DIGITAL NOTE TAKING TOOL USING A MEDIATION APPROACH

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ABSTRACT

Technology is used widely to serve education. However progress in transferring note taking into digital form age is slow. The necessity for digital note taking into digital era become importance because information resources were increased extensively where traditional note become insufficient to process these amounts of information. Digital notes are editable, searchable, portable, readable, can be indexed, linked, etc. Massive tools developed to bridge the gap between paper-based and technology-based notes. Unfortunately, these note taking tool still inadequate to replace the traditional approaches of note taking.

This study investigates the limitations of typical note taking systems and discusses the implications on the design of future note taking applications. Developing successful note taking applications is a challenge because of the complexity, technology learning dilemma, integrity, and inefficiency issues. These challenges are stated in thesis statement to shape the solution for transmitting the traditional note taking into digital era.

We proposed a framework to assist developer with specific guidelines about note taking roles, constraints, and responsibilities for a successful note taking application. The framework is meant here to resolve inefficiency, simplify complexity, and facilitate modular engineering to accelerate the development process of note taking systems. Additionally, intelligent mediator is proposed to resolve technology learning dilemma for smoothly moving into digital environments.

A prototype called SmartInk was developed based on the framework principles. The prototype was integrated with specific mediation tools to demonstrate the functions of the mediator in transferring realistic tasks into digital environments. The system

presented here was designed to provide similar functionality of traditional note taking on the Tablet PC.

Data were collected using survey questionnaires, and server log data of user activities to explore usability of SmartInk. A total of 42 volunteers participated in the evaluation for a period of seven weeks. Six students used SmartInk every week to take their notes in classroom and review taken notes outside campus. Evaluation was conducted to test SmartInk's effectiveness, usability, and efficiency for performing note taking tasks. An excellent result of evaluation system usability was obtained from the analysis of the data of student feedbacks, and server logs entries provided us with accurate summary about the student activities during interaction with the SmartInk system. Analysis of the server logs showed that all SmartInk functions were used frequently by students in an easy, efficient, and effective way. Based on evaluation results, we conclude that the combination of framework and mediator provide a solution to bridge the gap between traditional tasks of note taking and digital environments without losing learning consistency.

ABSTRAK

Teknologi digunakan secara meluas untuk berkhidmat pendidikan. Walau bagaimanapun kemajuan dalam memindahkan nota dalam bentuk digital adalah perlahan. Keperluan bagi nota digital telah meningkat dengan kerana nota tradisional adalah tidak mencukupi untuk memproses jumlah maklumat. Nota digital boleh disunting, dicari, mudah alih, boleh dibaca, boleh diindeks, dan lain-lain. Terdapat banyak aplikasi dibangunkan untuk merapatkan jurang antara nota berasaskan kertas dan yang berasaskan teknologi. Malangnya, alat pengambilan nota masih belum mencukupi untuk menggantikan pendekatan tradisional pengambilan nota.

Kajian ini menyiasat kelemahan sistem pengambilan nota yang tipikal dan membincangkan implikasi terhadap reka bentuk aplikasi masa depan. Membangunkan aplikasi mengambil nota adalah satu cabaran kerana isu-isu kerumitan, dilemma teknologi pembelajaran, integriti, dan ketidakcekapan. Cabaran-cabaran ini telah dinyatakan di dalam tesis untuk membentuk penyelesaian untuk penindalan nota tradisional ke era digital.

Kami mencadangkan satu kerangka untuk membantu pembangun dengan garis panduan khusus mengenai pengambilan nota, dalam bentuk kekangan, dan tanggungjawab bagi nota yang berjaya. Kerangka ini adalah untuk menyelesaikan ketidakcekapan, memudahkan kerumitan, dan memudahkan kejuruteraan modular untuk mempercepatkan proses pembangunan sistem pengambilan nota. Selain itu, pengantara pintar dicadangkan untuk menyelesaikan dilema teknologi pembelajaran untuk kelancaran pemindahan ke dalam persekitaran digital.

Satu prototaip yang dipanggil SmartInk telah disepadukan berdasarkan prinsip ke rangka diatas. Prototaip itu telah diagabungkan dengan alat pengantaraan tertentu untuk menunjukkan fungsi pengantara dalam memindahkan tugas realistik ke dalam persekitaran digital. Sistem yang dibentangkan di sini telah dibuat untuk menyediakan fungsi yang sama dengan nota tradisional memggunakan PC Tablet. Data dikumpul dengan menggunakan tinjauan soal selidik, dan data log pelayan aktiviti pengguna untuk meneroka kebolehgunaan SmartInk. Seramai 42 orang sukarelawan telah mengambil bahagian dalam penilaian bagi tempoh tujuh minggu. Enam pelajar setiap minggu telah menggunakan SmartInk untuk mengambil nota mereka di dalam kelas dan mengkaji semula nota yang diambil di luar kampus. Penilaian telah dijalankan untuk menguji fungsi SmartInk, kebolehgunaan, dan kecekapan untuk melaksanakan tugas-tugas mengambil nota. Keputusan yang cemerlang iaitu kebolehgunaan sistem penilaian telah diperolehi daripada analisis data maklumbalas pelajar, manakala penyertaan log pelayan telah disediakan dengan ringkasan yang tepat mengenai aktiviti pelajar semasa ber interaksi dengan sistem SmartInk. Analisis log pelayan menunjukkan bahawa semua fungsi SmartInk kerap digunakan oleh pelajar-pelajar dengan cara yang mudah, cekap, dan berkesan. Berdasarkan keputusan penilaian, kita membuat kesimpulan bahawa gabungan ke rangka dan pengantara menyediakan penyelesaian yeng mencukupi untuk merapatkan jurang antara tugas-tugas tradisional mengambil nota dan persekitaran digital tanpa kehilangan keseragaman pembelajaran.

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1.0 INTRODUCTION

Learning is a process of acquiring new knowledge, and understanding. Note-taking is one of the most important activities performed to acquire knowledge, and improve learning outcomes. It is a process of recording information captured from a transient source, such as reading material and attending lecture. Note taking assists learners in the process of concentration, thinking, memorizing, recalling process, and enhancing performance. Technology has always been used to enhance teaching and acquisition of knowledge. Consequently, learning environment has changed from traditional media to digital form using specific tools such as projectors and power point slides. Technology has served education well. Digital note can provide us with many advantages such as easily sharable, searchable, editable, legible, portable, indexing, linking, extract knowledge, and information managements. Recently, digital devices become ubiquitous, available largely with people such as PDA, iPhone, Tablet PC, and iPad (Cope & Kalantzis, 2009). Experimental studies of current tools of note taking showed great interest for replacing the digital devices to take notes instead of using traditional paper and pen (Bauer & Koedinger, 2005b; Steimle, Gurevych, & Mühlhäuser, 2007; Ward & Tatsukawa, 2003). The overall progress of technology in this area showed the possibility of transferring this task into digital environment if appropriate system is developed with usable and useful features (Hsieh, Wood, & Sellen, 2006).

Despite the exist note taking tools, they are still in its embryonic stage. Students still use traditional way of pen and paper to take their notes because technology research has made little progress in note taking (Reimer, Brimhall, Cao, & O'Reilly, 2009). The necessity of transferring note taking into digital era is becoming more urgent due to the increasing use of information resource. Manual note taking is incapable of processing these huge amounts of information. The lack of tools for digital notes can lead to learning gaps in the next decade when most education materials will be in the digital form.

1.1 Problem Statement

Despite of the popularly of technology in education, traditional note taking is still the main activity in learning environments (Kim, Turner, & Pérez-Quiñones, 2009). Note still taken traditionally because there is little technology specifically aimed to make digital note taking more effective and efficient (Reimer et al., 2009). In this research, we summarized the main challenges of digital note taking. They are divided into four categories as listed below and described briefly in chapter 4.

- **Complexity:** Note taking is a complex activity in terms of its functionality, components, and effects on learning behaviour and outcomes. Thus, a complex traditional activity is more difficult to represent in the digital world. The term *complex challenges* encompasses different types of note-taking issues, such as complexity in selecting appropriate tools based on learning theories and in implementing these tools and their interfaces.
- **Inefficiency**: By considering the theory of cognitive load of the note-taker with a tight time constraint, the current note-taking tools remain insufficient for taking notes in the digital form because of the unnecessary time and activity required of the note taker in performing several tasks (Anderson et al., 2005; Bauer & Koedinger, 2006).
- **Integrability:** Several tools have been developed to achieve various note-taking functions; however, most of these tools have been built for individual functionalities. Digital note taking tools are widely diverse in hosted devices, interface and functional components, system platforms, and programming language implementation.

- **Technology Learning Dilemma:** Current tools of note taking are still insufficient to achieve learning goals because they contain major learning deficiency and usability distraction. We categorized these issues into two critical problems:
    - The negative effects of the developed tools and their deficiency in terms of learning prospective;
    - The conflict between the benefits of using technology tools and learning theories.

1.2 Aim of Study and Objectives

The purpose of this study is to contribute to current progress for transferring note taking into digital media by developing a framework and mediator techniques for effective digital note taking system. To achieve this aim, we identified the following research objectives.

Objective 1: To investigate the issues of transferring the traditional note taking into the digital form.

Objective 2: To propose a note taking framework to solve the inefficiency, complexity, and integrability issues in future applications.

Objective 3: To design an intelligent mediator to solve the technology learning dilemma and to adapt the realistic activities of traditional note taking into digital environments.

Objective 4: To develop a prototype for the proposed solutions in the second and third objective.

Objective 5: To evaluate the developed prototype for validation of the proposed solution.

1.3 Research Questions

This research is conducted to answer the following questions:

Table 1.1 Research Questions related to Research Objectives.

	Research Questions
Obj. 1	a) What are the main learning features of traditional note taking? b) What are the tasks, activities, styles, behaviours, and individual factors of note takers? c) Why do we need to transfer traditional notes into digital media? d) What is the progress of current technology in achieving digital notes? e) What are the advantages and disadvantages of both traditional and digital note taking? f) What are the main issues of current note taking tools?
Obj. 2	g) What is our proposed solution to the current digital note taking issues? h) What are the roles, constraints, and responsibilities that developer should be aware of when developing such system? i) What are the appropriate tools that can facilitate the process of moving from traditional note taking to digital note taking?
Obj. 3	j) What criteria should be used to evaluate such system? k) What is the solution to the technology learning dilemma?
Obj. 4	l) How can we develop a prototype for the proposed solutions? m) What are the functional requirements for note taking prototype?
Obj. 5	n) What are the experimental methods used to evaluate the developed prototype? o) What are the attributes used for the evaluation? p) Are study results supports our research objectives?

1.4 Research Methodology

This thesis establishes the pedagogical occasions, and design challenges of the prevalent note-taking practices in traditional lectures and defines the design space of electronic note taking. Figure 1.1 shows the methodology of this research.

