, compatibility, usability, accessibility, and maintainability. An educational technology is considered reliable if it is less prone to service failures. Compatibility refers to the system's ability to run on multiple devices whereas accessibility is measured with the degree of easiness to access and transport. A system is usable if it is easy and effective to use for the given purpose, and maintainable if it is easy to troubleshoot and update [27].

Various solutions have been discussed in the literature to address the challenges associated with the design and use of e-textbooks in school education. The solutions discussed mainly relate to an improvement in hardware technology, software technology, and e-textbook content [25]. Within the scope of this thesis work only the solutions related to improvements in software technology and the e-textbook content have been analyzed. The development and use of e-textbooks as a web service can address the issues

of service reliability, cost efficiency, and quality of content [25]. Web-based e-textbooks can leverage newer web technologies such as HTML5, CSS3, WebGL, and cloud computing for e-textbook development and distribution. The web browser is an efficient runtime environment to render the e-textbook content [29], [60], [61].

TABLE 4.1: Required characteristics, issues to solve, and possible solutions of e-textbooks' development

Characteristics	**Issues to address**	**Possible solutions**
Reliability	Accuracy of content, technical quality	Use of web-services, authorized textbook as the primary source of content
Compatibility	Standardizing format of content	Use of e-textbook format and reader application supported by most operating systems and devices
Usability	User interface and functions, quality of content	Leverage existing features and design guidelines, include multimedia and interactive contents
Accessibility	Providing lower price, improving service reliability	Use open educational resources, web services, maintain offline usability
Maintainability	Requirements of application and content updates	Software updates should be made easy, maintain granularity of content

Table 4.1 shows the five main characteristics necessary to be realized in school e-textbooks along with the details about the identified issues and possible solutions. Issues such as maintaining technical quality of the overall system, standardizing the format of content, and ensuring the service reliability can be addressed with the use of web-based solutions by utilizing the state-of-the-art web technologies. Authorized school textbooks should be used as the primary source of e-textbooks, which not only helps to reduce the development cost but also ensures the accuracy of the content. Based on the findings so far, the first four procedures have been formulated to achieve the defined five characteristics. These four procedures are: digitize the print textbooks and use them as the primary content of e-textbooks, use a web-based system to develop, distribute, and read the e-textbooks, make the e-textbooks downloadable for offline use, and follow the available design guidelines about interface and functionalities of e-textbooks.

Exploration of the available design guidelines about interface and functionalities of e-textbooks shows that EBONI guidelines address most of the design aspects of basic e-textbooks. The EBONI projects have given more than 20 design guidelines under three broader categories: adhering to the book metaphor, adapting to the electronic medium, and hardware design guidelines [13]. As shown in Table 4.2, the first category of guidelines has been produced from the appearance and functionality of the paper book, such as the inclusion of a table of contents and index page. The second category of guidelines deals with integrating features possible in the electronic environment and the third category of guidelines talks about the guidelines for e-textbook reader devices. Among the three categories of EBONI design guidelines, adhering to the book metaphor and adapting to the electronic medium are applicable in this thesis work. The third category of guidelines which deals with hardware design is not necessary to research since this thesis work does not deal with e-textbook reader devices. Furthermore, the guideline which states 'use multimedia and interactive elements' does not sufficiently answer the important questions related to using multimedia in e-textbooks, such as, which type of multimedia to use, how much multimedia to use, how to integrate the multimedia, and where to display the multimedia.

TABLE 4.2: EBONI guidelines which are applicable, not applicable, or which requires further inquiry in the context of this research

Adhering to the book metaphor	Cover your book. Include a table of contents. Include an index. Treat the book as a closed environment. Provide bookmarking and annotation functions. Provide orientation clues.	Applicable as it is.
Adapting to the electronic medium	Provide a search tool. Use hyperlinks for navigation and cross-referencing. **Use multimedia and interactive elements.** Enable customization.	The highlighted guideline requires further inquiry.
Hardware design guidelines	Employ high-quality display technology. Balance portability against legibility. Design devices for comfort. Make devices robust.	Not applicable.

Even though no particular design guidelines were found about how to use multimedia content in school e-textbooks, guidelines on how to design multimedia learning and the cognitive load associated with multimedia learning has been studied systematically [32], [62]. A complete set of guidelines for e-learning design based on empirical research findings and research-based theories has been presented by [32]. The primary seven guidelines presented by [32] are: applying the multimedia principle, applying the contiguity principle, applying the modality principle, applying the redundancy principle, applying the coherence principle, applying the personalization principle, and applying the segmenting and pre-training principles. Table 4.3 list these seven guidelines along with a short description of each. These evidence-based guidelines are also applicable while using multimedia and interactive elements in school e-textbooks and should be followed where applicable. For example, applying the redundancy principle recommends explaining visuals with words in audio or text but not both. Similarly, applying the coherence principle informs that adding extra material can hurt learning. Such principles are also applicable while developing lecture videos, interactive assessments, etc for school e-textbooks and should be kept in consideration.

TABLE 4.3: Seven guidelines for e-learning design [32]

Principles	**Description**
Applying the multimedia principle	Use words and graphics rather than words alone
Applying the contiguity principle	Align words to corresponding graphics
Applying the modality principle	Present words as audio narration rather than on-screen text
Applying the redundancy principle	Explain visuals with words in audio or text: not both
Applying the coherence principle	Adding extra material can hurt learning
Applying the personalization principle	Use a conversational style and virtual coaches
Applying the segmenting and pre-training principles	Managing complexity by breaking a lesson into parts

Conclusions from a decade long research program at the University of California, Santa Barbara have presented nine principles of multimedia design to reduce cognitive overload associated with the use of multimedia for learning. These principles are rooted in the principles of cognitive science

which suggests that a human possesses an auditory/verbal channel for processing auditory input and verbal representations, and a visual/pictorial channel for processing visual input and pictorial representations. Cognitive overload occurs when the limited amount of processing capacity available in the verbal and visual channels is overwhelmed by the information presented [62]. Table 4.4 shows the five scenarios of cognitive overload, nine principles to deal with such scenarios, and a short description of each principle, from left to right columns respectively. These scenarios of cognitive overload should be considered carefully while using multimedia as part of school e-textbooks.

The e-learning design guidelines given in Table 4.3 and the principles to reduce cognitive overload given in Table 4.4 apply to the design and use of multimedia e-textbooks too. Even though these guidelines do not necessarily answer all the questions related to how to use multimedia and interactive elements in e-textbooks, they are applicable to ensure the effective use of multimedia e-textbooks for learning. Thus, adding to the four procedures defined above, the fifth procedure to apply while designing multimedia e-textbooks has been formulated as: follow the available evidence-based guidelines on how to design and use multimedia for learning.

4.4 The proposed framework for multimedia integration

In the design of digital learning materials, questions related to structuring and sequencing of the subject matter have not yet been decomposed in a comprehensible manner [55]. The literature review has also reflected a lack of specific design guidelines on how to integrate and display multimedia content within the e-textbook environment. If e-textbook content is limited to the printable content derived from the paper textbook then it is not necessary to define structure and order for the content because it is already determined by the school curriculum. Multimedia content is usually not a part of the print textbook, thus adding the requirement of defining structure and order while integrating and displaying it as the e-textbook content. The five procedures proposed so far do not address the issue of structuring and sequencing the multimedia content while using it

TABLE 4.4: Scenarios of cognitive overload and principles to reduce it [62]

Scenarios	**Principles**	**Description**
Essential processing in visual channel > cognitive capacity of the visual channel	Off-loading	Move some essential processing from the visual channel to the auditory channel.
Essential processing (in both channels) > cognitive capacity	Segmenting	Allow time between successive bite-size segments.
	Pretraining	Provide pretraining in names and characteristics of components.
Essential processing + incidental processing (caused by extraneous material) > cognitive capacity	Weeding	Eliminate interesting but extraneous material to reduce the processing of extraneous material.
	Signaling	Provide cues for how to process the material to reduce the processing of extraneous material.
Essential processing + incidental processing (caused by confusing presentation) > cognitive capacity	Aligning	Place printed words near corresponding parts of graphics to reduce the need for visual scanning.
	Eliminating redundancy	Avoid presenting identical streams of printed and spoken words.
Essential processing + representational holding > cognitive capacity	Synchronizing	Present narration and corresponding animation simultaneously to minimize the need to hold representations in memory.
	Individualizing	Make sure learners possess skills at holding mental representations

in e-textbooks. Therefore a framework has been presented which tries to deal with the above-mentioned issues of structuring and sequencing.

Images, audios, videos, animations, interactive assessments, simulations, and games are common types of multimedia contents used for educational purposes. This classification is usually tied to the technical aspects of the content such as file formats, methods to produce, store, and render [29].

Multimedia contents developed as learning materials have also been classified based on learning engagement associated with the content. Laurillard [34] has defined five classes of media, narrative, interactive, adaptive, communicative, and productive, whereas Hartog [55] has distinguished two major classes, presentational learning materials (PLM) and activating learning materials (ALM). The narrative, interactive, adaptive, communicative, and productive media types are associated with the attending, exploring, experimenting, discussing, and expressing learning engagements respectively [34]. PLM is defined as the learning materials designed to present the subject matter such as videos of lectures, instructional movies, etc whereas the ALM is distinguished by the interactiveness of learning materials which requires the learner to make decisions for engagement instead of simply presenting the subject matter in a predefined way [55].

TABLE 4.5: Different types/classes of media and their possible representation as lessons and exercises

Media types [34]	**Classes [55]**	**Examples**	**Lesson/Exercise**
Narrative	PLM	Video, animation	Lesson
Interactive	ALM	Assessment	Lesson and exercise
Adaptive		Game, simulation	Lesson and exercise
Communicative		Email, Internet forum	Lesson and exercise
Productive		Spreadsheet	Lesson and exercise

In the case of designing e-textbooks for school education in Nepal, I have defined two types of multimedia: lesson and exercise. Table 4.5 shows the categorizations of educational media presented by [34] and [55] along with their possible representation as a lesson or exercise. A lesson is usually narrative and uses the presentational learning materials whereas an exercise is interactive or adaptive and employs the activating learning materials. The categorization of media into lessons and exercises is primarily tied to the objective of the content rather than the degree of interactivity or learning engagement provided by it. The lessons are identified by their primary objective of explaining the subject matter to the learner whereas the exercises

have the primary objective of assessing the learner's understanding of the subject matter. As shown in Table 4.5, media types other than narrative can be presented as both lessons and exercises. For example, a discussion forum as a communicative medium can be seen as a lesson because it is more aimed at explaining the subject matter whereas an email as a communicative medium, while used to submit assignments for assessment, is an exercise. Similarly, interactive and adaptive media, which can be viewed as ALM too, can also be used as both lessons and exercises. Narrative media or PLM such as videos and animations are most suitable to be used as lessons only.

The terms lesson and exercise are metaphors derived from the activities related to the use of textbooks in the context of school education in Nepal. Lessons are the teachings delivered by teachers in the school classroom to explain the subject matter. Exercises are the problem solving activities carried out by the pupils to assess the understanding of the subject matter. In the simplest form, a school textbook is a combination of multiple chapters where each chapter is a combination of learning content and learning objectives. Learning content is the subject matter to learn, and a learning objective defines what the learner is expected to achieve after learning the subject matter. In the school textbooks, learning content is usually presented as the main text of chapters, followed by the exercises which represent learning objectives of the chapters.

The concept to use lesson and exercise metaphors as a rhetorical tool has been inspired by a comprehensive research on the use of visual rhetoric in the design of electronic books [18], which defines metaphors as "[...] rhetorical tools which are used for introducing and defining new concepts by using similar ones which are already familiar to the public." It is advisable to follow the traditional book metaphor while designing books in the electronic form to provide a familiar way to read and use them. When readers can use an electronic representation of books in a similar way to the original paper version, it increases their access to electronic information [18]. Lesson and exercise are familiar terms in school education in Nepal which are used to denote the activities related to the use of textbooks. The term lesson is used to indicate the subject matter given in textbook chapters as well as the teaching activities conducted by the teachers to explain the subject matter. The term exercise (or homework) usually indicates the tasks pupils are required to perform, followed by the teacher's feedback on the performance.

Traditional book metaphors can be implied as an activity, mode of interaction, and task domain. The activity metaphor expresses the actual activity to be performed, mode of interaction defines the way the reader engages with the activity, and the task domain metaphor informs about the primary task being supported [18]. As shown in Table 4.6, I have defined the lesson and exercise metaphors as an activity, mode of interaction, and task domain. The lesson as an activity is to attend the teaching delivered whereas the exercise is the activity of doing assignments and getting the feedback. The mode of interaction defines the way readers are supposed to engage with the content. A lesson can be interactive or requires no interaction from the user's side to engage with the content, whereas interactiveness is an essential part of an exercise, thus active interaction is necessary to use the content. The task domain metaphor expresses the primary task under it. Explaining the subject matter is the primary task of a lesson, and assessing the understanding of the subject matter is the primary task of an exercise.

TABLE 4.6: Three implications of lesson and exercise metaphor

	Activity	**Mode of interaction**	**Task domain**
Lesson	Attend the teaching delivered	Active or Passive	Explaining
Exercise	Do assignments and get feedback	Active	Assessing

To deal with the problem of sequencing the multimedia learning material while using it in e-textbooks, the chapter-based structure of school textbooks has been followed. As paper textbooks use a sequence of chapters to present the printable contents, the multimedia materials should be sequenced similarly and tied with individual chapters. For example, if a paper textbook contains ten chapters then its e-textbook form will contain a maximum of ten chapters of multimedia materials, each for an individual textbook chapter. As shown in Figure 4.1, multimedia materials tied to each chapter are further divided into two categories, lesson and exercise. It implies that all multimedia materials should be classified either as a lesson or exercise, primarily based on the activity they represent and the task domain they are aimed at.

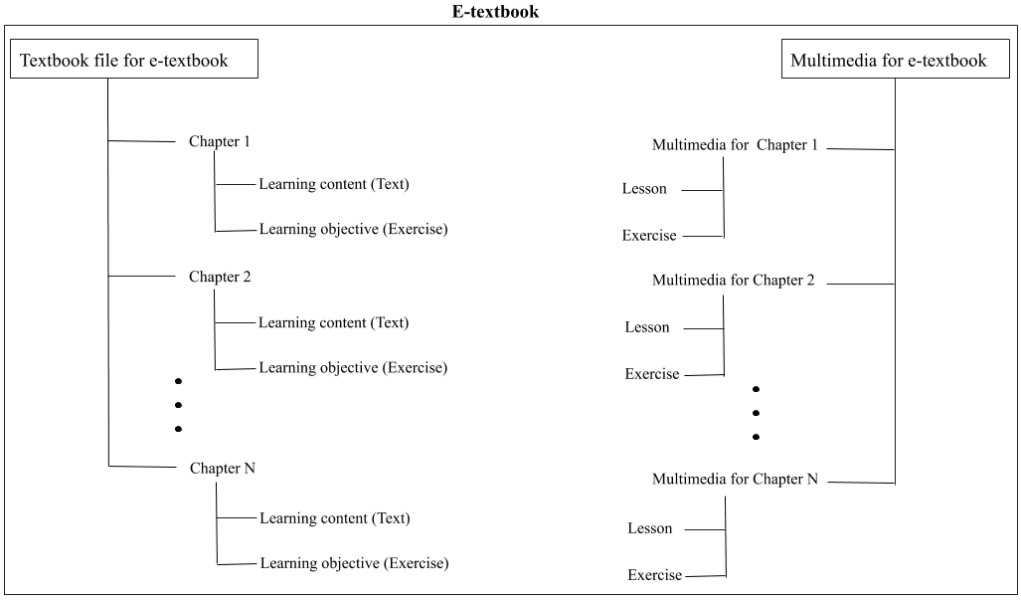


FIGURE 4.1: Lesson and exercise multimedia tied to textbook chapters.

Based on the proposed framework for multimedia integration I have added three more procedures to follow while designing an e-textbook. These procedures are: maintain a logical separation between contents derived from print textbooks and multimedia contents, use the chapter-based structure of textbooks to divide and sequence the multimedia contents, and classify multimedia contents into two broad categories, lesson and exercise. Table 4.7 shows the output of the entire preliminary phase that serves as the input for the subsequent design process.

Table 4.7: Output of the preliminary research phase in its entirety

Intervention (X) and context (Z) concluded from the needs and context analysis
• Intervention: an e-textbook system to create, distribute, and read e-textbooks. • Context: School education in Nepal
Intended functions (Y) concluded from the needs and context analysis
1. To provide an ICT-based alternative to print textbooks. 2. To provide supplementary material to the print textbooks for teaching and learning.
Expected characteristics (A, B, C ...) concluded from the exploration of the scientific knowledge base
1. Reliability 2. Compatibility 3. Usability 4. Accessibility 5. Maintainability
Proposed procedures (K, L, M ...) concluded from the exploration of the scientific knowledge base (1-5) and from the proposed framework (6-8)
1. Digitize the print textbooks and use them as the primary content of e-textbooks. 2. Use a web-based system to develop, distribute, and read the e-textbooks. 3. Make the e-textbooks downloadable for offline use. 4. Follow the available design guidelines about the interface and functionalities of e-textbooks. 5. Follow the available guidelines on how to design and use multimedia for learning. 6. Maintain a logical separation between contents derived from print textbooks and multimedia contents. 7. Use the chapter-based structure of textbooks to divide and sequence the multimedia contents. 8. Classify multimedia contents based on their objectives into two broad categories, lesson and exercise.

Chapter 5

Prototype development

5.1 Overview

A design proposal and a global design of an e-textbook system have been developed in the prototype development phase. The design proposal of the e-textbook system will be presented as a combination of software design artifacts which defines various aspects of the system such as users, data, components, interfaces, etc. The global design will be presented as a prototype e-textbook system with limited functionalities. The design proposal is created based on the design blueprint provided from the preliminary research phase. The design proposal is then developed into a global design which is a prototype of a web-based e-textbook system to create, distribute, and read the e-textbooks. The global design is the final output of the prototype development phase, therefore forwarded to the next stage for assessment.

Among the four paradigms of educational design, instrumental, communicative, pragmatic, and artistic [16], I have followed the pragmatic approach to take the design decisions in the prototype development phase. The pragmatic approach is a reasonable choice when detailed preliminary research is not possible, and when regular communication among different stakeholders of the project is also not possible. The output of the preliminary investigation phase documented in the previous chapter has only provided an overview of the e-textbook system which is not a detailed description of system specifications required to follow an instrumental approach. Moreover, carrying out regular communication among stakeholders was also found difficult due to the research setup, such as the physical distance between the context of the research (school education in Nepal) and the institution where this research has been carried out (a university in Finland). The pragmatic approach has been preferred mainly due to two

reasons: the research limitations which inhibited other possible approaches, and my firsthand experience with the school education of Nepal as a student and a teacher which I expected to be helpful in making pragmatic design decisions.

5.2 Design proposal

A web-based system to create, store, distribute, and read the e-textbooks is essentially an information system so the design proposal has been presented in the form of abstract models used in software engineering such as a data flow diagram, a use case diagram, a component diagram, etc. The architecture of the design and its interface definitions are basic abstract representations in software engineering and the value of such representations for communication, documentation, planning, and decision making is evident in design-oriented research [55].

5.2.1 Architecture of the e-textbook system

This section details the data, data flow, use cases, and components of the e-textbook system. The overview of the system data deals with defining the e-textbook content in the form of learning objects. The data flow diagram shows how data flow among the processes, datastores, and entities of the system. Use cases give an overview of the users and their interaction with the system. The system components detail the internal architecture of the system in the form of the components, the provided and required interfaces of the components, and interaction among these components.

IEEE Learning Technology Standards Committee defines a learning object as "[...] any entity, digital or non-digital, which can be used, re-used or referenced during technology supported learning" [63]. Facilitating reusability is considered as an inherent requirement of learning objects even though the definition does not make explicit reference to it [64]. The granularity of learning objects is decided by the possible benefits of reuse, the expense of cataloging, and the instructional scope of learning objects [65]. Figure 5.1 shows an overview of the data used to create the e-textbooks. The bold border signifies that the data can be represented in the form of a learning object. The entire database is logically separated into two parts: textbooks

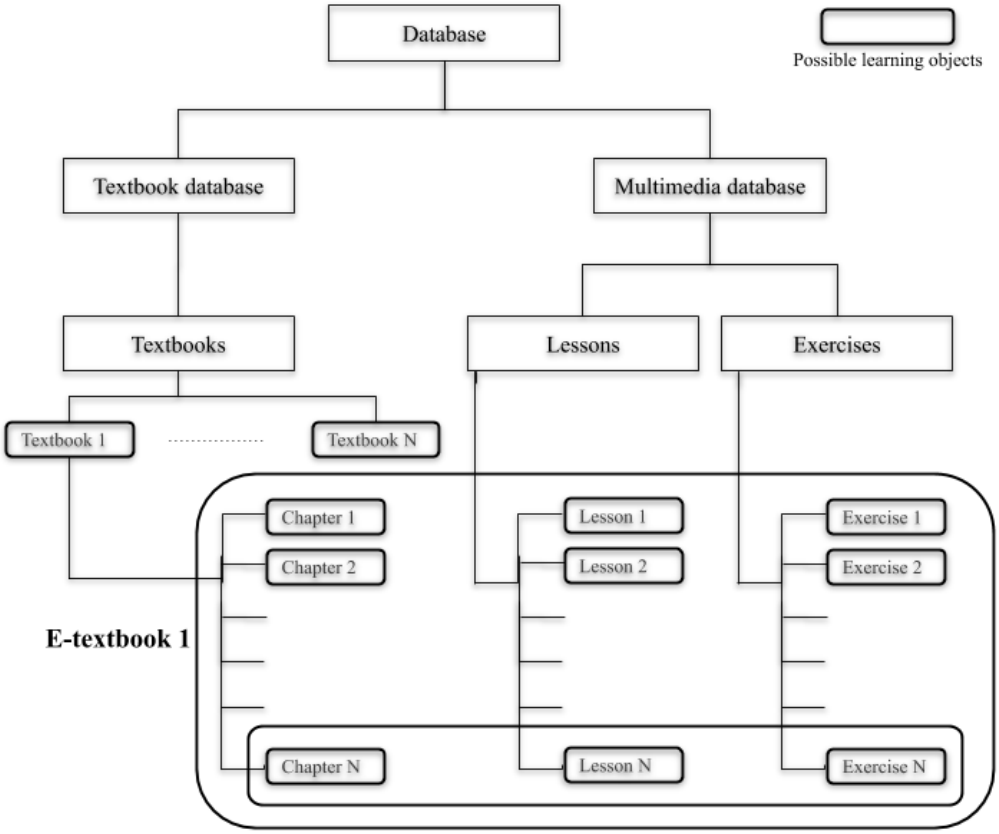


FIGURE 5.1: Overview of e-textbook data (content) as a collection of learning objects.

and multimedia. This separation helps to maintain the independent development and updating of textbooks and multimedia. The multimedia is further separated as lessons and exercises, thus the primary three types of content available in the e-textbook system are textbooks, lessons, and exercises. The textbooks serve as the base content and derive from the print textbooks whereas lessons and exercises are multimedia contents and serve as supplementary materials to the textbooks. Further granularization of textbooks, lessons, and exercises results in learning objects. Each textbook, as well as its every chapter, can be maintained as a learning object. Similarly, individual lessons and exercises can also be maintained as learning objects. A tuple of textbook chapter and its lesson and exercise multimedia together can also be treated as a learning object. Nonetheless, an entire e-textbook package is also logically a learning object. A lesson or exercise can be a combination of multiple learning objects and can further be granulated accordingly. For example, a lesson learning object can be a combination of a video, an animation, and an illustrated graphic. In such scenarios, each

multimedia module (video, animation, and graphic) can be maintained as individual learning objects.

An e-textbook is a package of a textbook file, zero or more lessons, and zero or more exercises linked together. The number of lessons and exercises in the package is always less than or equal to the number of chapters in the textbook file. Figure 5.2 shows the data flow diagram for the e-textbook system. The administrator entity is responsible for supplying textbooks, lessons, and exercises to the process (1, package) which is responsible for storing the data to data stores and linking them together logically to create the e-textbooks. The user entity is supplied with the e-textbooks by another process (2, distribute) which is responsible for fetching the textbooks, lessons, and exercises from data stores as e-textbooks. D1, D2, and D3 represent the logically separated data stores for textbooks, lessons, and exercises.

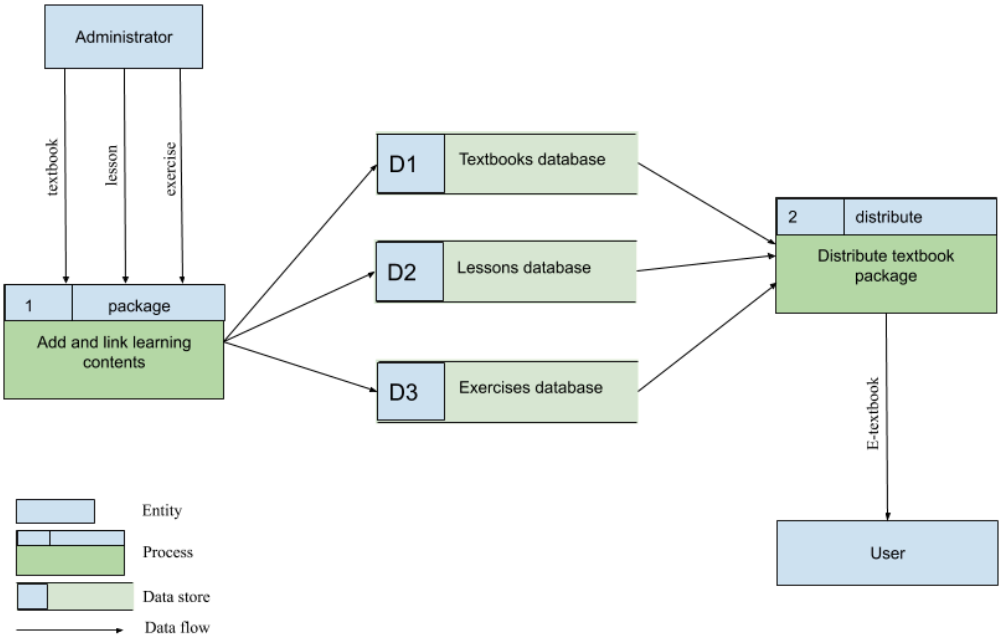


FIGURE 5.2: Data flow diagram of e-textbook system.