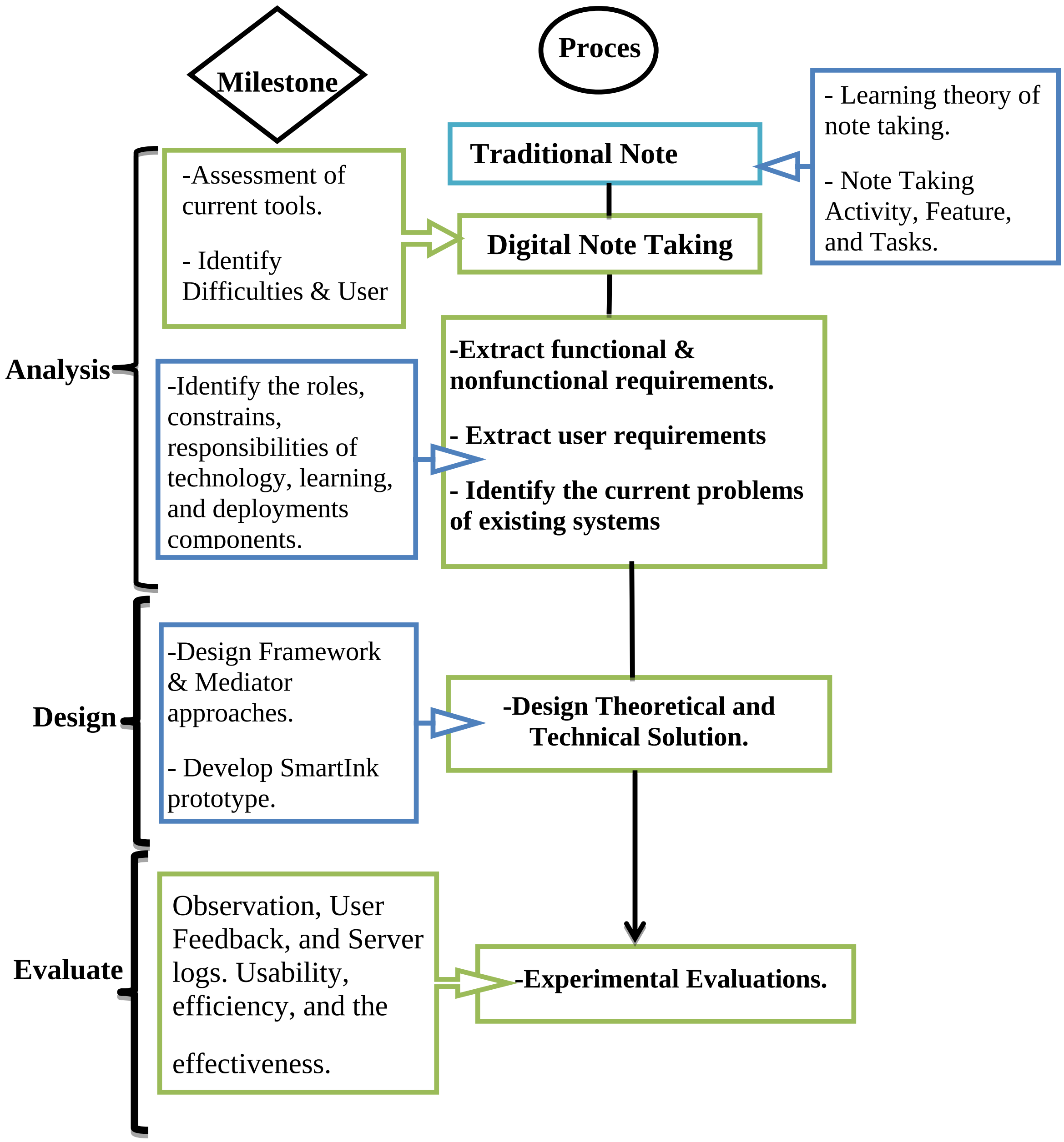


Figure 1.1 Research Methodology Flowchart

As shown in Figure 1.1, several methods were conducted to achieve the research objectives. We elaborate in the following points:

1. We investigated the traditional note taking activities, tasks, and behaviours to identify the learning and educations theories of note taking. We analysed different note taker activities to drive the essential of system requirements.
2. We explored the current tools of note taking with concerning about their effect on learning outcomes and relationships between the note taking components and development difficulties to understand the impact of technology on the learning process.
3. We investigated both traditional and digital note taking to identify functional, and non-functional requirements of note taking systems based on learning criteria and education theories.
4. We investigated the current tools of digital note taking to discover the critical issues that prevent the developments of effective note taking systems. We analysed the current issues of digital note taking tools together with the essential requirements of typical note application to propose our solution by initiating theoretical framework and mediator approaches.
5. Accordingly, we developed a prototype based on the framework and the mediator techniques for the note taking application.
6. Finally, we evaluated the proposed prototype and analysed the results of three experiments: observation, log event activities, and user feedbacks. The validation experiments were conducted to evaluate usability, efficiency, and effectiveness of the SmartInk prototype in achieving note taking tasks.

1.5 Thesis Organization

This thesis is organized into four main parts: traditional note taking, digital note taking, framework architecture with mediation approaches, and the design and evaluation of the specific solution implementation. Chapter 2 provides a comprehensive overview of the learning and cognitive theories of traditional note taking with specific functionality, properties, and different styles of traditional notes. Chapter 3 provides an extensive study about the attempts to convert traditional notes into digital environments, with a description about the main issues that limit the digital notes. Chapter 4 describes the problems with current tools, and addresses our proposed solution in this research. Chapter 5 and 6 describe our proposed solutions as two main components: the framework architecture of digital notes, and the smart mediator solution for adapting the note taking tasks into digital media. Also, these two chapters describe the implementation of our proposed solutions within SmartInk prototype developments. Chapter 7 describes the evolution approaches of SmartInk prototype, and presents a detailed analysis of the experimental results of the evaluation. Finally, Chapter 8 summarizes the key contributions, and the conclusion of this thesis.

2.0 TRADITIONAL NOTE TAKING

Learning is a process for acquiring new knowledge, behaviours, skills, values, preferences or understanding. It is the process of synthesizing different types of information (Butler & Winne, 1995). Human learning process occurs as part of education or personal development. However learning process is not restricted to humans only, the ability to learn is possessed by animals and some machines.

The learning process is goal-oriented aided by motivation. The study of how learning comes to mind is a part of neuropsychology, educational psychology, learning theory, and pedagogy (Fosnot & Perry, 1996). Furthermore, for a long time lectures have been used as primary tools for human learning. Lecture is driven from latin word lectus which means "to read aloud".

Classroom practice has not change much over the last 6000 years (Cole, 2005). According to (Bligh, 2000) , lectures are still considered as the most effective method for conveying information or facts from an expert to a novice. A learner performs many activities during learning process; some of these activities help learners to capture, store, and memorize the knowledge. Taking notes is considered as one of the most important activities performed by learners. Furthermore, note taking is an effective information-processing tool that is still commonly used both in daily life and in many professions (Hartley, 2002).

Note-taking is a process of recording information captured from a transient source, such as reading, oral discussion, and a lecture (Boch & Piolat, 2005). Notes are used mostly to record events, capture information, and for several learning purposes. Note taking is a process of summarizing information in short sentences which allows a large amount of information to be shortened on the paper quickly. The practice of writing information on paper while listening to lectures is universally considered as an important skill for academic success (Carrier, Williams, & Dalgaard, 1988). Making note is a common and important practice for learners both in lecture and during reading texts. Several researchers discussed the importance of note-taking behaviour on the education process for learning (Palmatier & Bennett, 1974). In this chapter, we investigated several researches on traditional note-taking to explore the behaviour, impact, and effect of taking notes on cognitive education and learner achievement.

2.1 Traditional Note taking with Cognitive and Learning Theories

Students write information on paper during the lecturer presentation or while reading an information source. This process is called note-taking. The activity of note-taking can be considered as a part of writing across the curriculum (Rivard, 1994). Experimental studies found that taking notes essentially affects learner education and his cognition. Some of the effects of note-taking are discussed as follows.

2.1.1 Note Taking As an Education Tool

Crawford (1925) first began note-taking research by studying its effects on education outcomes. He examined the effects of note-taking during lectures on student achievements and test performance. He found that students who take notes demonstrate a positive impact on their test performance. Early research focused on examining note-taking activities, and how the process of note-taking improves the ability to learn, integrate, and capture new knowledge (Corey, 1935; Crawford, 1925; Palmatier & Bennett, 1974). Moreover, other studies confirmed Crawford’s finding that taking notes helps students to recall the noted information, and to perform well on exams related to that information. They specified that the produced notes could be later used for studying or for other reviewing tasks as an external memory enhancer (Di Vesta & Gray, 1972; Einstein, Morris, & Smith, 1985; Fisher & Harris, 1973; Kiewra, 1985, Kiewara 1987).

Over the past decades, research on education demonstrated that note-taking during lectures supports student learning. Some studies showed that up to 96% of students rely on note-taking as an important part of their learning process and educational experience (Palmatier & Bennett, 1974). In addition, about 99% of college students take notes during a lecture, and 94% of college students consider note-taking as an essential behaviour for assimilating lecture content (Bonner & Holliday, 2006). Between 71% and 91% of students take notes while reading materials (Fowler & Barker, 1974; Lonka, Lindblom-YlÄnne, & Maury, 1994).

DiVesta and Gray (1972) studied the components of note-taking activities, and found two essential functions that support the learning process; encoding and retrieval processes. The encoding perspective means that simply taking notes enhances learner performance, and the retrieval process facilitates the review, organization, and reconstruction of knowledge. Peper and Mayer (1978) studied note-taking functions and indicated that encoding is performed during the learning process. They identified encoding process as three types of activities including receiving material, prior experience/knowledge, and learning process with their prior experiences. In addition, Peper and Mayer (1986) reported that note-taking is a generative activity that encourages students to build external connections between the presented materials with their prior knowledge.

Kiewra et al. (1991) examined the impact of the note-taking function (encoding versus external storage) on learning. Their experiments indicated that the external storage function results in higher synthesis performance than the encoding function. No performance differences were observed between students who did not review notes and those who neither took or reviewed notes, which indicated that notes alone does not serve an encoding function. Furthermore, according to constructivist views of the learning theory, learners are not passive recipients of information; rather, they need to construct or generate meaning by building relationships between the parts of information and their own beliefs, existing knowledge, and experiences (Vygotskiĭ & Cole, 1978). Theoretically, the greatest learning outcomes are achieved when learners are involved in the most generative activities of the note-taking process (Flippo & Caverly, 2000).

Within the last 30 years, researchers began to focus more on the importance of taking notes from text material or during lectures. Taking notes was found to increase learning by encouraging the students' retention and their connections of information. Students reported that note-taking tasks are essential to accomplish a variety of goals, such as learning achievements, maintaining attention during lectures, and directing them during their study. In addition, studies on the impact of note-taking strategies on recall and achievement during exams demonstrated that students not only learn when they review notes, but also during the process of note-taking itself (Foos, Mora, & Tkacz, 1994; Van Meter, Yokoi, & Pressley, 1994).

Recent observation studies showed that the note-taker performs several tasks during the process of note-taking. As readers, note-takers must comprehend information well; as learners, they must attempt to store information in long-term memory by writing the information and as writers, they must select the information to record and format it in ways different from the source material. Clearly, note-takers are required to manage several problems related to the flow of information, especially when note is taken during lectures. In addition, the note-taker is mostly constrained by the rate of speed of the lecturer. Certain studies indicated that providing students with complete notes could be an effective strategy of learning methods and improve student performance (Davydov & Kerr, 1995). Other studies investigated the effects of individual variables on note-taking, such as accuracy, completeness, and quantity of notes (Guri-Rozenblit, 1988; Katayama & Robinson, 2000; Worth, 2000).

In general, note-taking improves the learning process due to the activity and behaviour exerted by the note-taker. Note-taking has several functionalities that improve learning outcomes such as enhancing the recall function, improving the retention process, encouraging learner concentration, as well as generally helping increasing academic test performance.