The administrator will be responsible for adding textbooks, lessons, and exercises into the system database. Book-map is created and maintained for each textbook from its manifestation data. Manifestation data of a textbook is the meta-data of details such as the total number of pages, the number of chapters in the textbook, page range of each chapter, etc. The lessons and exercises are linked to specific chapters of the textbooks utilizing the

book-maps. Administrator use cases are related to the back-end operations of the system. As shown in Figure 5.3, the basic administrative tasks include adding textbooks, lessons, and exercises and binding the lessons and exercises to textbook files utilizing the book-maps. School pupils are the primary end-users of the system and they will access the e-textbook via a web browser.

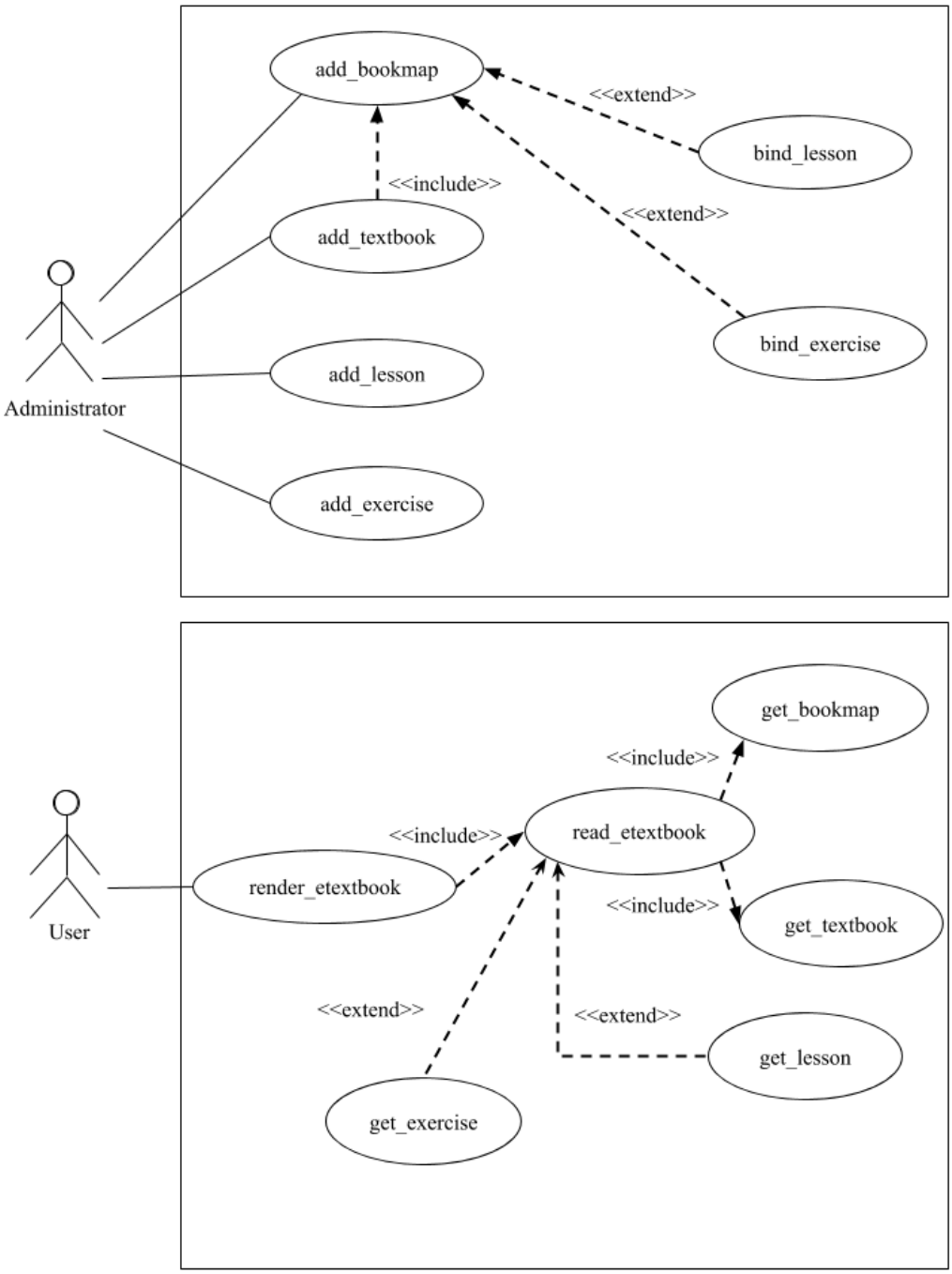


FIGURE 5.3: Use case diagram for administrator and user.

Figure 5.4 shows the component diagram of the e-textbook system. The main six components of the system are the lesson, exercise, textbook, e-textbook, user interface, and administrative interface. Each component provides methods for interaction which are shown with the line ending in a circle, such as the add_textbook and add_bookmap methods provided by the textbook component. A component not only provides the methods but also requires methods for interaction shown with a line ending in a half-circle. The user interface component provides the render_etextbook method which is the only way for an end-user to interact with the system. The administrative interface component provides the access_control method via which an administrator can access the administrative tasks. The administrative interface is one of the main components of the e-textbook system and requires six methods from other components to interact with.

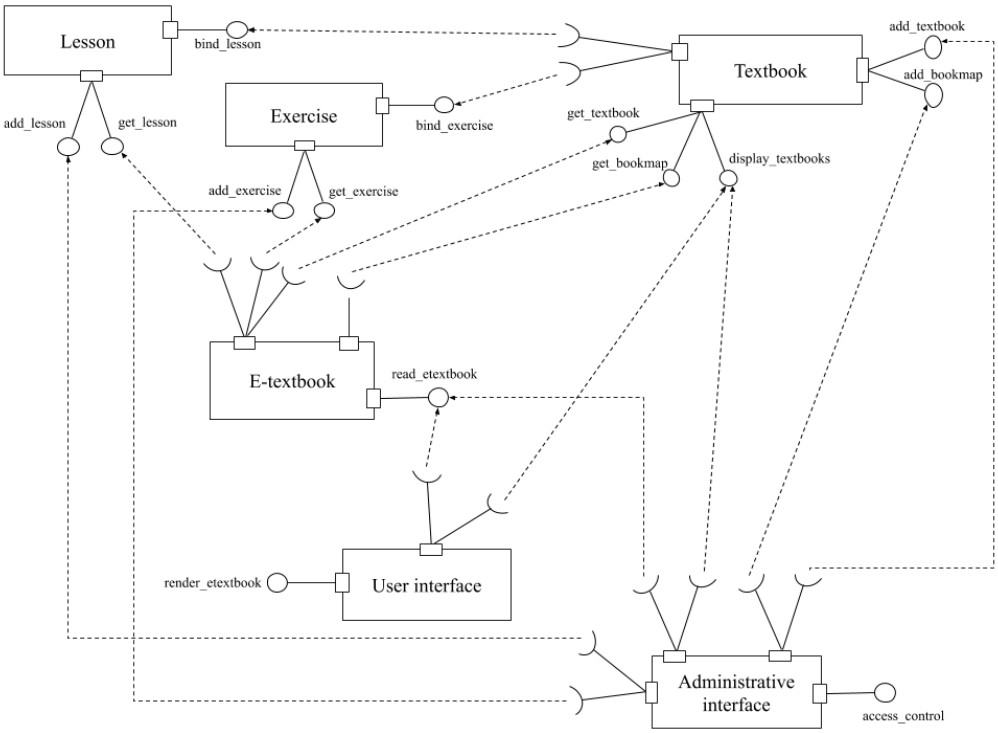


FIGURE 5.4: System component diagram.

5.2.2 Interface definitions of e-textbook system

The interface to display the e-textbook content is the main interface to define. Figure 5.5 shows an overview of the user-interface displaying the e-textbook content. E-Textbooks are rendered via a book-alike user interface,

which serves as a single entry and exit point for content navigation. The content of an e-textbook are available in two different interface layers. The primary interface layer is visible by default and responsible for displaying the textbook part of the e-textbook, whereas the secondary interface layer is responsible for displaying the multimedia part and is only visible when a lesson or exercise multimedia is requested by the user. The primary interface layer is a book-alike interface which mimics the physicality of paper-based books. It shows a consecutive pair of pages at a time and allows horizontal scrolling for navigating the pages, resembling reading of a printed book.

The hyperlinks for lessons and exercises appear in the primary interface only when the specified textbook pages for such links are navigated. At the most, one lesson and one exercise are embedded into each textbook chapter via hyperlinks and such hyperlinks are given at the end page of each chapter. Limiting the number of hyperlinks to only two and embedding them only in the end page of the chapter helps to tackle the problems associated with the use of too many hyperlinks in multimedia e-textbooks. The multimedia part of an e-textbook is displayed in the secondary interface which overlays the primary interface. The basic functions which should be available to perform on the textbook part are zooming, bookmarking, highlighting, searching, note-taking, and annotating.

The combination of all the five design artifacts presented above is the design proposal of an e-textbook system, which can be summarized as follows. An e-textbook is a combination of two parts, textbook, and multimedia. The multimedia content is further categorized into lesson multimedia (lessons) and exercise multimedia (exercises), thus providing three broad content categories: textbook, lessons, and exercises. The e-textbook system has an administrator and a user as the two user roles. The administrator role is responsible for creating the e-textbooks whereas the user role includes the activities performed on e-textbooks such as reading the textbook and using the multimedia. The textbook content presentation should mimic the style of the paper-based book reading process and the multimedia content is displayed only when requested via hyperlinks given only at the end page of the textbook chapters.

The design proposal is in the form of a combination of five design artifacts that should be assessed formatively before taking it to the next step of the design. Screening, which is a self-evaluation method of formative evaluation, has been used to evaluate the relevancy and consistency of the design

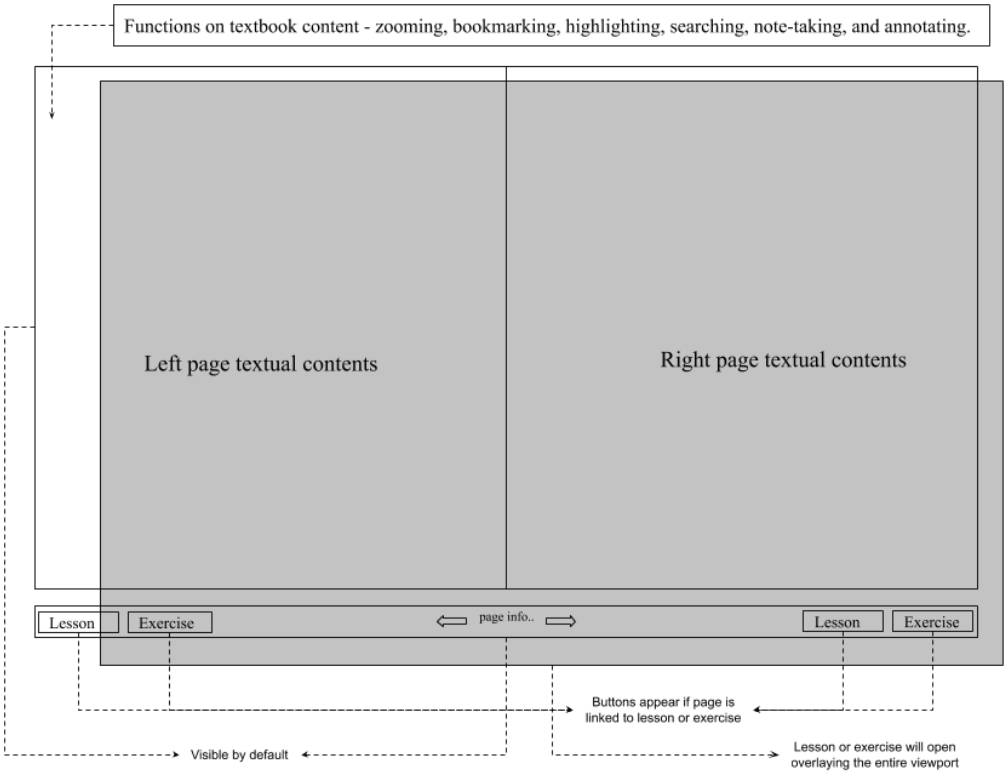


FIGURE 5.5: Overview of the user interface to view the e-textbook content.

proposal. Other quality criteria such as practicality and effectiveness have not been assessed here. A checklist containing six criteria has been formulated to evaluate the design representations. These six criteria have been drawn from the output of the preliminary research to assess the relevancy and consistency of the design proposal. These criteria can be seen as a set of criteria to be implemented for a relevant and consistent design proposal of an e-textbook system for the context of school education in Nepal.

The five final system representations used to present the design proposal are an overview of the e-textbook data, a data-flow diagram, a use case diagram, a component diagram, and a user-interface mock-up. The six criteria used to assess the relevancy and consistency of the design proposal representations are use of print textbook content, integration of multimedia, content granularization as learning objects, interface and functionality as per state-of-the-art design guidelines, consistency of system components, and consistency of interaction among system entities. The output of the screening performed on the five design representations via using a checklist of these six criteria is shown in Table 5.1. R1, R2, R3, R4, and R5 are

the five design representations and C1, C2, C3, C4, C5, and C6 are the six criteria. Each design representation has been checked for all six criteria and a checkmark has been given in the corresponding cell if any criterion is found implemented in the design representation. For example, the design representation to show an overview of e-textbook data as a collection of learning objects has been written as R1 and the checkmarks show that it has implemented the first three criteria, C1, C2, and C3.

TABLE 5.1: Checklist showing the criteria (C) addressed by representations (R)

	R1	R2	R3	R4	R5
C1	✔	✔	✔	✔	✔
C2	✔	✔	✔	✔	✔
C3	✔				
C4					✔
C5			✔	✔	
C6		✔	✔	✔	✔

C1: Use of print textbook content
C2: Integration of multimedia
C3: Content granularization as learning objects
C4: Interface and functionality as per state-of-the-art design guidelines
C5: Consistency of system components
C6: Consistency of interaction among system entities (components /data /users)
R1: Overview of e-textbook data (content) as a collection of learning objects
R2: Data flow diagram of e-textbook system
R3: Use case diagram for administrator and user
R4: System component diagram
R5: Overview of the user interface to view the e-textbook content.

As seen in Table 5.1, no single artifact is adequate to describe the design proposal because none has implemented all six criteria. R1 and R5 are important artifacts because the third and fourth criteria C3 and C4 have been implemented by only these two artifacts respectively. The remaining four criteria have been solely fulfilled by R3 and R4, thus a combination of R1, R3, and R5 or R1, R4, and R5 can represent the design proposal in its entirety. Even though some design artifacts could be left out based on criteria fulfilled, it is recommended to treat the combination of all five artifacts together as the design proposal which fulfills all the six criteria given via one or another individual artifact.

5.3 Global design

Based on the design proposal a prototype e-textbook system has been developed as a web application in a client-server architecture. A server-side

(back-end) scripting language, a database, and a client-side (front-end) framework are the main components of a web application [66], [67]. Some of the popular languages for server-side scripting are PHP hypertext preprocessor (PHP), Perl, Ruby, Java, Python, etc and some of the popular database management systems for web applications are MySQL, SQLite, PostgreSQL, Oracle, etc [66]. The client-side framework generally consists of standardized code in hypertext markup language (HTML), cascading style sheets (CSS), and JavaScript. Some of the popular open-source front-end frameworks available based on their GitHub popularity are Bootstrap, Foundation by ZURB, Semantic UI, and Pure by Yahoo [68]. The choice of web technologies for the prototype e-textbook system has been influenced by the intention of making it as compatible as possible with the Modular Object-Oriented Dynamic Learning Environment (Moodle). Moodle is probably the most popular open-source learning management system (LMS) with 80 million users worldwide. It was developed in 2001 under the terms of GNU General Public License (GPL) [69]. A webserver with PHP is required for the installation of Moodle [70], therefore, PHP has been used for back-end scripting of the prototype e-textbook system. MySQL is a preferable choice when PHP is used for back-end scripting because it is installed by default on most PHP-supported web servers [66].

MySQL 5.7 for database management, PHP 7.2 for back end scripting, HTML5 and CSS3 for web page layout, JavaScript for front end scripting, and two external libraries Semantic UI and Mozilla pdf.js have been used for prototype development. MySQL is an open-source relational database management system (RDBMS) based on structured query language (SQL) and it has a client-server architecture [67]. PHP is a server-side scripting language that allows generating web-pages dynamically and programmatically by allowing one to embed code within HTML templates [66]. Web technologies such as HTML5, CSS3, and JavaScript are preferred to develop educational technologies due to their wide adaptability and open-source nature [29]. The Semantic UI is an open-source user interface framework [71] and the Mozilla pdf.js is also an open-source JavaScript library to read PDF documents on web-browsers [72]. See Appendix A for more details on code repository, instructions about how to deploy it as a web application, and the inputs used to test the operation of the application. This prototype e-textbook system serves as the final output of the development phase and will be forwarded to the assessment phase for evaluation.

5.3.1 The prototype e-textbook system and inputs

Once the e-textbook system is developed and deployed in a web server, it is accessible via web-browsers as a web application. As shown in Figure 5.6, the website index page does not have any e-textbooks to list yet. The primary inputs to create an e-textbook are the textbook file in PDF format and a textbook manifestation file in extensible markup language (XML) format which are uploaded via the administrative dashboard page. Lesson and exercise multimedia are uploaded from separate pages that are anchored to the dashboard page via hyperlinks.

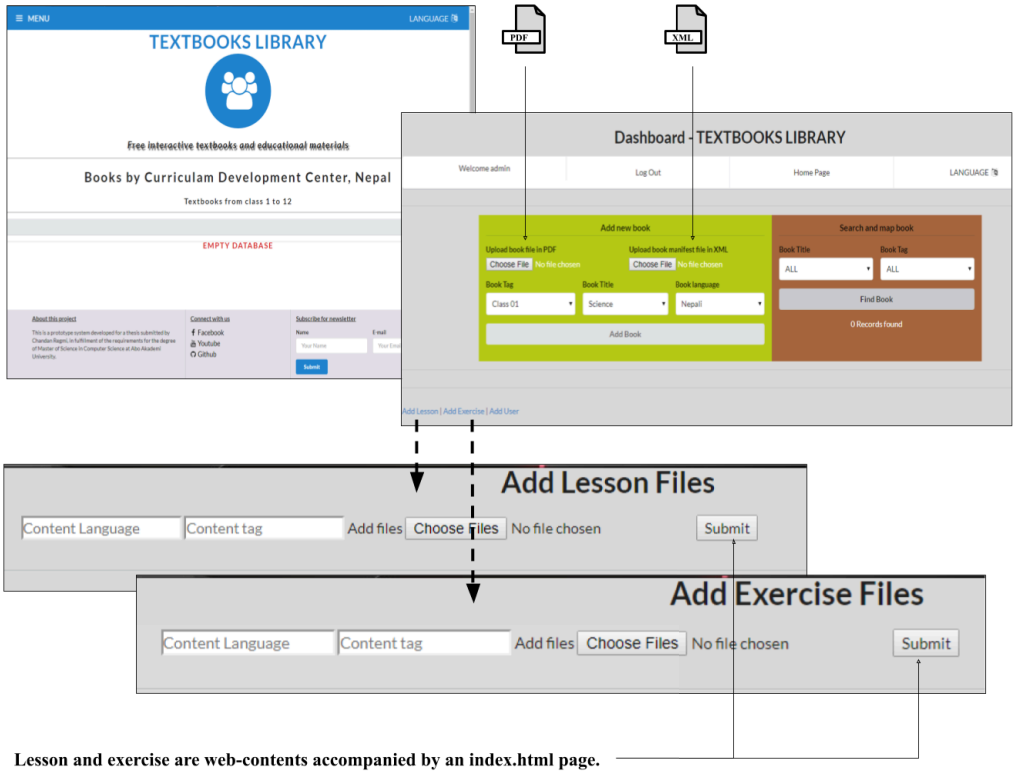


FIGURE 5.6: E-textbook system and inputs.

Table 5.2 shows a description of all the inputs used to test the operation of the e-textbook system. The actual input files are available in the code repository (see Appendix A). A textbook file in PDF and a manifest file in XML are the primary inputs required to create an e-textbook. Multimedia content can be added later and linked to the textbook file as lessons and exercises. The integration and display of multimedia content as lessons and exercises have been shown by using templates and examples.

TABLE 5.2: Inputs used in the e-textbook system

Inputs used	**File description**	**Source**
science textbook of grade 9.	A PDF file	Downloaded from CDC website[1]
Textbook manifest	An XML file	Created
Lesson template	An index.html	Created
Exercise template	An index.html	Created
Lesson example	Web contents accompanied by an index.html	1. Embedded a video by Crash Course[2], and 2. a simulation by PhET Interactive Simulations[3].
Exercise example	Web contents accompanied by an index.html	1. Created and downloaded a multiple choices questions game with Wisc-Online[4], and 2. developed an interface to email assignment to the teacher.

[1]http://nkcs.org.np/cdc/library/opac_css/, [2]https://thecrashcourse.com/, [3]https://phet.colorado.edu/, [4]https://www.wisc-online.com/

5.3.2 An e-textbook with the textbook part only

For the textbook file in PDF format, I downloaded an open textbook provided on the website of the CDC, Nepal. Textbook manifestation data in XML format has been created manually. When these two files are uploaded through the administrative dashboard, the e-textbook listing appears in the website index page as shown in Figure 5.7. The manifestation data provided as an XML file is utilized to create the book map which is the metadata about the textbook such as the number of chapters, total pages, page range of each chapter, etc. This book map is required later to link lesson and exercise to the individual textbook chapters. Even though the e-textbook has only textbook content so far, it is accessible and usable.

5.3.3 An e-textbook with both textbook and multimedia part

To test the multimedia integration I created templates for lesson and exercise, uploaded and linked them to the first chapter of the textbook as shown

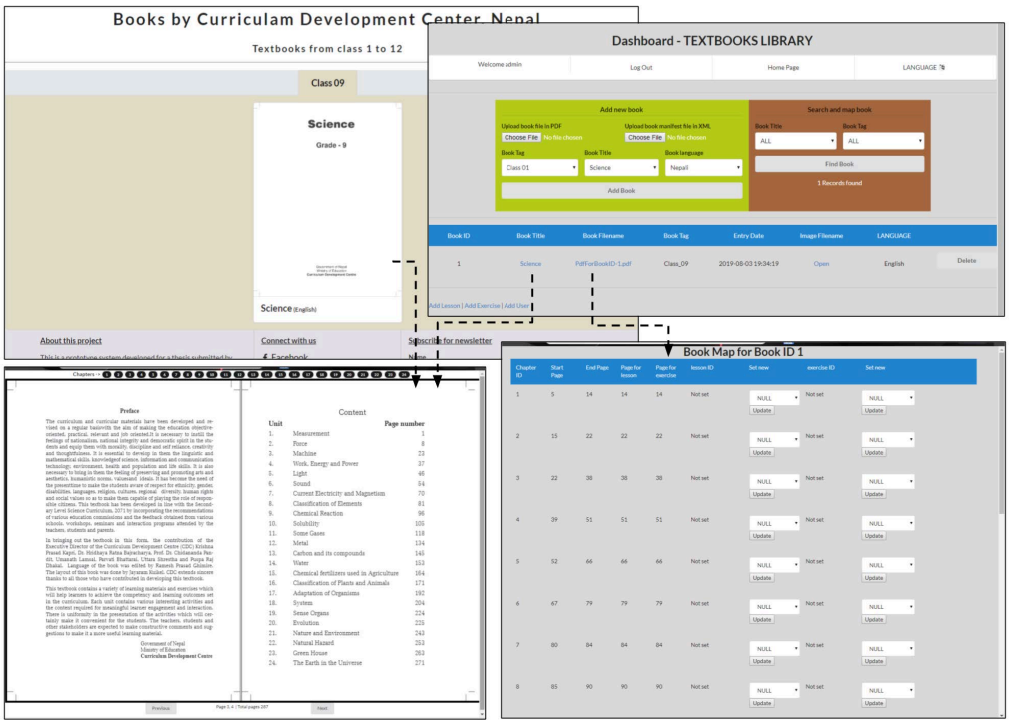


FIGURE 5.7: An e-textbook with only textbook part.

in the book-map record in Figure 5.8. To present an actual example of lesson and exercise, I used some open educational resources and linked them as the lesson and exercise of the second chapter of the textbook as shown in Figure 5.9. The lesson and exercise linked to the first chapter are layout templates and do not contain any actual multimedia whereas those linked to the second chapter are a combination of open educational resources, thus presenting examples of an actual lesson and exercise multimedia.

The lessons and exercises are linked or unlinked to the textbook chapters via the book map page. The end pages of textbook chapters have been set as the pages to display the hyperlinks to the lesson and exercise. This implies that the links to open a lesson or exercise of any chapter are only visible when the end page of that chapter is navigated. As shown in Figure 5.8, the green buttons to open the lesson and exercise of the first chapter are visible only when the end page of that chapter has been navigated. The lesson or exercise opens in a modal window which overlays the textbook content in the background.