2.1.2 Note taking with Cognitive Overview

Cognitive learning is a learning style derived from the concept that people learn by watching what others do; it is about enabling people to learn by using their reason, intuition, and perception (Schunk, 1989). It is the acquisition of knowledge from listening, watching, touching, or experiencing. Such learning is used to change the learning behaviour of people, and involves the understanding of how learner behaviour is influenced by learning factors such as culture, upbringing, education, and motivation (Wilson & Berne, 1999). This understanding is then used to develop learning styles. Metacognition as "cognition about cognition", or "knowing about knowing”, and reported that it includes knowledge about when and where to use particular strategies for learning or for problem solving (Veenman, Van Hout-Wolters, & Afflerbach, 2006).

Taking notes can serve as an external storage function because it builds a repository of information for later review and additional cognitive processing. Furthermore, note-taking while reading materials requires less cognitive effort than taking notes during a lecture;

thus, note-taking during lectures can be considered as an activity that strongly depends on the working memory to manage, comprehend, select, and produce notes (Alamargot & Chanquoy, 2001; Piolat, Olive, & Kellogg, 2004). In addition, note-taking is a fundamental aspect of a complex human behaviour related to information management, which involves a range of mental processes and interactions with other cognitive functions (Piolat et al., 2004).

Recently, cognitive constructivist views of learning have focused on the importance of cognitive processes such as motivation, attention, knowledge acquisition, encoding, learning strategies, and the metacognition on developing new learning styles and techniques. The main aim of a cognitive analysis on note-taking is to describe the mental processes, knowledge representations, memory functions for note-taking activities, a short-term memory buffer retained during note-taking, mental representation, selection and understanding of incoming information, as well as to interact with and update stored knowledge (Piolat et al., 2004). Furthermore, taking notes becomes an extremely important factor in academics, as it is one of the most established cognitive technologies that offload cognitive processes and extends cognitive abilities (Makany, Kemp, & Dror, 2008). Several researches described the note-taking process as a behaviour that potentially aids or deters recollection of specific information. Note-taking can facilitate learning by enabling the student to process the lecture content by interpreting, inferring, condensing, paraphrasing, and supporting external memory storage (Hartley & Davies, 1978) .

Garcia-Mila and Andersen (2007) argued that metacognition is important for at least two reasons. First, learners often misperceive the task demands with their own future state of knowledge; they do not see the utility of note-taking. Second, these misperceptions cause learners to not refer to their notes and thereby miss feedback that refines their metacognitive knowledge and strategy use (Garcia-Mila & Andersen, 2007).

Recent research of note-taking mostly depends on the working memory that contributes to processes of cognitive load, comprehension, and writing (Baddeley, 2007; Yeung, Jin, & Sweller, 1998). A close relationship exists between cognitive factors and produced notes. Cognitive overload, ability, and behaviour, as well as working memory, strongly impact the produced notes and learning outcomes (Daneman & Merikle, 1996; Katayama & Robinson, 2000; Levy & Ransdell, 2001).

In addition, metacognitive knowledge is a key factor for academic performance. Note-takers perform several cognitive operations while note-taking to acquire knowledge. These operations are mainly conscious and subjected to metacognitive control, which note-takers use in their activities to simultaneously comprehend, evaluate, store, and write selected information to produce notes (Hacker, Dunlosky, & Graesser, 1998; Piolat et al., 2004).

2.1.3 Individual Factors of Note Taking

Research in the education field and cognitive explored the note-taking process in further detail to better describe the individual variables of note-taking that impact the learning activity. Most of those individual differences occur because of the variances in cognitive variables of people such as working memory, cognitive style, transcription fluency, conceptual models of lecture learning, prior knowledge, and overall cognitive ability. These individual differences are described in more detail as follows.

2.1.3.1 Notes Quantity

Earlier research provided significant evidence that students who take more notes could perform better on measures of learning from lectures (Kiewra, 1985). The number of words in student notes is used to measure the student learning performance, which positively correlated with free recall of both important ideas and details from a lecture. The length of lecture notes was significantly associated with the length and organization of essays that students wrote about the lecture content (Benton, Kiewra, Whitfill, & Dennison, 1993; O'donnell & Dansereau, 1993). Overall, considerable evidence in several research indicated that note completeness is positively related to student achievement.

2.1.3.2 Notes Quality

Significant positive relationships were observed between the content of student’s notes and performance on a test of the lecture content. Students who take notes to capture the most important lecture ideas could recall most of the lecture content (Baker & Lombardi, 1985; Einstein et al., 1985; Kiewra, 1984). Notes were found as the best predictor of test performance compared to other logical predictors (Peverly et al., 2007). Overall, students mostly record a few notes during lectures; the quantity of note-taking decreases over the lecture time; as well as both the quantity and quality of note-taking can impact the learning process (Kiewra, 1984).

2.1.3.3 Gender

Gender is one of the individual variables. Females value note-taking higher than males do. In addition, studies found that females record more words and information details (Carrier et al., 1988; Cohn, Cohn, & Bradley, 1995). Other studies determined that, females produced notes in a more predictive matter, and recorded more complete, accurate, and organized notes (Williams & Eggert, 2002).

2.1.3.4 Writing Speed

Experimental studies showed that note-takers who could write fast are able to record higher quality notes. Thus, writing speed or rate of writing words strongly affects the quality and quantity of produced notes, because note-taking demands a quick writing process (Peverly et al., 2007).

2.1.3.5 Prior Knowledge

Researchers reported that prior knowledge strongly impacts the quantity and quality of the produced notes. Prior knowledge also affects the note-taking activities in different aspects (Petty & Cacioppo, 1984). In an experimental study to determine the effect of prior knowledge of the lecture topic on note-taking behaviour, people with adequate background knowledge generated more external connection between lectures (Peper and Mayer, 1986). Even language proficiency on the learning material significantly affects note-taking. Compared with non-native speakers, native speakers recalled more concepts and detailed information (Dunkel & Davy, 1989).

2.1.3.6 Working Memory

Working memory is the executive and attention aspect of short-term memory involved in the interim of integration, processing, disposal, and retrieval of information. Working memories is the capability to remember specific information over a short period of time. Working memory has limited capacity, which varies among people (Fuster, 1997; Miller, 1956; Pascual-Leone, 1970). Recent research showed that taking notes from lectures exerts demands mainly on the limited resources of the central executive and the storage components of working memory. People with greater working memory are generally more effective note-takers, and students with higher capacity of working memory performed better on recall information. Unfortunately, only a few studies examined the relationship between working memory and its effect on note-taking (Baddeley, 2003, 2007; Cohn et al., 1995; Hadwin, Kirby, & Woodhouse, 1999; Kiewra, 1989).

2.1.3.7 Cognitive Style

Cognitive style has dependence and independence fields, where both can be considered as important variables that affect note-taking process. Field-independent learners have an active, flexible, hypothesis testing approach, whereas field-dependent learners have a more passive and rigid approach. The main difference between them is that field-independent learners can restructure the incoming information, whereas field-dependent learners prefer to process information in its given structure. In terms of notes quality, field-independent students outperformed field-dependent students; however, no differences in performance were observed between the two types of learners. Field-dependent learners benefit more from the external storage function of note-taking than from the initial encoding function (Frank, 1984; Kiewra & Frank, 1988).

2.1.3.8 Cognitive Ability

Cognitive ability can affect the note-taking process. Hughes and Suritsky (1993) reported that students with learning disabilities face difficulties while taking notes (Hughes & Suritsky, 1993). Similarly, students with disability encounter significant problems with taking notes, and significant difference on the amount of recorded information was observed between students with learning disability and non-disable students.

2.2 Importance of Traditional Note taking

As an education and cognitive psychology tool, note-taking has been extensively studied from diverse views to explore the note-taking functions, behaviours, as well as its effect on learning outcomes and education performance. In addition, several experiments examined the impact of note-taking on student performance and academic success (Marzano, Pickering, & Pollock, 2001). Most researchers agreed that the note-taking process facilitate learning and enhance the cognitive ability of learners to achieve better understanding of knowledge (Rivard, 1994).

Empirical studies prove that note-taking is an important skill for students, who use it mainly to implant the presented material in their mind (Coon & Mitterer, 2008). The produced note is used secondary for review. Note-taking performs a range of intellectual processes, such as making judgments, resolving issues, and making decisions. Moreover, taking notes supports time-consuming, real-time thought processes (Hartley, 2002). In this research, the note-taking field has been classified into two types; 1) manual note-taking that requires pen and paper, and; 2) electronic note-taking that requires a computing device, often with special note-taking software. In this section, the necessity of note-taking is explored in further detail as listed below.

2.2.1 Note taking Assists on Recording Information and Documenting Events

Many examples of using notes in daily life for recording information have been provided, such as student at school or in the university classroom using pen and paper for recording notes. At times, we need to record a list of items for specific use, such as a buying list, to do list, and so on. For certain procedures or experiments, scientists also rely heavily on the documentation that may later become crucial for patent applications or for important scientific breakthroughs. One of the fundamental purposes of taking notes is to record information and document events for later review, providing note-takers with external storage media to keep track of their notes. The note-taker widely uses notes as a record of important information, reminder of things to do, summary or synopsis, a way of communicating with someone, annotations in the margin of a text book, entry in a diary or journal, transcript of a conversation or meeting, or a way to learn new information. At a glance, note-taking is used to record information for later use or as temporary storage unit for later review.

2.2.2 Note taking Supports Efficient Processing and Understanding of Information

Note-taking highly assists in processing information in specific ways to increase comprehension and memory capability. Many studies examined the effects of taking notes on processing information and learning materials (Peper & Mayer, 1978, 1986). This process guided human memory and made information meaningful. Research in this area investigated specific criteria of note-taking, such as the lecture speed (Aiken, Thomas, & Shennum, 1975), subject familiarity with the note-taker background (Peper & Mayer, 1986; Shrager & Mayer, 1989), and the impact of reviewing notes (Carrier & Titus, 1979; Hartley & Davies, 1978; Wittrock & Cook, 1975). Researchers reported that most people could increase their comprehension and memorability of a given material simply through the process of writing notes. Furthermore, note-takers can create stronger connections between the received information and that already stored in their long-term memory. This is named the generation effect of note-taking in processing information (Foos et al., 1994). In addition, the processing information task for encoding and reviewing notes leads to positive impact on learning regardless of its association with a reorganization of the information, and supports the note-taker to reinforce the integration of knowledge (Sharples et al., 2002).

2.2.3 Note Taking Supports Focusing and Improves Concentration

Taking notes requires a high degree of concentration for presented or reading materials, and thus, the attention is to be more precisely focused on the accessing, sorting, and coding of information, rather than simply listening to the speaker or reading a text material (Piolat et al., 2004). Taking notes usually enforces the note-taker to focus on the relevant points to better understand the information, and help them to summarize the ideas and concepts. Researchers collected feedback from several students on taking notes, and reported that students often mentioned that taking notes helps them remain attentive, select important ideas, and improve the concentration or their implication of attention to resources (Van Meter et al., 1994).

2.2.4 Note taking Assists Thinking

Education research concluded a general truth that the writing process in note-taking can be considered as a thinking process (Hartley & Davies, 1978). In fact, writing notes encourages to think, and taking notes can assist real-time thought processes such as the resolution of mathematical problems. According to this truth, notes are similar to a rough draft that allow information to be coded, which relieves mnemonic processes and consequently helps with the solution development (Cary & Carlson, 1999).