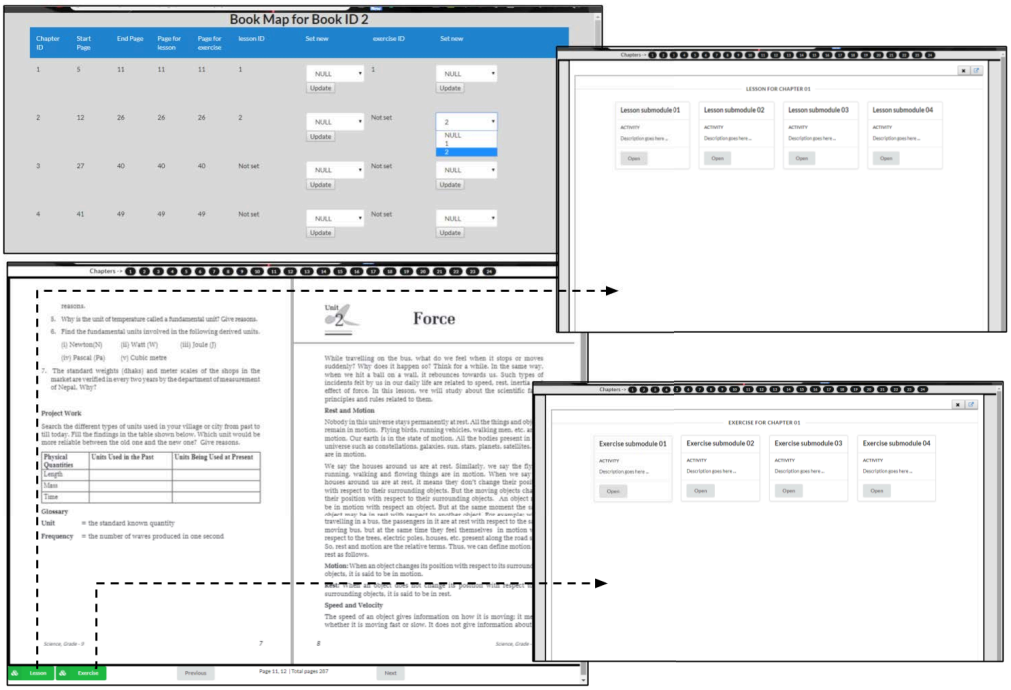


FIGURE 5.8: An e-textbook with both textbook and multimedia part.

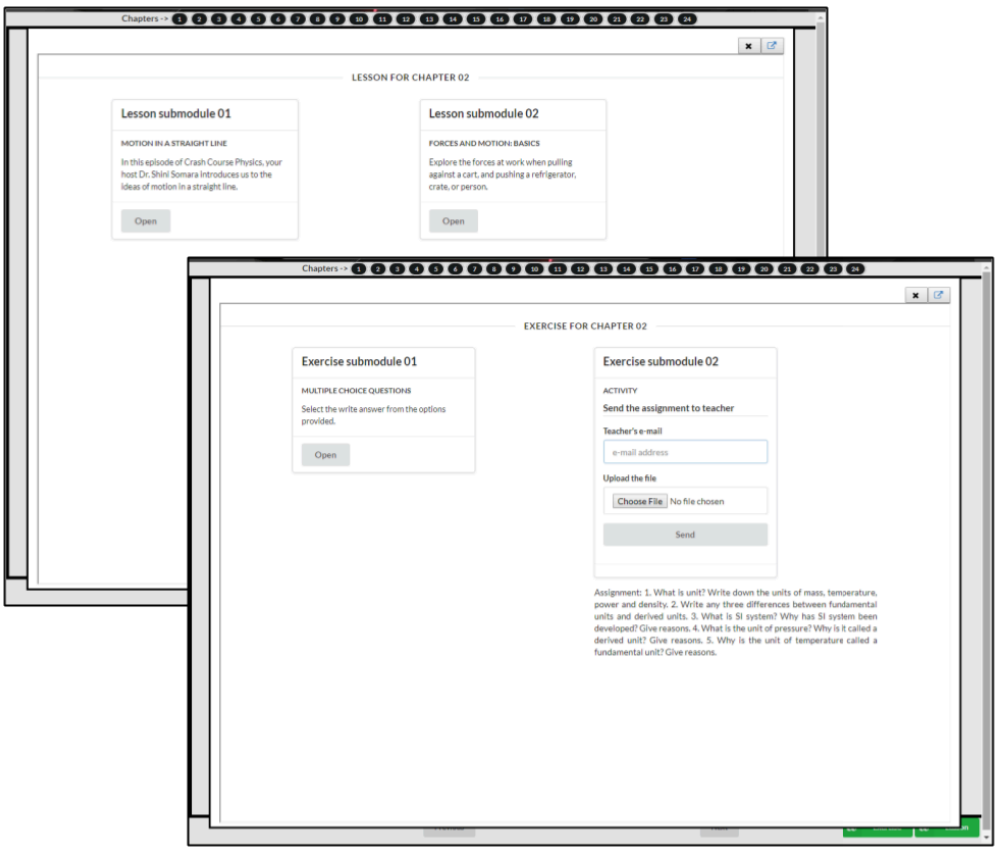


FIGURE 5.9: Example of lesson and exercise multimedia.

Chapter 6

Prototype evaluation and discussion

6.1 Prototype evaluation

The global design of the e-textbook system was presented as a prototype web-based application that can be used and assessed. The prototype system is supposed to have realized the expected characteristics so that it can fulfill the intended functions. The five expected characteristics were reliability, compatibility, usability, accessibility, and maintainability. The intended functions were to provide an alternative to print textbooks and to deliver supplementary materials to the textbooks. The evaluation process is carried out to assess if the claimed characteristics have been realized and if they lead the system to fulfill its intended functions. A focus group interview has been used for the evaluation process. A focus group interview is a variation of group interviews to collect data and discover the perceptions of participants around a focused topic.

6.1.1 Quality criteria to assess

Four quality criteria to assess the overall quality of a developed educational intervention are relevancy, consistency, practicality (expected and actual), and effectiveness (expected and actual) [17]. The prototype e-textbook system under evaluation is not a completed product and thus lacks the functionalities to evaluate actual practicality and actual effectiveness. Therefore relevancy, consistency, expected practicality, and expected effectiveness have been assessed. This is a semi-summative evaluation indicating the dual aim of the evaluation process: to validate the design artifact (to proof) and to collect feedback from stakeholders (to improve). A summative evaluation is

usually carried out on a completed product, therefore, semi-summative evaluation is a preferred evaluation method to perform on a prototype product that lacks the functionalities to use it in realistic settings.

Five questions were formulated to discuss in the focus group interview. The focus group interview had four different sessions for students, teachers, policymakers, and developers as respondents, in which the same five questions were discussed. The uniformity of questions was maintained to get the responses on the same issue from the different perspectives of the stakeholders. As shown in Table 6.1, two questions were tied with the quality criterion of relevancy and one question each was tied with the consistency, expected practicality, and expected effectiveness of the prototype e-textbook system. The first two questions are expected to elicit feedback from different stakeholders about the relevancy of the system, based on usability and cost-value comparison. The third question tries to collect the respondents' views on the system's compatibility according to cost, need, policy orientation, available resources, etc. The last two questions try to explore the respondents' views on the practicality and effectiveness of the e-textbook system within the context of school education in Nepal. The questions were asked in a five-point Likert-scale where a respondent provides his/her agreement to the statement by selecting one option from five given choices: strongly agree, agree, neutral, disagree, and strongly disagree. Likert scale is a psychometric response scale used to obtain responses in a five or seven scale range. Likert scale data can be analyzed as interval data and mean value can be used to measure the central tendency [73]. After providing the responses by selecting one of the five options in the Likert-scale, the respondents were asked to provide their suggestions for improvement when each question was discussed. See Appendix B.1 and Appendix B.2 for the materials used in the focus group interview.

6.1.2 Participants and process

Participants in focus group interviews are purposefully selected from a specific population, based on the criterion that they have something to say on the topic, have knowledge of the study area, have similar socio-characteristics, and would be comfortable talking to the interviewer and each other [58]. The focus group used in the prototype evaluation had twenty participants out of which sixteen were respondents and four were

TABLE 6.1: Questions used to assess the different quality criteria

Relevancy	1. The e-textbook system is an appropriate choice to provide alternatives to the use of print textbooks.
	2. The e-textbook system can be an effective way to deliver multimedia educational materials.
Consistency	3. The e-textbook system is compatible with its described use in the classroom and at home.
Expected Practicality	4. The e-textbook system is easy to use in the context of school education in Nepal.
Expected Effectiveness	5. The e-textbook system can be an effective educational technology to improve the teaching/learning in school education.

moderators. All the respondents were selected from two public schools of Kathmandu, Nepal and confirmed for participation in advance. The entire focus group interview was carried out in four different sessions with a group of five in each session. Each group had four respondents and a moderator. The four groups were made in such a way that each group consisted of either students, teachers, policymakers, or ICT service developers as respondents. Each session of the focus group was about an hour long and all four sessions were conducted on the same day. The place where the focus group interview was conducted had computer systems to access and use the prototype e-textbook system.

The sessions were started by the moderators by introducing the prototype e-textbook system and instructions on how to use it. The participants were given 15 minutes to use and see the functionalities of the system, which was then followed by the group interview. The same five questions were then discussed in all the sessions. Each participant was provided with five questions in written form before the interview, and the moderator was provided with a different form to collect the responses. The interviewing process can be described as follows. First, the moderator put a question and explained it if required. Then each respondent gave his/her response in turn. A maximum of three minutes was provided to each respondent for the discussion on each question. The moderators collected the main points of the discussions in writing using the form provided to them.

6.1.3 Data collection and analysis

The two main sources of data were the responses provided by the respondents on the Likert-scale and the open-ended responses collected by the moderator. See Appendix B.3 for the complete data collected via the Likert-scale. The frequency distribution of the responses, for each question and all the questions combined, is shown in Figure 6.1 and Figure 6.2 respectively. As shown in Figure 6.1, at least eleven participants out of sixteen have found the prototype system relevant for the intended purposes, which was assessed via question 1 and question 2. Similarly, fifteen participants strongly agreed or agreed to the statement of question 4, showing a high degree of expected practicality from the prototype e-textbook system. The expected effectiveness of the prototype system has also been found satisfactory as assessed by question 5 which was strongly agreed or agreed with by nine participants, while four participants were neutral. Seven participants strongly agreed or agreed with, and seven were neutral to, the statement of question 3 which assessed the consistency of the system.

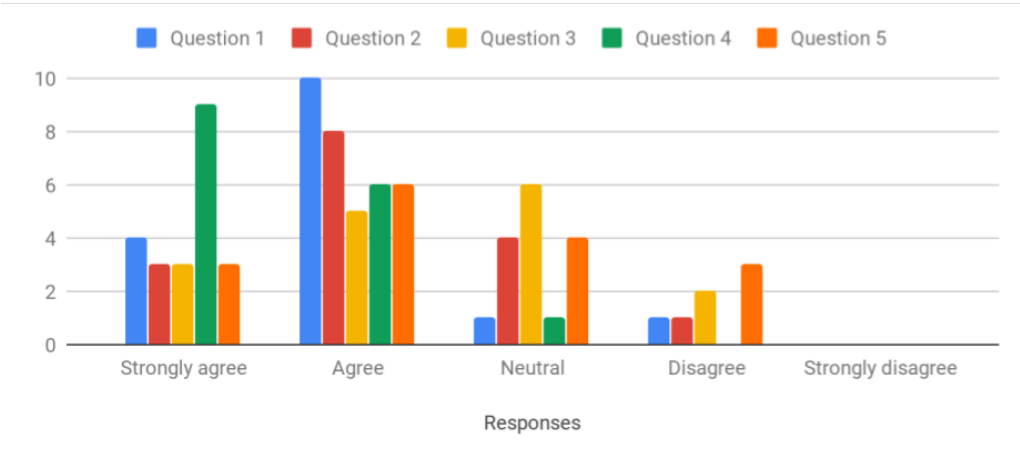


FIGURE 6.1: Frequency distribution of responses for each question.

While analyzing the frequency of responses combined for all questions, 70 % of the responses signaled agreement as shown in Figure 6.2, while only 8.6 % signaled disagreement and 21 % were neutral. While analyzing the different sessions of the focus group, the sessions with students and developers indicated the highest percentage of the agreement, at 80 % and 75 % respectively. The sessions with teachers and policymakers both pointed out 65 % of responses with strongly agree or agree. Overall, the feedback

collected via Likert-scale shows that the prototype e-textbook has been found relevant for the intended functions with a high degree of expected practicality. The prototype has been found to offer a sufficient level of expected effectiveness and consistency too.