In addition, note-takers found to participate in an internal monologue with themselves during the writing process. However, when they write while listening to other voices or reading materials, this internal monologue becomes an external dialogue or a discourse community. People mainly write their thoughts and ideas on paper to seek clarity and to eventually organize their works. However, when the note-taker is writing notes, they are involved in the thinking process to select the important parts of this information, and they are writing notes to solve complex problems (Badger, White, Sutherland, & Haggis, 2001).

2.2.5 Note taking Organizes Information

Common note-taking styles and strategies classify the written notes into several categories such as title, subtitles, outline, and so on. Writing notes improves the organization of information inside the human brain. The process of taking notes to organize information appears clearly when writing relative information together within a closed area or page. Using the note-taking process to organize information increases the conceptual link between the presented information during lessons or reading books. Organized information are much easier to remember than unorganized information. Outlined or organized notes support the note-taker to develop a special structure that demands attention to any missing information, and enables the note-taker to arrange and reflect the varied topics in a sketchy, fragmented, and suggestive manner.

2.2.6 Note taking Assists Memorizing and Recall

Note-taking enables the learner to record interim pieces of information for later use by easing the load on the working memory; thus, notes are considered as external memory storage by reducing load on the working memory, note-taking increases the capability of the learner to memorize and produce better notes (Cary & Carlson, 1999). Experimental studies indicated that the spatial formatting of notes could be used to facilitate the production and clear presentation of useful information (Cary & Carlson, 2001).

People take notes to record information, assist their memory to remember something that would occur in the future or to remember a past occurrence. Note-taking is considered as part of the memorization process that creates an external memory to reduce the load on the working memory and to help people resolve complex information storage problems (Alloway, Gathercole, Kirkwood, & Elliott, 2009; Kiewra, 1987; Meacham, 1982). Students have approximately 50% chance of recalling recorded notes and only about 15% chance of recalling non-recorded notes. Most note-takers rely on taking notes to support the memory and recall processes for original thoughts, as they are unable to immediately explore all ideas during the lecture, wherein materials are generally presented in a rapid manner.

2.2.7 Note taking Enhances Learning and Improves Student Achievements

Early research reported that note-taking improves the ability to learn, integrate, and capture knowledge. Studies in this area showed that note-taking enhances learning achievements because of the encoding and retrieval functions that note-taking supports (Di Vesta & Gray, 1972; Peper & Mayer, 1978; Rickards & Friedman, 1978).

Several activities are performed during the learning process such as understanding, transformation, and greater intensity in the effectiveness of learning. Recently, many studies have described note-taking activities such as reading, highlighting, and summarizing. For example, summarizing notes is better than rewriting them, and highlighting notes is better than reading notes (Kiewra, et al., 1995). Researchers advise note-takers to re-read their notes as many times as necessary for better learning achievements. These studies compared these types of activities with their effects on learning outcomes and found that these tools can improve the learning model (Rickards & Friedman, 1978; Worth, 2000).

2.3 Traditional Note taking Styles and Strategies

People take notes in various ways to organize information. The styles used depend on certain criteria such as personal preferences, learning styles, manner in which the material is presented, and subject matter. Note-takers write notes with different styles, and notes are mostly organized in either linear or structure formats (Hartley, 2002). Many note takers use graphical organizers, which are visual format or structural representation of presented material in a systematic format. Graphic organizers include Venn diagrams, concept tree, and columnar format. A graphic organizer is a specific type of tactic that is part of an overall strategy or plan to take notes (Williams & Eggert, 2002). The style of taking notes in any strategy affects the learning process. Thus, substantial evidence demonstrate that the ability to reorganize the information, rather than simply copying the information, and the use of these styles lead to a successful approach and comprehensive information processing (Hirumi & Bowers, 1991; O'donnell, Dansereau, & Hall, 2002; Randall, 1996; Reynolds & Werner, 1993). Some of the common note-taking strategies and styles are listed below.

2.3.1 Two-Column Method

The two-column method splits the paper into two columns, where different types of information are recorded. The left column is used to record keywords, and the right column is used to describe the keywords, as shown in Figure 2.1 (Beecher, 1988).

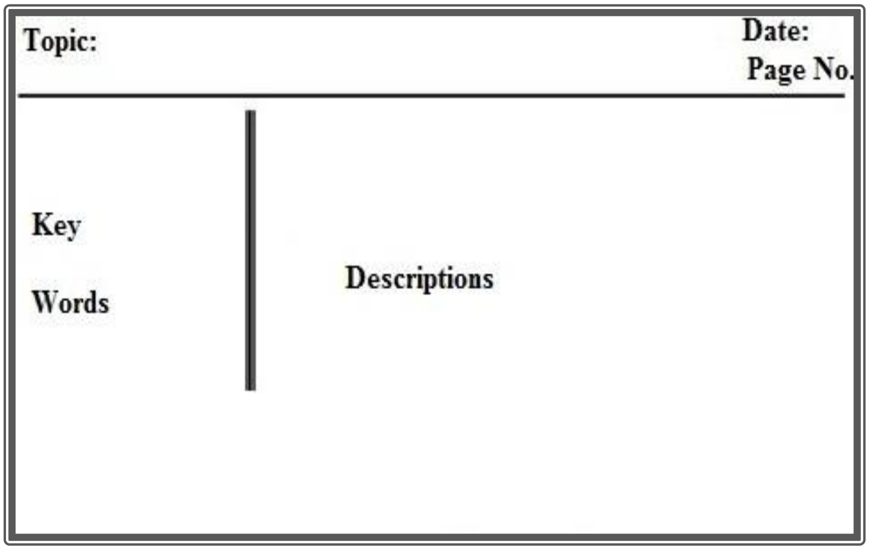


Figure 2.1. Two column Notes Style.

This method is a common, simple, and widely used note-taking style.

2.3.2 Cornell Method

The Cornell method divides the paper into three parts. The left part or the recall column is used to record key words and concepts. Notes are recorded in the right part, and a summary is recorded at the bottom of the paper, as shown in Figure 2.2 (McAndrew, 1983) .

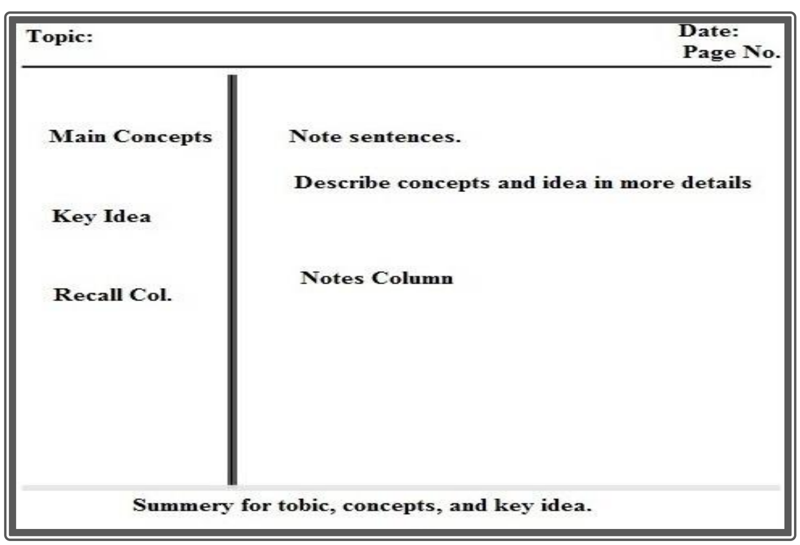


Figure 2.2 Cornell Notes Style

The Cornell method provides a systematic format to summarize and organize notes, and has many advantages as listed below:

- The method is simple to learn and efficient to use, with an easy format to identify keywords, concept, and summary.
- It saves time and effort. The information format makes it easy to scan and to locate particular information.
- It affords more organized and systematic notes.

2.3.3 REAP Strategy

REAP is an acronym for relating, extending, actualizing, and profiting. REAP is used to organize notes, and to assist the note-taker to produce information in a more personalized manner (Devine, 1987). REAP divides the paper into three columns. The first column is used to record memory triggers, the second column is used for related information or keywords, and the third column is used for writing notes, as shown in Figure 2.3 (Tasdemir, 2010). This strategy guides the note-taker using four simple steps:

- Relate materials to his or her own life.
- Extend the material to the outside world or to his or her prior knowledge.
- Actualize the material by noting how the information might work in the real world.
- Describe how the note-taker or society profits or benefits from the ideas.

The advantages of this method are as follows:

- The method motivates the note-taker to create interest and relevance, which makes the learning process meaningful.
- It improves the ability of the note-takers to remember the notes well.

- It helps the note-taker make the note more personalized.

It supports the thinking strategy for reviewing notes.

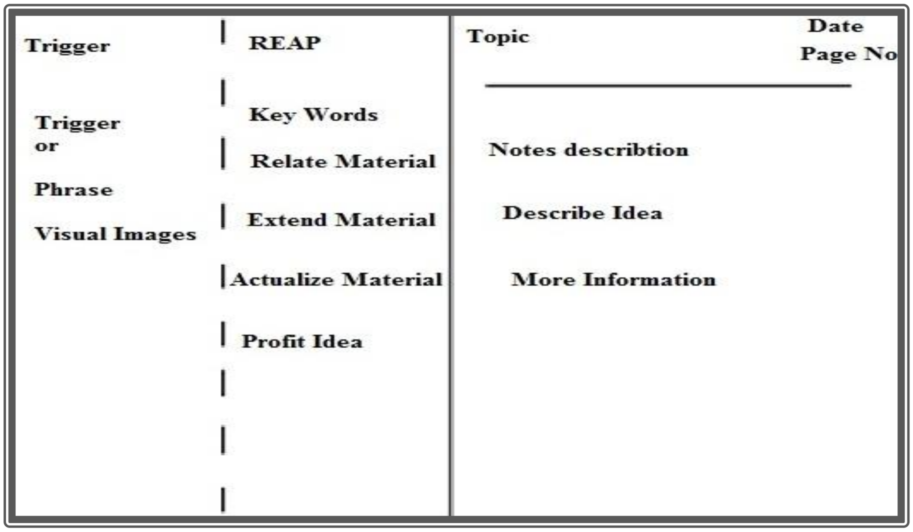


Figure 2.3 REAP Strategy.

2.3.4 Outline Format

In this method, information is arranged from general to specific. The first level is reserved for each new concept or idea, and then, each sub level must be related to the main level in the categorization process. The method involves organizing information in such a way that the inclusive material is followed by more exclusive but related information, as shown in Figure 2.4. Outline strategies offer certain advantages such as well-organized information, records relationships and content of information, reduces editing and modifying, as well as facilitates easier review by turning the main points into questions (Williams & Eggert, 2002).

A sample outline is given below.

Topic Title **Date – Page No.**

- I. MOST INCLUSIVE INFORMATION ON A TOPIC (GENERAL)
  - A. More Inclusive
    - 1. Least Inclusive
      - a. least exclusive
        - (1) more exclusive
        - (2) more exclusive
          - (a) most exclusive (specific)
    - 2. Least Inclusive
  - B. More Inclusive
    - 1. Least Inclusive

Figure 2.4 Outline Note Style.

2.3.5 The Mapping Method

Mapping is a graphic representation of the content of presented material or lecture that relates each concept or idea to every other fact or idea. The method maximizes active participation during the lecture, affords immediate knowledge understanding, and emphasizes critical thinking (Chang, Sung, & Chen, 2002). The mapping method is shown in Figure 2.5.

Mapping methods offer some advantages as listed below:

- The method helps the user to track a lecture regardless of conditions visually.
- Minimal thinking is needed, and relationships are observed easily.
- Editing the notes is easy by adding numbers, marks, and colour coding.
- The note-taker is motivated to review his or her notes to restructure thought processes and check knowledge comprehension.
- The method could be used for memory drill by covering the lines.

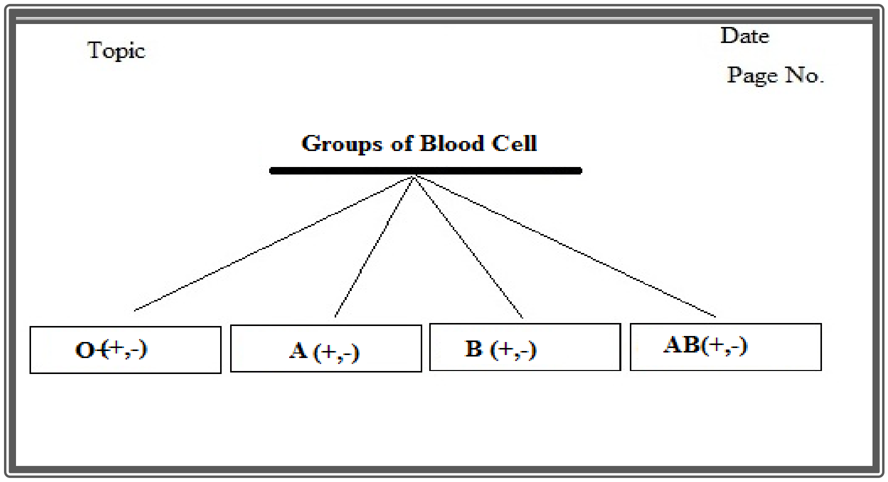


Figure 2.5 Mapping Notes Style.

2.3.6 The Charting Method

This method is mostly used when the presented material or lecture format is distinct, such as history. Columns are drawn with appropriate labelling as shown in Figure 2.6, where each topic is classified into different categories and recorded in each column (Marzano et al., 2001). The information (words, phrases, main ideas, and so on) are listed under the appropriate category or column.

This method has certain advantages, as listed below:

- The method helps the note-taker to track conversation and dialogue.
- It reduces the amount of time spent on writing and reviewing.
- It provides an easy review mechanism to memorize facts, as well as to compare and study the relationships of contents.
- It provides the note-taker an overview of the entire topic.

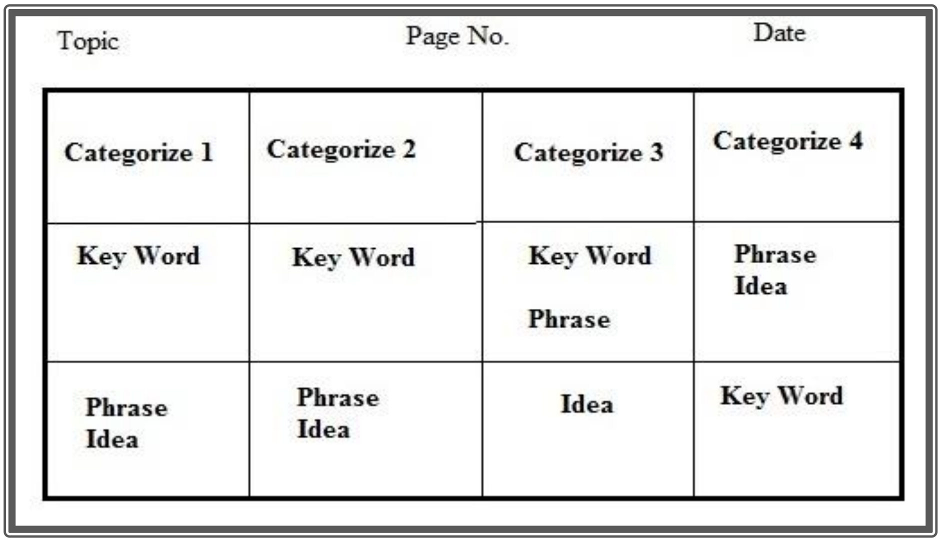


Figure 2.6 Chart Note Style.

2.3.7 The Sentence Method

This method is popular and used without any planning to take notes under certain strategy. This method is simple in which every thought, fact, or topic is written on separate lines, as shown in Figure 2.7. The method is slightly more organized but has two disadvantages. First, determining the major and minor points from the numbered sequence may be difficult. Second, the method may be complicated for editing and reviewing (Weinstein & Mayer, 1986).

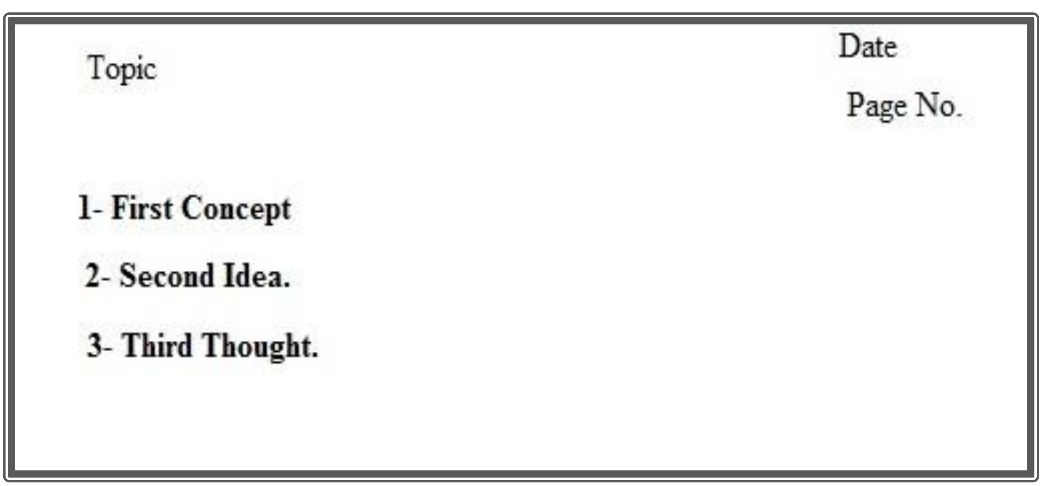


Figure 2.7 Sentence Note Style.

2.3.8 The Mind Map Strategy

Recently, a new effective note-taking strategy called mind maps had been developed. The method records information by using diagrams that are easy to use, adapt, and recall. The method is considered as the most effective because it works similar to the way of brain works. The brain has a creative side (right) and a logical side (left) (Mintzberg, 1991). A mind map consists of a central topic with a central picture attached to the central topic as main branches (Buzan, 2002). These branches are often the outlines of a textbook, which are represented by thinner lines to connect to the main topics and followed by sub branches with more details. Figure 2.8 illustrates the mind map style format (Hirumi & Bowers, 1991).

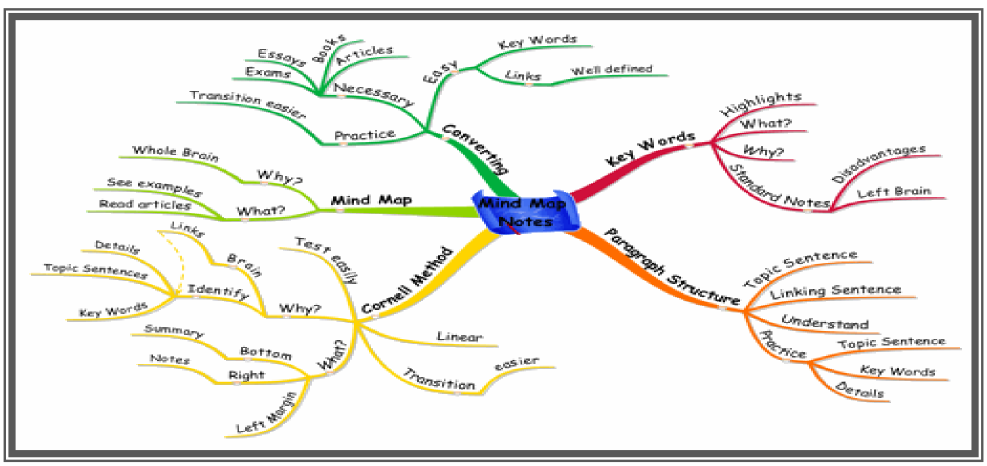


Figure 2.8 Mind Map Note Strategy.

Principles of mind map

1. Start at the centre of the page with a clear title, preferably incorporating a strong image or anything to help jog the memory later.
2. Main ideas are written on the lines branching off the subject. Other ideas proliferate like twigs that would grow from the boughs of a tree.
3. Write only keywords, not sentences.

4. Write keywords on the lines so the text is always connected to the lines to show the whole idea structure. Draw additional lines to connect ideas where necessary.
5. Print words. Mix lower and upper case (capital) letters so the text is varied, clear, and easy to read.

Advantages

- It is quick to record more in the same amount of time, and can easily add ideas or links later.
- It helps the user to concentrate on information structure and relationships between ideas rather than disconnected facts.
- Adding sketches makes the map more memorable than conventional notes.
- Mind maps can incorporate a mass of material.

Mind mappings can help in the revision although the course notes are conventional. The method condenses material into a concise and memorable format. Most research reported that taking notes in any of the above-mentioned strategies affects the learning process. Substantial evidence indicate that being able to reorganize the information rather than copying the information, and using these styles could lead to a successful approach to comprehensively process information (Akinoglu & Yasar, 2012; Eppler, 2006; Randall, 1996). However, no unique strategy is appropriate for all note-takers, and individual differences may require consideration when note-taking tactics are taught (Reynolds & Werner, 1993).

2.4 Characterization of Traditional Notes

Notes are an activity and a product, produced by the note-taker using some styles for certain purposes (Abowd et al., 1997). Traditional notes have unique properties unlike other document types. Common characteristics of note-taking are briefly discussed in the subsequent sections.

2.4.1 Notes Have Short Text Elements

As opposed to other kinds of documents, notes have short text elements. Full sentences are seldom used and full paragraphs are rare because only key words and ideas are presented on the board during lectures, whereas most details and explanations are presented orally, as shown in Figure 2.9. The note-taker selects the main idea or concept to write down for further exploration later. Sometimes, time constraints and cognitive load make writing one complete sentence very difficult.

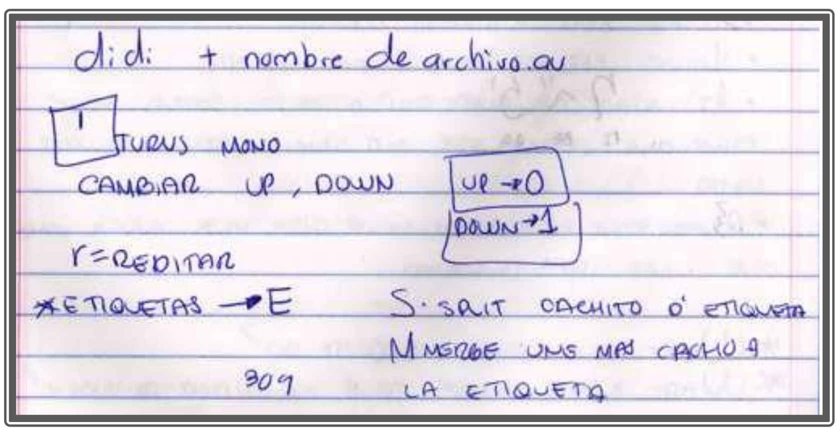


Figure 2.9 Notes Example for Short Text Element.