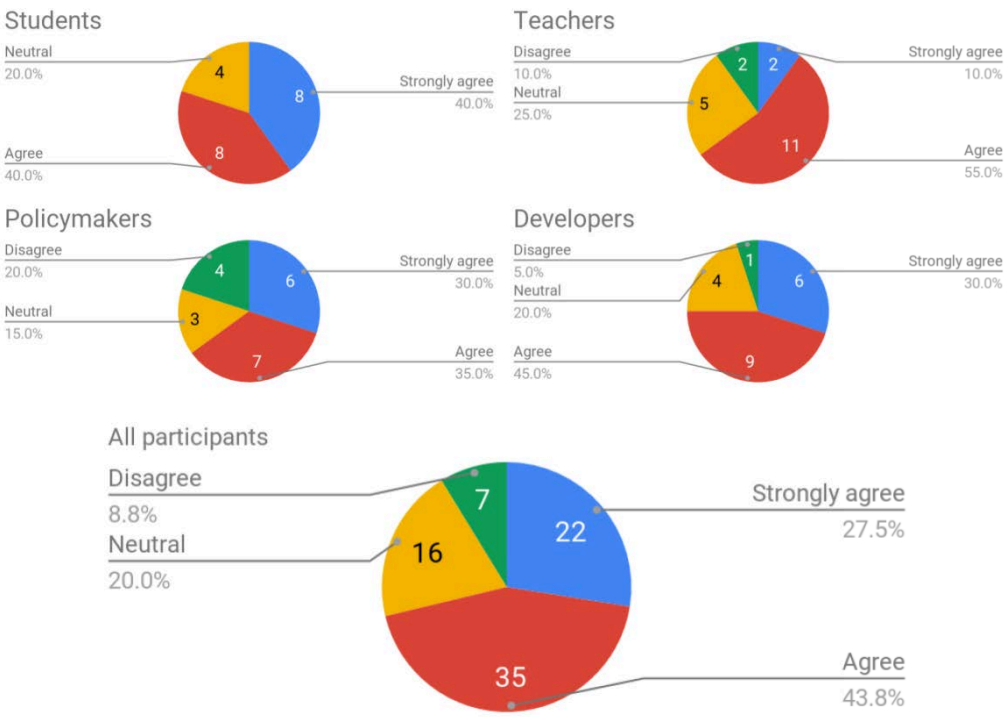


FIGURE 6.2: Frequency distribution of responses combined for all questions.

The respondents were asked to provide suggestions for improvements while each question/statement was discussed, thus expecting at least five suggestions from each respondent. The suggestions for improvements were open-ended responses and they were collected by the moderators in writing, and analyzed later to gather the thematic meanings and categorize them accordingly. Each response has been thematically analyzed and categorized as shown in Table 6.2. See Appendix B.4 for the materials/process used for this thematic analysis. Among the possible 80 responses, six responses have been categorized as no response or irrelevant. The remaining 74 suggestions have been categorized into eleven categories.

Almost half of the responses have been categorized into three categories: ensuring the prerequisites such as infrastructure and human resources, adding more functionalities and features, and addressing the issues related to media content development. These were the main three categories

Table 6.2: Categorizations of the participants' responses into main themes

Categories of suggestions	**Number of suggestions**
1. Improvements in the textbook content presentation	3
2. Make the e-textbooks usable on handheld devices	7
3. Add more functionalities and features	11
4. Improvements in the quality of textbook content	4
5. Address issues related to media content development	10
6. Ensure the prerequisites (infrastructure, human resources, etc)	15
7. Reduce the cost of development and implementation	5
8. Improvements in the quality of media content	4
9. Align with government policies	6
10. Minimize the assumed workload to teachers/other staff	4
11. Address issues of the file size of e-textbooks	5
12. No or irrelevant response	6

of suggestions, each category having 15, 11, and 10 responses respectively. Responses related to infrastructure in the classroom, availability of the Internet, human resources in the schools, etc have been included under the category ensuring the prerequisites. Participants had provided suggestions to add functions and tools such as audio narration, dictionary, and calculator. Such suggestions have been kept under the category add more functionalities and features. The third category of suggestion with the highest number of responses is: address the issues related to media content development. The main issues related to media content development indicated by the participants were the high cost of media development, ensuring the quality and relevance of the content, and the requirement of a large quantity of media content for e-textbooks.

A significant number of suggestions were to make e-textbooks available in handheld devices such as tablet computers and mobile phones. Some participants also indicated the need to align with ongoing government policies

and plans for a successful implementation of e-textbooks in school education. Reducing the cost of development and implementation, addressing the issues related to the possible huge file size of e-textbooks, and minimizing the presumed workload of the teachers were other important suggestions provided by the participants.

6.2 Discussion

A final discussion on the design characteristics realized in the prototype e-textbook system and the methods followed to achieve those characteristics will be presented here. After the prototype evaluation it can be argued that, in the context of school education of Nepal or similar, e-textbooks as an educational intervention with certain characteristics should lead to expected outcomes/purposes. Here the expected outcomes of e-textbooks are to provide an alternative to print textbooks, and to provide supplementary material to the print textbooks. The characteristics of the prototype e-textbook system, the methods followed to achieve those characteristics, and the arguments for following those methods will be discussed here and can be read as design guidelines in the following format: if you want to design <intervention X> for the <purpose/function Y> in <context Z>, then you are best advised to give <that intervention> the <characteristics A, B, and C> [substantive emphasis], and to do that via <procedures K, L, and M> [procedural emphasis], because of <arguments P, Q, and R>.

6.2.1 Design characteristics

Reliability, compatibility, usability, accessibility, and maintainability were the five main characteristics aimed at in the prototype e-textbook system. The reliability of an e-textbook system depends on the reliability of content and the overall reliability of the system to create, distribute, and read the e-textbooks. Content reliability of e-textbooks derives from the accuracy, relevancy, and trustworthiness of the content for given educational purposes. The overall reliability of an e-textbook system primarily depends on the reliability of the hardware and software technology used. The prototype e-textbook system has defined authorized school textbooks as the primary content, which maintains the content reliability. The development of the e-textbook system as a web application provides the benefit of using

open source technologies, as well as ensures the compatibility of content over various kinds of devices and easy accessibility of content via the Internet. Available design guidelines, for example EBONI guidelines, have addressed various aspects of interface and functionalities such as presenting the content in a book-alike interface and providing basic functions like searching, highlighting, bookmarking, note-taking, zooming, etc. Applying these state-of-the-art guidelines ensures the usability of the e-textbooks to a great extent. Some aspects of the maintainability of an e-textbook system, such as content updates, can be made easier by maintaining the granularity of the content in the form of learning objects. The prototype e-textbook system has defined the textbook and multimedia content as separate learning objects, which facilitates their independent development and maintenance.

The complexity of design increases when the content of e-textbooks is not limited to the content derived from print textbooks, and multimedia contents are added as an integral part. The issues of structuring and sequencing the multimedia content, as well as the issues related to the user interface such as where to embed and display multimedia, should be dealt with carefully. The goals of an educational system follow the underlying educational curriculum, and its user interface is expected to be as self-descriptive as possible. Therefore, maintaining the orientation of the learner as expected by the underlying curriculum is one of the most relevant issues of the interface design of educational systems [43]. In paper textbooks, the orientation of a learner is guided by dividing the content into chapters, pages, and paragraphs, and by providing orientation clues such as page numbers and bookmarks, etc. Multimedia e-textbooks not only incorporate print textbooks in digital form but also require including a considerable amount of multimedia. Even though hypertext can be used to embed the multimedia, the resulting excessive connectivity can result in cognitive overload and confuse the orientation of the learners [8], [43]. The prototype e-textbook system has defined the structure of multimedia used in e-textbooks according to the chapter-based structure of the print textbooks. Furthermore, the multimedia content tied with each textbook chapter is divided into lessons and exercises. Multimedia content in an e-textbook, when presented either as lessons or exercises tied with specific chapters, provides the pupils with a familiar structure for using the e-textbooks.

6.2.2 Design methods

Eight methods were proposed for designing e-textbooks for school education in Nepal. These methods, when employed to design and develop e-textbooks, ensure that the resulting e-textbooks are reliable, compatible, usable, accessible, and maintainable.

1. Digitize the print textbooks and use them as the primary content of e-textbooks

This ensures the reliability of the e-textbook content because print textbooks used in school education in Nepal are authorized by the government agencies such as the curriculum development center. Apart from the content reliability, it also helps to reduce the development cost by reusing already available resources.

2. Use a web-based system to develop, distribute, and read the e-textbooks

The use of a web-based system is preferred because it helps in multiple aspects such as reducing the development cost by using open-source technologies, ensuring content uniformity and thus compatibility, greater accessibility when deployed on the Internet, etc.

3. Make the e-textbooks downloadable for offline use

Making some content of e-textbooks downloadable, at least the textbook part if not media also, is a useful method to ensure greater accessibility and usability in a context like school education in Nepal where continuous availability of the Internet in schools might not be guaranteed.

4. Follow the available design guidelines about interface and functionalities of e-textbooks

To ensure the usability of e-textbooks, it is best advised to follow the state-of-the-art design principles wherever possible because such guidelines have been proven effective by evidence-based research.

5. Follow the available guidelines on how to design and use multimedia for learning

A multimedia learning material can not be claimed effective only because it is multimedia. To ensure the effectiveness of multimedia content this should have been designed as per instructional design theories, and its use should be carefully examined so that no cognitive overload is induced.

6. Maintain a logical separation between contents derived from print textbooks and multimedia contents

Separation of textbook contents and multimedia contents is important to facilitate the independent development of such content. It also helps to improve the maintainability because both contents can be updated independently.

7. Use the chapter-based structure of textbooks to structure and sequence the multimedia

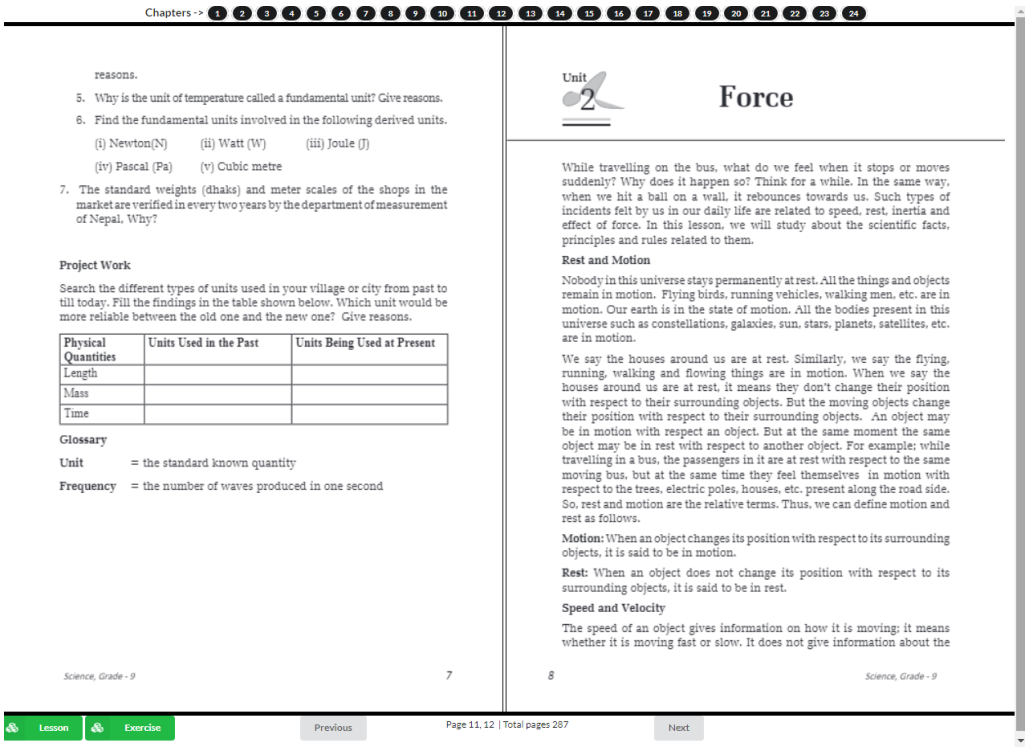
It is efficient to maintain multimedia content according to the chapter-based structure of textbook content, so that each chapter of textbooks and the multimedia content of that chapter together can be maintained as a learning object. By following the chapter-based structure of a textbook while integrating media into it, the process of defining the structure and sequence of multimedia can be made easier.

8. Classify multimedia contents based on their objectives into two broad categories lesson and exercise

Classifying multimedia content as lessons and exercises increases the usability of the e-textbooks due to the familiar concepts of lessons and exercises in the context of school education in Nepal.

The last three design methods 6, 7, and 8 have been primarily proposed to deal with issues related to the design of multimedia e-textbooks. These design methods suggest that multimedia content used in e-textbooks should be chapter-specific, defined either as lessons or exercises, and logically separated from the textbook content. These methods also determine the user-interface decisions such as limiting the hyperlinks needed to link multimedia to two per chapter, using the predefined labels lesson and exercise for hyperlinks, and binding the hyperlinks to the last pages of chapters as shown in Figure 6.3. The user-interface has minimized the number of hyperlinks required to integrate multimedia to only two, thus dealing with the issue of excessive connectivity when hyperlinks are used. The hyperlinks are displayed only when the last pages of chapters are navigated, to ensure that the learner's orientation will not be distracted.

Among the proposed eight design methods, some have not been applied to the prototype e-textbook system due to the early stage of development. Making the e-textbooks downloadable for offline use has been left out, considering it as a non-substantive feature to implement in an early-stage prototype. Similarly, the fifth design method which advocates following the available guidelines on how to design and use multimedia for learning, is



Chapters -> 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

reasons.

5. Why is the unit of temperature called a fundamental unit? Give reasons.
6. Find the fundamental units involved in the following derived units.
   (i) Newton(N) (ii) Watt (W) (iii) Joule (J)
   (iv) Pascal (Pa) (v) Cubic metre
7. The standard weights (dhaks) and meter scales of the shops in the market are verified in every two years by the department of measurement of Nepal. Why?