2.4.2 Free Form Format

The essential feature that makes notes different from other document types is its free form or writing in a nonlinear format. Note elements can be placed in any position in the document without any constraint of a specific pattern, organization, or sequence. The free form structure of notes is a reflection of the environment of taking notes, as most presented material shift between ideas, concepts, and related information. The position of note elements contains implicit information on the relation between elements and structure of the document.

2.4.3 Graphic Elements

Graphic elements can be considered as non-textual elements. Many graphic elements are included in most notes, such as diagrams, drawing, charts, special symbols, and figures because notes are written to explore ideas and concepts. Graphic elements reflect the interior of the human brain, and are recalled more than text elements (Ward & Tatsukawa, 2003; Ware, 2012), as shown in Figure 2.10. Although some note styles support text material, such as outline and sentence styles, notes with graphic elements only or text elements only are seldom found.

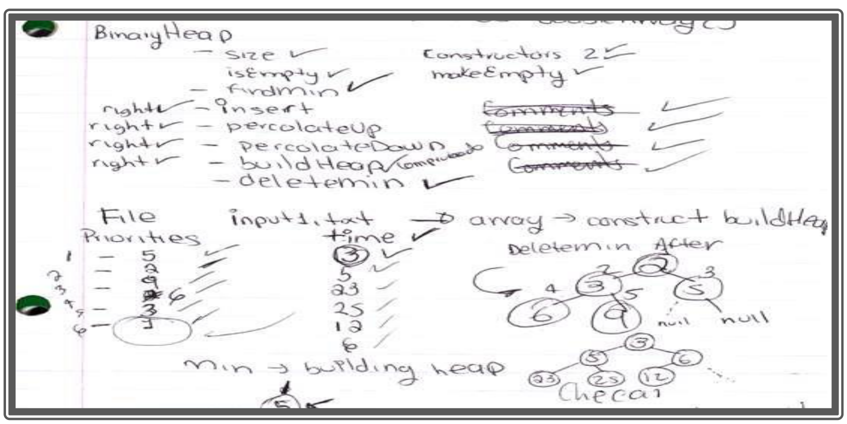


Figure 2.10 Notes on Binary Heaps

2.4.4 Notes Produced Under Several Limitations

A note-taker has limited time to produce notes because the information flows faster than the writing process. The writing speed process approximately produces 0.2 to 0.3 words per second, whereas an oral presentation produces approximately 2 to 3 words per second. By contrast, note-takers need to pay attention to the presented material to understand the assimilated information in order to summarize long sentences and produce notes. The time to write notes is constrained as most time is spent in the thinking process.

2.4.5 Notes Are Often Sloppy

As discussed in the previous section, notes are created under different constraints, resulting in sloppiness of presentation; thus errors in spelling, grammar, and even minor facts are likely to occur. Most of these errors exist in drafts of other documents, but they appear in notes more often and are not revised. The common process of drafting and revising in other documents is not applicable during take notes. Several note-takers rewrite their notes to avoid these errors, but rewriting is often done to review the material rather than to produce a readable and correct reference.

2.4.6 Abbreviations and Shorthand

With the time constrains, most note-takers intuitively develop exceptional shorthand processes and methods to record notes, thereby using abbreviations, truncating long words, and employing keywords. Note-takers are very conscious on the quantity of notes taken. Thus, they attempt to reduce the amount of time to write full sentences, idea, and concepts.

2.4.7 All Notes Need Inhibiting Indicators

Before note-takers write notes, several inhibiting indicators motivate them to take notes. Several studies explore the inhibiting indicators using quantitative methods, such as writing on the board, dictation, definition, catch phrases, and parentheses (Ward & Tatsukawa, 2003). All these indicators are connected to written communication, and note-takers intuitively recognize written communication as important because of these triggers. Common to all these inhibiting indicators is that they are the product of a real, oral communication situation (Boch & Piolat, 2005).

2.5 Chapter Summary

In this chapter, we investigated note taking as an educational tool and to extract the main note-taking learning functions, where more focus was given to psychological and learning theories about the note-taking process itself, as a critical learning tool for most students. We then emphasized the traditional note-taking definition, process, and the activities involved. We addressed the importance of note taking as a tool in education to explore theoretical aspects of encoding, elaborating, focusing, and reviewing. We listed the effect of traditional note taking to support learning activities, learning outcomes, student performance, cognitive styles, cognitive ability, working memory, note-taking function encoding, and recall function.

3.0 DIGITAL NOTE TAKING

In the past decades, computers and technology have grown to become a general-purpose tool that is accessible to the public. This evolution occurs after the modern computer designed with high computation power and processing speed was introduced. Accordingly, computers are widely used with varying human application range, from developing basic or advance tools to performing a wide range of human tasks. Technologies are tools that humans created and used to accumulate and evolve across generations. In general, technologies are mainly used to accomplish the human traditional tasks by allowing the digital devices to mimic and perform tasks digitally.

Recently, technology application in education is evolving, and pedagogy is beginning to change the way educators teach and students learn the subject matter. Substantial evidence indicated that current technologies are promising, introducing better ways to teach and acquire knowledge. All evidence shows that technology integration in education will increase in the future (Livingston & Wirt, 2004). Most learning environments began to transform from traditional media into digital tools, such as by using projectors to replace blackboards; slides presenting from the computer instead of writing on the blackboard; using microphone, digital pen, laser pointer, and many other digital devices in the learning environment.

Although we are in the digital age, note-taking as an education tool still struggles to exist in a traditional way. The lack of support for note-taking in digital format would increase the gap between traditional and digital learning tools in the next decades because most information and knowledge are transformed into digital representations. Note-taking is considered as one of the tasks that remain traditional, although many studies have been conducted to transform this task into digital format (Miura, Kunifuji, Shizuki, & Tanaka, 2005; Pinkwart, Hoppe, Milrad, & Perez, 2003; Schilit, Golovchinsky, & Price, 1998). By contrast, people still use the traditional pen and paper method to take notes because little progress have been made to transfer the activity of taking notes into digital applications.

Challenges to the usability of traditional notes clearly appear in information management tasks because of the pervasiveness of current digital technology. Furthermore, people are expected to manage a large amount of information with different formats and from varying resources to complete their academic tasks. Traditional note-taking unable to meet these challenges and encouraged the development of electronic note-taking applications.

Technology offer special devices essentially to improve education and learning methods via developing various systems and applications to facilitate learning activity. Furthermore, to improve the active learning environments is a global effort; hence, the idea that most devices would be integrated with standard note-taking capabilities using pen-based technology to replace traditional note-taking in the future is conceivable. Similarly, technology has begun to produce new ways to support education by developing new environments, such as web-based courses. In general, current technologies support note taking in different aspects including active learning, active reading, information assimilations, and collaboration activities. In this chapter, we investigate the recent research and existing tools of electronic note-taking, and how they affect the learning process.

3.1 Importance of Digital Notes

Digital notes are documents created using a computer or digital equipment, which can be stored on a digital device such as hard disk, and flash memory. The digital document is not seen in the physical world, but has more advantages compared to paper documents, such as storability, transportability, computability, reproducibility, legibility, searchability, printability, and security (Grabe & Christopherson, 2005b; Kam et al., 2005). Since the learning materials are in digital format they afford new functions that can be used to enhance learning achievements. Compared with traditional note-taking, the digital format has additional advantages to perform such research and encourage both researchers and developers to develop tools to facilitate note-taking. These advantages are discussed in the subsequent sections.

3.1.1 Editable

Digital documents do not depend on physical media for storage and visualization. Editing digital documents before they are printed on paper or other physical resources is possible. When typewriters and hand writers are the main tools used to create typed text, a single error or modification could mean having to retype a complete page, and a small change could affect several pages, a complete chapter, or the entire document. Moreover, editing digital document facilitates many functions such as auto-correction for spelling and grammatical errors, which are impossible to support in traditional note-taking. The editing ability is the most important advantage, which saves time especially for large documents such as books. The correction process is done during the typing of the text and reduces the time and effort of the note-taker.

3.1.2 Portability

Portability is an advantage inherited from the nature of digital documents. As long as digital means of storage (discs) or communication (computer network) are available, digital documents can be easily transferred, copied, or shared. Portability, which means movability and transferability, is an essential advantage of digital documents. Overall, digital documents are much less expensive to store, transport, reproduce, and search. This function provides users with easy access to information from anywhere by using a network facility.

3.1.3 Searchable

Searchability is the ability to search a piece of text without having to skim or read the entire document. Computer-based search is always faster and less time consuming. The process reduces unwanted effort and stress, and is mainly useful for searching long documents to determine specific information such as quotes, names, or dates, or to find the beginning of a section. This advantage can be used to help the note-taker to find specific information such as title, topic, and date. In the traditional way, this task is a time consuming process and strenuous to perform with documents stored in paper or other traditional media. Computers can efficiently perform other related search such as counting words, finding all the occurrences of a word, searching for pattern, searching several documents, and comparing documents.

3.1.4 Indexing and Hyperlinking

Indexing enables users to immediately access the elements of a document, such as sections, tables, graphics, and references. Indexing and/or tagging services that exist only for digital documents allow users to access any section, page, and words to efficiently obtain more details or related information.

Hyperlinking is the ability to connect different documents or sections of the same document by providing a link to access the document or section. These types of functions provide the user with efficient access to documents for better interaction and information flow.

3.1.5 Legibility

Digital notes can be represented with consistent style or typeface, which also has the ability to separate content, change typeface, colouring, and text size. The user can adjust the content of documents for better legibility without affecting the document contents. Legibility of digital documents makes them easier to read.

3.1.6 Security

In general, people's notes are considered confidential and private information. Digital documents are more secure than paper documents and can offer many security options. The security of digital documents can be divided into two types or categories. The first retains data and/or information in safe places and the other forbids unauthorized access. In both categories, the digital document is more secure than other document types.

3.2 Existing Tools for Note Taking

Several systems designed to support note-taking in digital formats, and many tools in both hardware and software designed to facilitate note-taking activities. Existing systems for note-taking vary from simple tools to complete applications. Several studies focused on the note-taking functionality such as handwriting and highlighting (Hsieh et al., 2006; Pinkwart et al., 2003), whereas other studies concentrated on the advantages of taking notes in digital formats (Kim et al., 2009; Ward & Tatsukawa, 2003). In this section, we investigated the most developed system and tools in note-taking, where we classify them based on learning theories, active learning, active reading, collaboration, and sharing, although a few overlaps in categorization exist for these developed tools (Weibel, Fouse, Hutchins, & Hollan, 2011).

3.2.1 Note Taking tools for Active Learning

Active learning is about building knowledge in different ways based on different prior background (McConnell, 1996). Active learning places the responsibility of learning and creating activities on the students by doing things, and thinking about the things that they are doing. Recent research has focused more on the design of an application that can support active learning (Alvarez, Alarcon, & Nussbaum, 2011). The note-taking application is one of the important areas for the design of an active learning system. Some of these developed systems are described in more detail below.