Project Work

Search the different types of units used in your village or city from past to till today. Fill the findings in the table shown below. Which unit would be more reliable between the old one and the new one? Give reasons.

Physical Quantities	Units Used in the Past	Units Being Used at Present
Length		
Mass		
Time		

Glossary

Unit = the standard known quantity

Frequency = the number of waves produced in one second

Science, Grade - 9 7

Unit 2 **Force**

While travelling on the bus, what do we feel when it stops or moves suddenly? Why does it happen so? Think for a while. In the same way, when we hit a ball on a wall, it rebounces towards us. Such types of incidents felt by us in our daily life are related to speed, rest, inertia and effect of force. In this lesson, we will study about the scientific facts, principles and rules related to them.

Rest and Motion

Nobody in this universe stays permanently at rest. All the things and objects remain in motion. Flying birds, running vehicles, walking men, etc. are in motion. Our earth is in the state of motion. All the bodies present in this universe such as constellations, galaxies, sun, stars, planets, satellites, etc. are in motion.

We say the houses around us are at rest. Similarly, we say the flying, running, walking and flowing things are in motion. When we say the houses around us are at rest, it means they don't change their position with respect to their surrounding objects. But the moving objects change their position with respect to their surrounding objects. An object may be in motion with respect an object. But at the same moment the same object may be in rest with respect to another object. For example; while travelling in a bus, the passengers in it are at rest with respect to the same moving bus, but at the same time they feel themselves in motion with respect to the trees, electric poles, houses, etc. present along the road side. So, rest and motion are the relative terms. Thus, we can define motion and rest as follows.

Motion: When an object changes its position with respect to its surrounding objects, it is said to be in motion.

Rest: When an object does not change its position with respect to its surrounding objects, it is said to be in rest.

Speed and Velocity

The speed of an object gives information on how it is moving; it means whether it is moving fast or slow. It does not give information about the

8 Science, Grade - 9

Lesson Exercise Previous Page 11, 12 | Total pages 287 Next

FIGURE 6.3: User interface to read e-textbooks where hyperlinks are bound to the last pages of chapters and have labels lesson and exercise.

more applicable in later stages of e-textbook development. The design characteristics, design methods, and the arguments together can be presented as design guidelines. For example, a design guideline can be written as "if you want to design e-textbooks to provide alternatives to print textbooks in school education of Nepal, then you are best advised to give the e-textbooks the characteristic reliability and to do that by using digital form of print textbooks as primary content because of the argument that this maintains the authenticity of the content."

Chapter 7

Conclusion

7.1 Research limitation

The research was limited by the scope of the thesis work manifested as a lack of time and resources to carry out complete educational design research. The preliminary investigation phase was limited to document analysis only which could be better if combined with other research methods, such as a survey to maintain strong validity of the findings. Similarly, the formative evaluation carried out on the design proposal was limited to the screening method only which could be further elaborated by including expert reviews. The design process was limited to develop a prototype system only, due to limited time and resources.

7.2 Future work

The immediate future work is to develop the prototype e-textbook system into a completed product so that a summative evaluation could be carried out to validate the design characteristics and methods. The aim of early-stage design research is not the theoretical yield, rather it provides a foundation for theoretical yields from later randomized clinical trials or other laboratory tests [10]. The development of a prototype e-textbook system for school education in Nepal was early-stage design research and I argue that it provides a foundation for theoretical yields in the direction of defining an optimal user-interface for multimedia e-textbooks. Researchers have discussed various drawbacks of using hyperlinks in educational systems such as the extensive requirement of navigation both cognitively and practically [43], risk of confusing users with too much information [6], and risk of

hindering immersed reading and resulting in superficial reading [8]. A comparative study to evaluate the book-alike interface used in the prototype e-textbook system (shown in Figure 6.3) against its web-alike alternative (shown in Figure 7.1) can provide more definitive answers on how to use hyperlinks efficiently in e-textbooks.

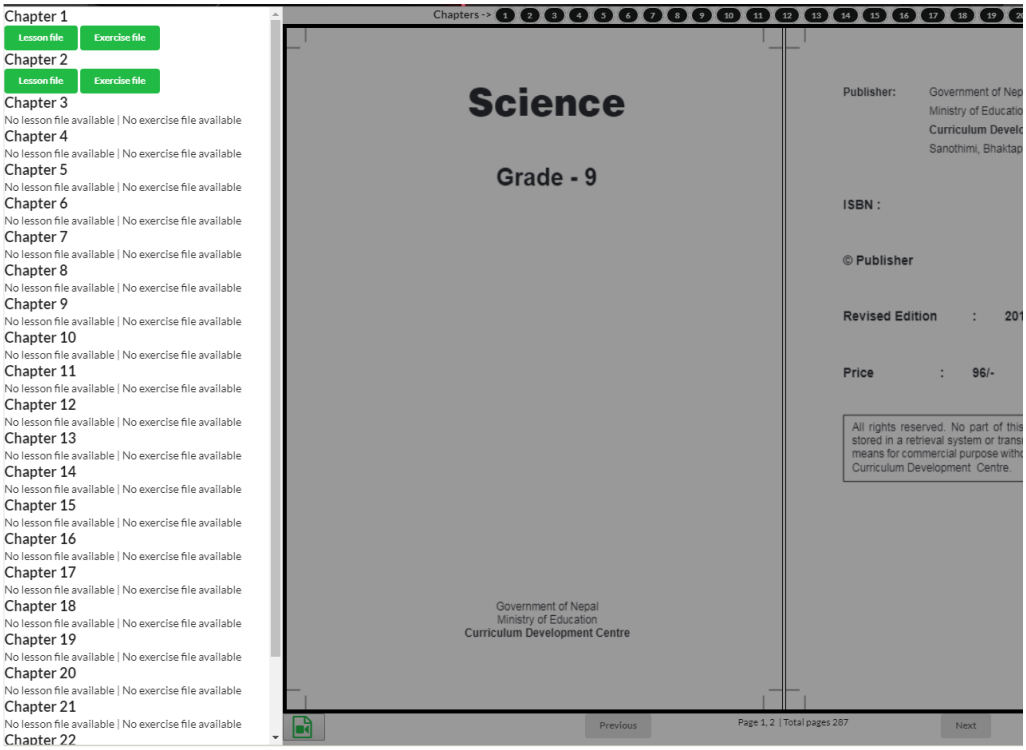


FIGURE 7.1: An alternative interface to read e-textbooks where hyperlinks to open multimedia are available as a side-menu.

7.3 Conclusion

This thesis work was early-stage educational design research aimed to develop a prototype e-textbook system for school education in Nepal. The developed prototype will provide a reference for similar developments in the future. The research work also detailed five characteristics of e-textbooks as well as presented design methods to realize those characteristics. I believe that the design method proposed would be useful to follow while developing e-textbooks for school education in Nepal or in a similar context. The overall design process documented as educational design research is also expected to provide an important reference for conducting similar research.

While developing the prototype e-textbook system, a design framework on how to sequence, integrate, and display multimedia has been proposed. This design framework suggests the use of chapter-specific multimedia divided into lessons and exercises which are bound to the last pages of chapters via hyperlinks. This framework can be an efficient way to deal with various aspects of multimedia e-textbook design such as careful use of hyperlinks, maintaining e-textbooks as familiar as paper textbooks, and making the interface as self-descriptive as possible.

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Appendix A

Code repository of the prototype e-textbook system

A.1 GitHub Repository

https://github.com/cregmi/etextbook (79 files, 24,000 + lines of code). The repository has two folders. The EtextbookSystem folder contains the code files and the InputsToTestSystem folder contains the input files.

A.2 Steps to deploy the code as a web application

1. Copy and paste all the code files inside the EtextbookSystem folder to the webroot of your webserver.
2. Create the database and tables using the SQL command given in the code file /include/table.sql
3. Make the necessary changes to provide MySQL access credentials in the code file /include/config.php on line 7 and 8.
4. The system is now ready and the website index page is accessible via the web browser.
5. The login page is accessible at /login. Though at this point, there are no user credentials to log in to the system.
6. To create the first admin account, run the /login/add-default-admin.php from browser. This script creates an administrator with the username 'admin' and password 'password'.

7. Now access the dashboard with username 'admin' and password 'password'.

8. Test the system by uploading input files available in the InputsToTestSystem folder.

9. If the PHP extension Imagick[1] is not available, the default image file available at /upload/book/image/default.png is used instead of creating an image from the cover page of the textbook file. See the lines from 85 to 103 in the code file /login/dashboard.php

[1] https://www.php.net/manual/en/book.imagick.php

A.3 A live instance of the system

A live instance of the system is available at http://www.textbookslibrary.tk. The dashboard at /login is accessible with username 'admin' and password 'password'.

Appendix B

Materials used for the prototype evaluation

B.1 Likert scale questionnaire used by the respondents

Questions to discuss
(छलफल गर्नुपर्ने प्रश्नहरु)

Question 1, The e-textbook system is an appropriate choice to provide alternatives to the use of print textbooks.
(प्रश्न १, ई-पाठ्यपुस्तक प्रणाली प्रिन्ट पाठ्यपुस्तकहरूको विकल्प प्रदान गर्न उपयुक्त विकल्प हो |)

❒ Strongly Agree (दृढ सहमत) ❒ Agree (सहमत) ❒ Neutral (तटस्थ) ❒ Disagree (असहमत) ❒ Strongly Disagree (दृढ असहमत)

Question 2, The e-textbook system can be an effective way to deliver multimedia educational materials.
(प्रश्न २, ई-पाठ्यपुस्तक प्रणाली मल्टिमेडिया शैक्षिक सामग्री वितरण गर्ने एक प्रभावकारी तरीका हुन सक्छ |)

❒ Strongly Agree (दृढ सहमत) ❒ Agree (सहमत) ❒ Neutral (तटस्थ) ❒ Disagree (असहमत) ❒ Strongly Disagree (दृढ असहमत)

Question 3, The e-textbook system is compatible with its described use in the classroom and at home.
(प्रश्न ३, कक्षाकोठा र घरमा वर्णन गरिएको प्रयोगको लागि ई-पाठ्यपुस्तक प्रणाली संगतपुर्ण छ |)

❒ Strongly Agree (दृढ सहमत) ❒ Agree (सहमत) ❒ Neutral (तटस्थ) ❒ Disagree (असहमत) ❒ Strongly Disagree (दृढ असहमत)

Question 4, The e-textbook system is easy to use in the context of school education in Nepal.
(प्रश्न ४, ई-पाठ्य पुस्तक प्रणाली नेपालमा स्कूल शिक्षाको सन्दर्भमा प्रयोग गर्न सजिलो छ |)

❒ Strongly Agree (दृढ सहमत) ❒ Agree (सहमत) ❒ Neutral (तटस्थ) ❒ Disagree (असहमत) ❒ Strongly Disagree (दृढ असहमत)

Question 5, The e-textbook system can be effective educational technology to improve teaching /learning in school education.
(प्रश्न ५, ई-पाठ्यपुस्तक प्रणाली स्कूल शिक्षाको शिक्षण सुधार गर्न प्रभावकारी शैक्षिक प्रविधि हुन सक्छ.

❒ Strongly Agree (दृढ सहमत) ❒ Agree (सहमत) ❒ Neutral (तटस्थ) ❒ Disagree (असहमत) ❒ Strongly Disagree (दृढ असहमत)

Name: ……
Sign: ……...

B.2 Form used by the moderators to collect open-ended responses

Moderator:
Respondents:

Name	Role in detail
1. …….	
2. …….	
3. …….	
4. …….	

Question 1, The e-textbook system is an appropriate choice to provide alternatives to the use of print textbooks. Discuss suggestions for improvements. (focus on usability and cost-value comparison)
1.

2.

3.

4.

Question 2, The e-textbook system can be an effective way to deliver multimedia educational materials. Discuss suggestions for improvements (focus on usability and cost-value comparison)
1.

2.

3.

4

Question 3, The e-textbook system is compatible with its described use in the classroom and at home. Discuss suggestions for improvements (focus on if compatible as per cost, need, policy-orientation, available resources, etc)
1.

2.

3.

4.

Question 4, The e-textbook system is easy to use in the context of school education in Nepal. Discuss suggestions for improvements.
1.

2.

3.

4.

Question 5, The e-textbook system can be effective educational technology to improve teaching /learning in school education. Discuss suggestions for improvements
1.

2.

3.

4.

Date: …….
Time: …….
Duration: ……..
Place: …….

Signature: …….