StuPad

Truong and Abowd (2000) at Georgia developed the StuPad to support student learning with many streams of information, such as personal notes, video and audio stream, and related topic websites. StuPad is designed to organize and manage different types of information. The tool has two different interfaces, one for capturing and recording information, and the other is for accessing and reviewing information. StuPad has a simple interface and supports a pen-based interface for writing notes, as shown in Figure 3.1. Experiments on StuPad demonstrated that the tool can provide students with the means for active note-taking in a classroom. Researchers recommended that this system be improved by deploying typical infrastructure with more extensive studies to support active learning in the classroom (Abowd, 1999; Truong & Abowd, 1999).

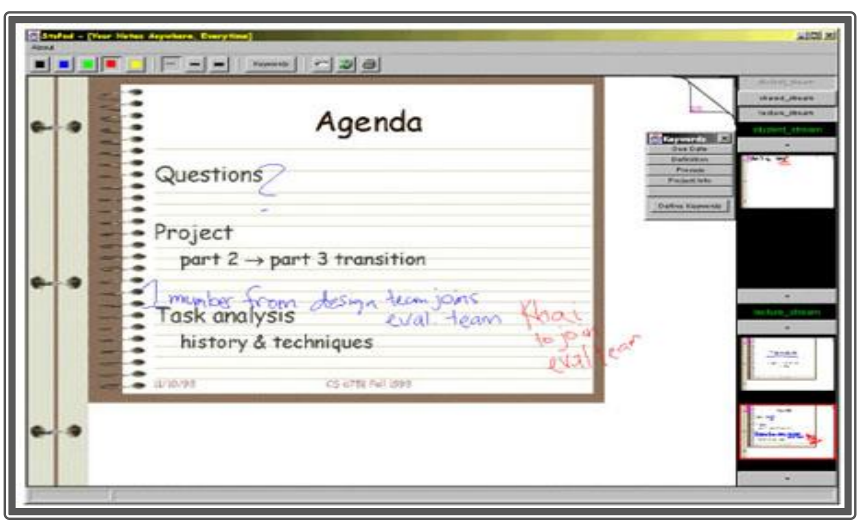


Figure 3.1 StuPad System Interface.

NoteTaker

Tatsukawa, a student at the University of Tokyo, developed the NoteTaker system (as shown in Figure 3.2) in 2002 to solve the problem of using computers for taking class notes (Ward & Tatsukawa, 2003). They attempted to combine the advantages of digital documents with the free form of note-taking on paper. This system is designed based on several investigations on note-taking activities, such as flexibility for writing non-textual note elements and entering text data. The system is designed to select the appropriate computer function to represent note-taking tasks, such as using a pen for graphics, using keyboard for text input, using a pointing device for positioning and selecting, reducing overhead action, and providing shortcuts. They found that developing a note-taking system that allows students to take notes in classroom is possible, but many hardware and software limitations need to be resolved. In 2003, they conducted another study to describe the features of note-taking, such as personal natures, short fragments, combination of graphic and text, and time constraints for attempting to meet note-taking application functional requirements to support active learning in the classroom (Ward & Tatsukawa, 2003).

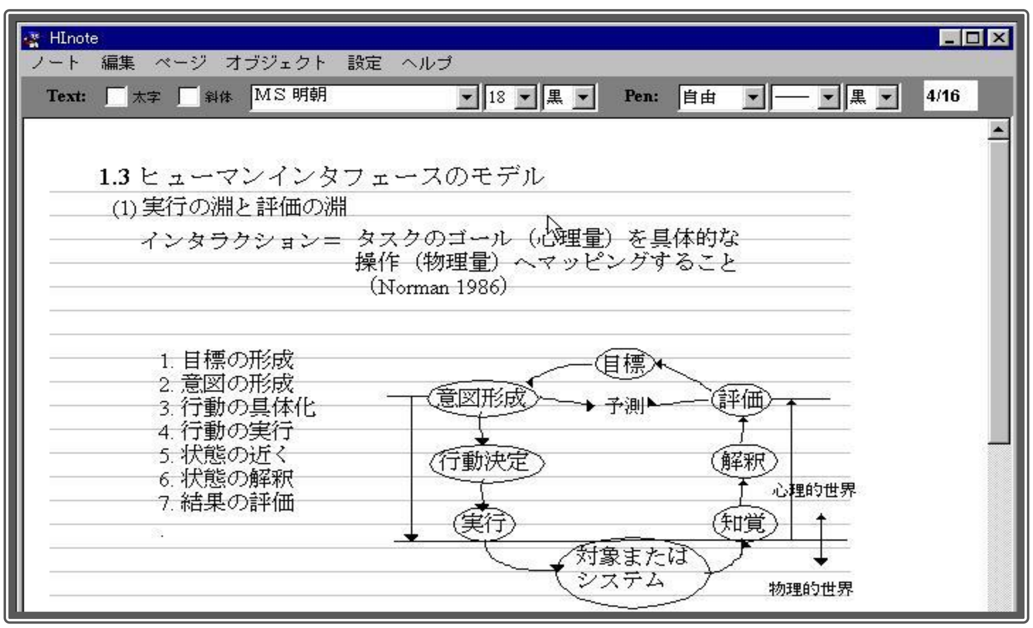


Figure 3.2 NoteTaker System interface.

Classroom Presenter

Figure 3.3 shows the distributed tablet PC-based classroom interaction system called Classroom Presenter (CP), which was developed at the University of Washington in 2005. The system is designed to provide many tools to both students and instructors in order to facilitate the learning process in the classroom. The device supports instructions with the ability to collect, review, and provides feedback to students. The device supports students in taking notes and sharing their own works, but with limited functionality for later access and revision of notes.

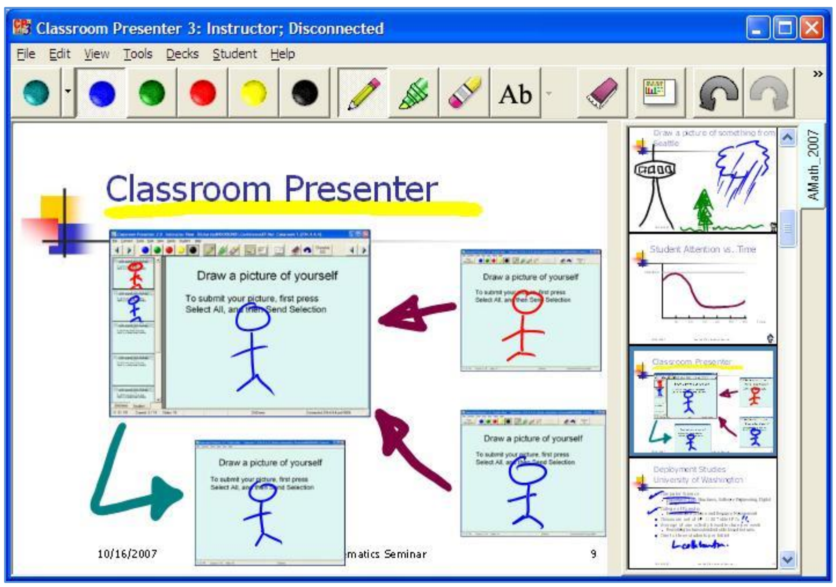


Figure 3.3 Classroom Presenter System Interface.

Anderson in 2005 improved the CP to support active learning using the materials presented during the lecture. The CP system is integrated with specific functions such as flexibility to present material, supports views and interaction mechanisms in the classroom, and uses wireless technology to support active classroom teaching (Anderson et al., 2005). Lastly, they deployed the CP to explore a set of classroom interaction techniques, mainly to enhance student engagement in class and capitalize on the flexibility and range of expression that the digital link affords. Initial deployments of their system indicated that instructors could exploit this technology not only to successfully achieve a wide range of instructional goals, but also to create a more participatory and collaborative environment (Anderson et al., 2007).

Ubiquitous Presenter

As an extension of the CP, the ubiquitous presenter (UP) was developed at UC San Diego to support both pen-based and typed student submissions on the web. UP include additional functions to support student interaction during lecture using any web-enabled devices such as laptops, notebooks, and smart phones. The UP system designed based on a web-server architecture, in which the server acts as the data repository for instructor and student interactions. This system allows students to use the web browser to submit their work to the instructor via the server. All lecture contents, including lecture slides, instructor link, and student-generated responses are published online (Wilkerson, Griswold, & Simon, 2005).

CP and UP were developed to support the interactive learning environment rather than support the note-taking functionality. They could be used as interactive tools between students and instructors for an active learning purpose, and to facilitate learning via doing things and obtaining feedbacks.

DyKnow

DyKnow is a commercial system developed for classroom management and interactive education. The system provides students with many note-taking functions, such as student response, content delivery, class capture, recorded notes, and notes review. DyKnow likewise allows the instructor to broadcast to students' screens to stimulate discussion, transmits prepared contents to student computers, allows students to poll for a quick comprehension assessment in real time. The system supports many note-taking tasks such as creating, annotating, saving class notes, and audio recording on central server for later access.

DyKnow has two different interfaces, as shown in Figure 3.4(a), and 3.4(b). The DyKnow monitor allows teachers to maintain control of the digital classroom. DyKnow vision includes student response tools, note-taking functionality, class capture functionality, collaborative learning tools, and anytime-anywhere access that enhances teaching and learning in and out of the classroom. Most features of DyKnow are developed based on student and classroom requirements. Only a few functions are built based on education and learning theories. Dyknow has been reported to require extensive experiments to evaluate its impact on learning achievement and performance (Berque, 2006).

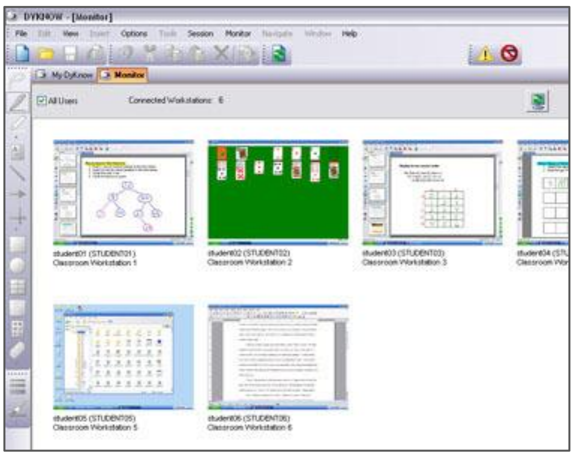


Figure 3.4(a) DyKnow Monitor Interface

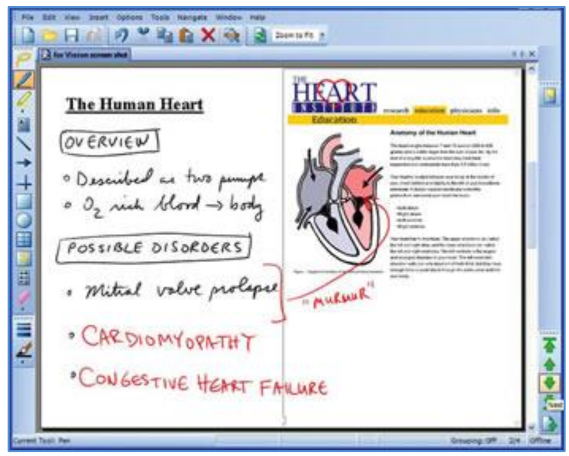


Figure 3.4(b) Dyknow Vision Interface

Microsoft Tablet PC

Tablet PC was the first step in using pen as input device to computer, which was preferred by most people. Tablet PC promotes some features such as handwriting recognition, annotating, and indexing. In addition, ink strokes in the tablet PC are stored differently from text and images as native data type. Tablet PC presents an alternative method for input data by using pen rather than other input device such as mouse and keyboard (Mock, 2004). Figure 3.5 shows the tablet PC platform released by Microsoft in 2000 based on pen-enabled computers for general purpose instead of a specific platform, such as Palm or Pocket PC.