B.3 Data collected on the Likert scale questionnaire

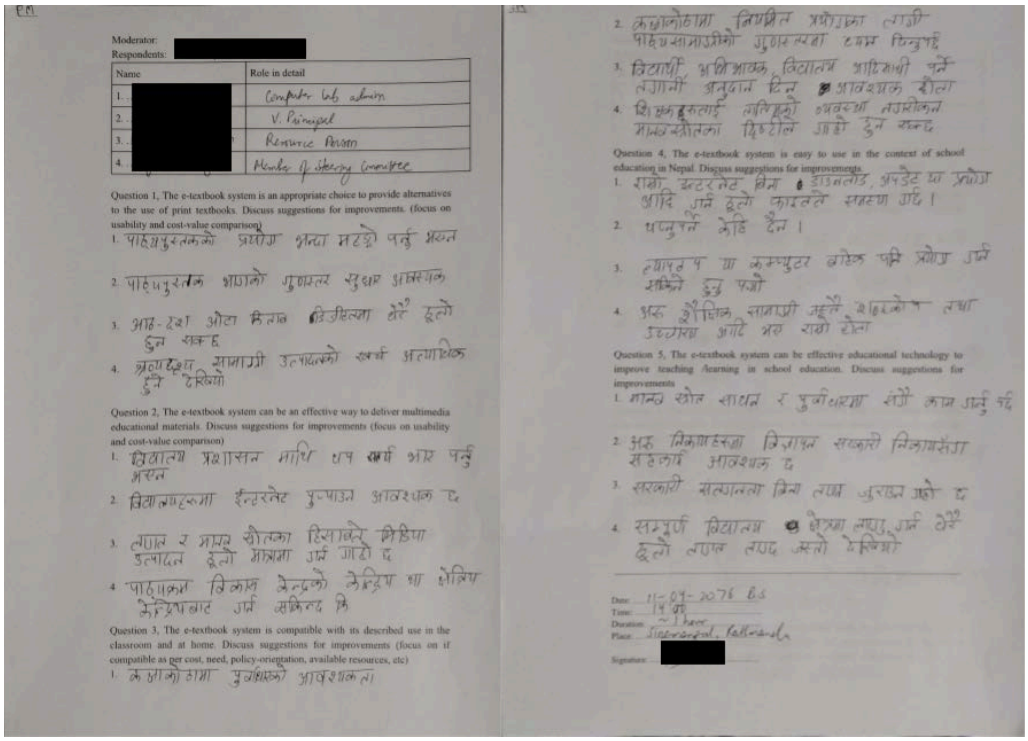
Data collected on Likert-scale questionnaire

(Q. : Question)

Students						
	Question 1	Question 2	Question 3	Question 4	Question 5	Total
Strongly agree	2	1	1	3	1	8
Agree	2	2	1	1	2	8
Neutral	0	1	2	0	1	4
Disagree	0	0	0	0	0	0
Strongly disagree	0	0	0	0	0	0
Teachers						
	Question 1	Question 2	Question 3	Question 4	Question 5	Total
Strongly agree	1	0	0	1	0	2
Agree	3	3	1	2	2	11
Neutral	0	1	2	1	1	5
Disagree	0	0	1	0	1	2
Strongly disagree	0	0	0	0	0	0
Policymakers						
	Question 1	Question 2	Question 3	Question 4	Question 5	Total
Strongly agree	1	1	1	2	1	6
Agree	2	1	1	2	1	7
Neutral	1	1	1	0	0	3
Disagree	0	1	1	0	2	4
Strongly disagree	0	0	0	0	0	0
Developers						
	Question 1	Question 2	Question 3	Question 4	Question 5	Total
Strongly agree	0	1	1	3	1	6
Agree	3	2	2	1	1	9

Neutral	0	1	1	0	2	4
Disagree	1	0	0	0	0	1
Strongly disagree	0	0	0	0	0	0
All						
	Question 1	Question 2	Question 3	Question 4	Question 5	Total
Strongly agree	4	3	3	9	3	22
Agree	10	8	5	6	6	35
Neutral	1	4	6	1	4	16
Disagree	1	1	2	0	3	7
Strongly disagree	0	0	0	0	0	0

B.4 Thematic data analysis



Moderator: [redacted]
Respondents:

Name	Role in detail
1. [redacted]	Computer lab admin
2. [redacted]	V. Principal
3. [redacted]	Resource Person
4. [redacted]	Member of Steering Committee

Question 1, The e-textbook system is an appropriate choice to provide alternatives to the use of print textbooks. Discuss suggestions for improvements. (focus on usability and cost-value comparison)

Question 2, The e-textbook system can be an effective way to deliver multimedia educational materials. Discuss suggestions for improvements (focus on usability and cost-value comparison)

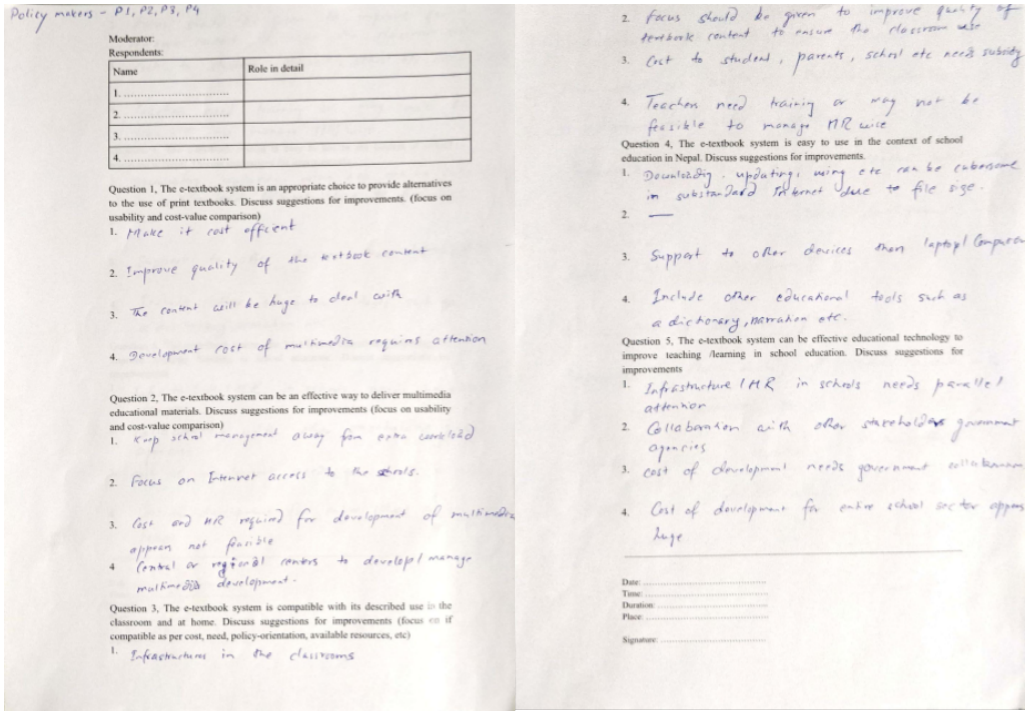
Question 3, The e-textbook system is compatible with its described use in the classroom and at home. Discuss suggestions for improvements (focus on if compatible as per cost, need, policy-orientation, available resources, etc)

Question 4, The e-textbook system is easy to use in the context of school education in Nepal. Discuss suggestions for improvements.

Question 5, The e-textbook system can be effective educational technology to improve teaching /learning in school education. Discuss suggestions for improvements

Date: 11-09-2076 B.S
Time: 14:00
Duration: ~1 hour
Place: Sisuwagadi, Kathmandu
Signature: [redacted]

Figure B.1: Image of the form used by a moderator to document the open-ended responses in Nepali language, there were four forms in total used for students, teachers, policy makers, and developers.



Policy makers - P1, P2, P3, P4

Moderator:
Respondents:

Name	Role in detail
1.	
2.	
3.	
4.	

Question 1, The e-textbook system is an appropriate choice to provide alternatives to the use of print textbooks. Discuss suggestions for improvements. (focus on usability and cost-value comparison)

1. Make it cost efficient
2. Improve quality of the textbook content
3. The content will be huge to deal with
4. Development cost of multimedia requires attention

Question 2, The e-textbook system can be an effective way to deliver multimedia educational materials. Discuss suggestions for improvements (focus on usability and cost-value comparison)

1. Keep school management away from extra workload
2. Focus on Internet access to the schools.
3. Cost and HR required for development of multimedia appears not feasible
4. Central or regional centers to develop/manage multimedia development.

Question 3, The e-textbook system is compatible with its described use in the classroom and at home. Discuss suggestions for improvements (focus on if compatible as per cost, need, policy-orientation, available resources, etc)

1. Infrastructures in the classrooms
2. Focus should be given to improve quality of textbook content to ensure the classroom use
3. Cost to student, parents, school etc needs subsidy
4. Teachers need training or may not be feasible to manage HR wise

Question 4, The e-textbook system is easy to use in the context of school education in Nepal. Discuss suggestions for improvements.

1. Downloading, updating, using etc can be cumbersome in substandard Internet due to file size.
2. —
3. Support to other devices than laptop/Computer
4. Include other educational tools such as a dictionary, narration etc.

Question 5, The e-textbook system can be effective educational technology to improve teaching /learning in school education. Discuss suggestions for improvements

1. Infrastructure/HR in schools needs parallel attention
2. Collaboration with other stakeholders government agencies
3. cost of development needs government collaboration
4. Cost of development for entire school sector appears huge

Date: .....
Time: .....
Duration: .....
Place: .....

Signature: .....

FIGURE B.2: English translation of the form shown in Figure B.1 which was used in the session with policy-makers. There were four translated forms in total used for the thematic analysis.

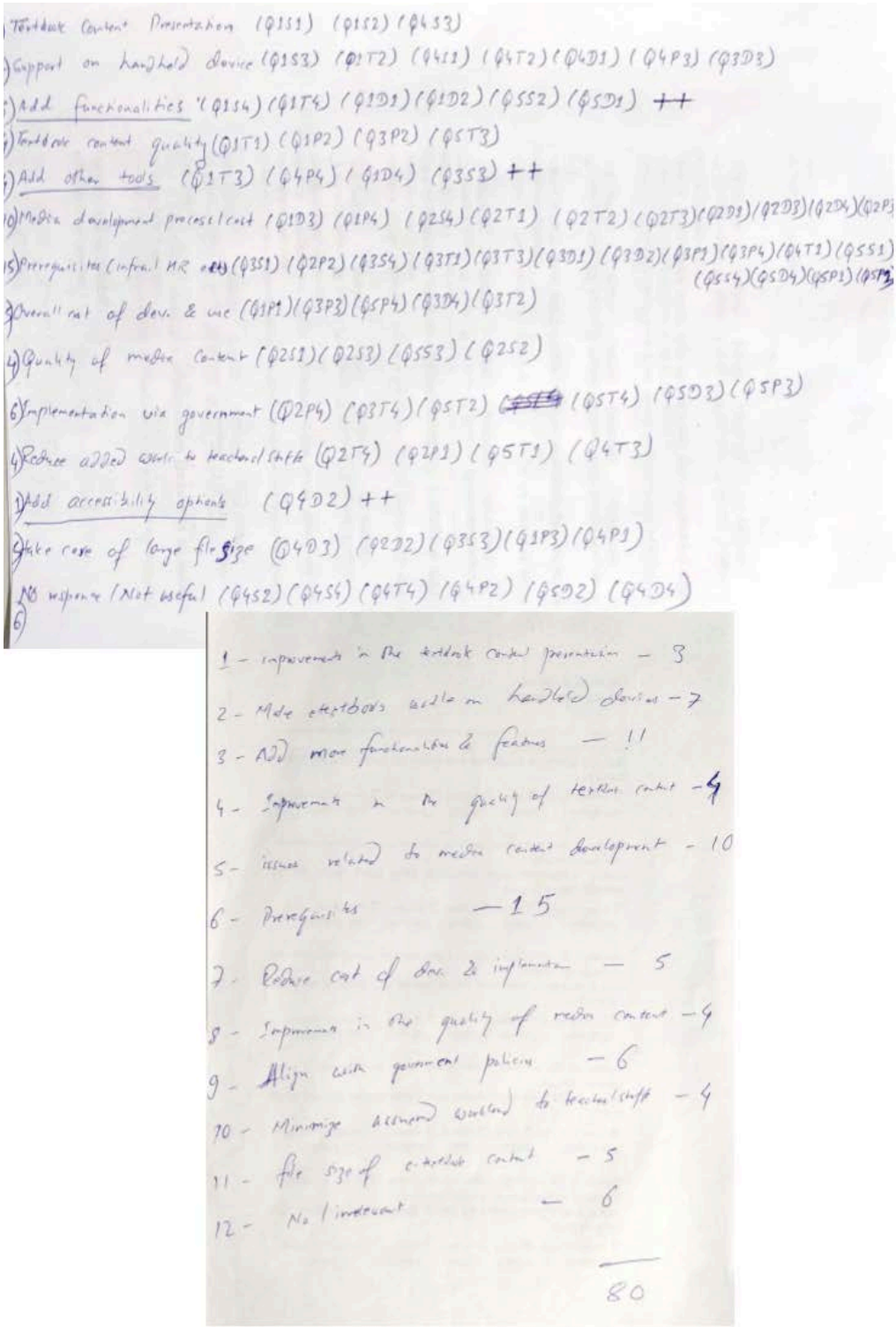


FIGURE B.3: Thematic analysis of the open-ended responses.

The responses have been tagged as $Question_i Respondent_j$ where, Question: Q, Respondents: [S, T, P, D] for students, teachers, policymakers, and developers, i: [1, 2, 3, 4, 5] for five questions, and j: [1, 2, 3, 4] for four respondents of each group