Later, Microsoft released the OneNote software for Tablet PC application, which was designed for taking notes either by professionals or students. The Windows Journal software for note-taking application was also included on the tablet PC of Windows XP, Vista, and Windows 7. This application allows the user to create and organize handwritten notes and drawings using pen or mouse to compose handwritten note. According to research, this application is insufficient to meet the note-taking system requirements because of a few disadvantages, such as the inaccurate handwriting recognition, which affects the cognitive response of students (Pittman, 2007).

Figure 3.5 Microsoft Pc Tablet System.

Evernote

Evernote is a commercial software designed to support the note-taking activity based on server-client architecture. Evernote is designed to assist people to capture idea, inspiration, or experience easily anytime and anywhere, and to make recorded information easy for access and review. Evernote is a web service with full-feature desktop and mobile clients designed to allow users to easily capture and find information, memories, and content in any environment. This software supports users with its various functions and tools to capture texts, snapshots, digital ink, or audio. Likewise, users could easily find, share, access, and review these data. This software is supported by wireless Internet technology. All notes are automatically synchronized between the network and local devices. This system is reported as one of the top five software for note-taking application, and contains most of the note-taking functions (Geyer & Reiterer, 2012). However, Evernote is designed for commercial purposes without any evaluation of its effect on learning achievements and performance. Figure 3.6 shows the interface of Evernote, which is available for all platforms and most digital devices (Cordell, 2011).

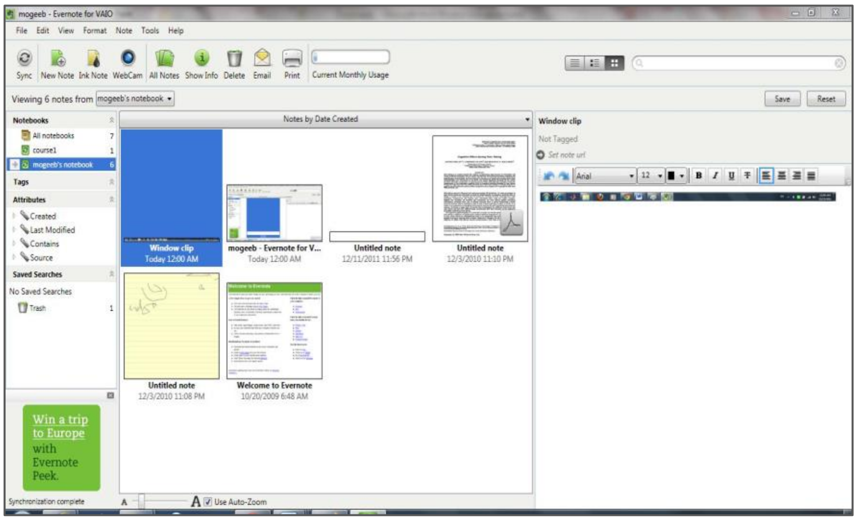


Figure 3.6 Evernote System Interface.

E-Notes

Several systems have been developed to support note-taking tasks. One such effort was E-notes developed by Wirth in 2003. E-notes provide an electronic form of lecture notes that can be printed and annotated in the classroom. E-notes evaluation indicated an improvement in student understanding and achievements. Experimental results showed that 96% of students found E-notes viable for use in electronic note-taking application. Students likewise reported that E-notes assisted them in concentrating more on absorbing and understanding the material rather than the written one. This system supports the delivery of notes to students before the lecture, as well as the annotation tool for note-taking applications. However, only a few note-taking can be implemented in E-notes, which was difficult to integrate with other existing tool applications (Wirth, 2003).

Paper-Top –Interface (PTI)

PTI is an abbreviation for paper-top interface prototype system, which was developed by Mitsuhara on (2010) to mix paper with digital technology. PTI was developed to support the note-taking activities of students in a classroom. A visual marker based on augmented reality (AR) technique is used in designing PTI prototype and projector e-Learning material to display the materials in a classroom desk, as shown in Figure 3.7. PTI allows students to view notes and write on paper using pencils. PTI has several advantages such as easy annotation, quick navigation, flexible spatial layout, and intuitive interaction. A preliminary experiment was conducted to evaluate PTI prototype (Mitsuhara, Yano, & Moriyama, 2010). Results indicate that PTI is not in conflict with traditional learning style and can be efficiently used to take notes in classrooms. PTI did not investigate the learning effect and efficiency. Furthermore, this study did not consider the review process of note-taking.

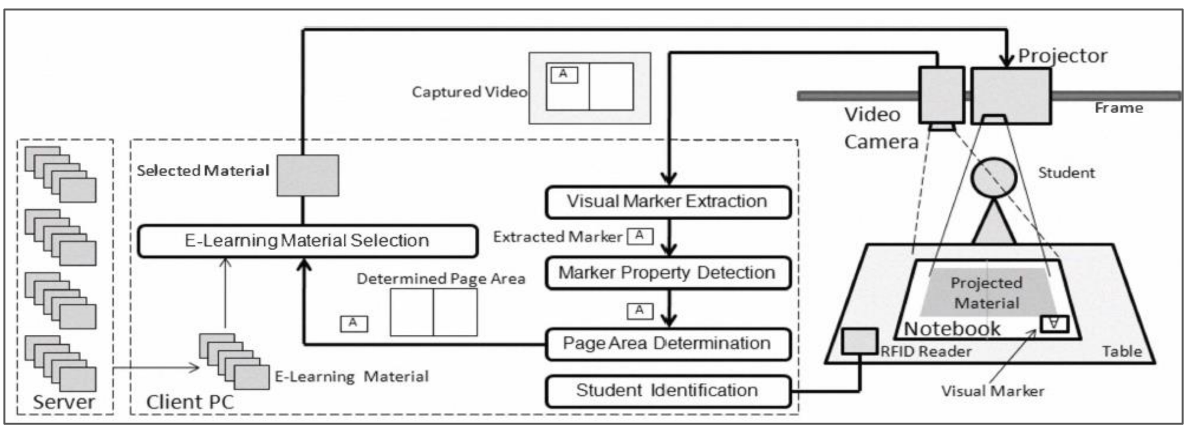


Figure 3.7 Paper-Top –Interface (PTI) System overview.

Livenotes

Livenotes was designed to facilitate cooperative and augmented note-taking during lectures. The system has a shared whiteboard that supports real-time interaction between small groups. The system includes wireless communication with a computer tablet to facilitate material sharing (Kam et al., 2005). Livenote’s interface was designed to enable each group member to interact by cooperatively taking lecture notes, and the system provides presented material in the background of shared board to enhance student note-taking and annotation tasks. Livenotes is used in wireless networks with portable tablet PCs to connect peers in small groups. The system interface is designed with many iterations based on user feedback to deliver the final Livenote interface, as shown in Figure 3.8. This system was specifically designed for augmented note-taking and for interaction between students to support classroom learning environments with no cooperative consideration for notes review after class.

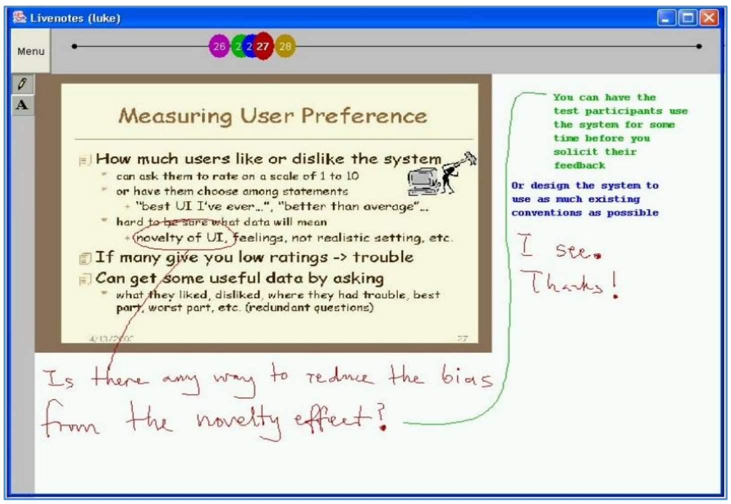


Figure 3.8 Livenotes System Interface.

In addition, several applications and tools were developed to support note-taking in classroom. NoteLook was developed by Chiu et al. in (1999), which allows students to integrate notes and digital video by supporting automatic snapshots. This system uses a classroom camera to capture the screen and allows students to annotate snapshot images. This system requires significant infrastructure with complex interface, which may hamper note-taking.

Live Classroom is a commercial system developed in 2005 to support note-taking in classroom environments. This system allows video recording and audio streams during the lecture, with the ability to add notes. Live classroom has several note-taking and active learning components, such as providing pop quizzes, survey, feedback, type text. However, it is difficult to use these components and the interface is cluttered. The system supported a number of useful features, but difficult to use (Kam et al., 2005).

Bauer and Koedinger in 2005 conducted an extensive research on technology and note-taking, and developed the first prototype for note-taking. However, they found it difficult to address demands on system function requirements in the development of note-taking applications. Then, they investigated how several features of developed note-taking tools can impact behaviour and performance of the note-taker. They found that a simple copy-paste function in electronic note-taking can negatively impact the note-taker performance because this function reduces the attention of the note taker (Bauer & Koedinger, 2005a).

Additionally, Bauer and Koedinger, (2007) evaluated the impact of several note-taking tools on student behaviour and learning outcomes. This study can be considered as the first right step in designing an efficient note-taking application, using empirical data to drive and guide the designer of the note-taking system. They evaluated the impact of different tools on the copy-paste function, typing text, highlighting, and menu selection. Their results suggested the possibility of developing note-taking tools that encourage efficient learning if the selected tools are designed by mimicking traditional note-taking functions. Their study similarly evaluated the impact on learning gain and note-taker behaviour. In addition, selected tools were found to improve the efficiency of note-taking applications without associated learning loss (Bauer & Koedinger, 2007).

Furthermore, Bauer and Koedinger, (2008) developed a prototype system for note-taking application that encourages students to focus more on the presented material while recording notes. The interface is designed to increase desirable behaviours and improve satisfaction. Overall, they recommended the results of their empirical studies for designing note-taking applications (Bauer & Koedinger, 2008).

Kim et al. (2009) performed a study on university students to identify the effect of using electronic note-taking on current note-taking behaviour and activities. Three types of studies were conducted, namely, survey for current note-taking practice, observation study in a classroom environment, and case studies for long-term use of electronic note-taking devices. Their study identified the limitation of typical note-taking system, and explored several aspects about the implication of future note-taking application designs. Overall, electronic note-taking tasks reported as not sufficiently supported, and essential requirements are identified as guidelines for typical note-taking systems (Kim et al., 2009).

3.2.2 Note Taking Application for Active Reading

Other types of note-taking are performed when people read information resources. Taking notes while reading media content becomes one of the most common note-taking behaviours. Annotation is one of the most common note-taking activities when reading a material, as well as writing comments to elaborate a specific topic mentioned in a paper or lecture slide. Several applications have been designed to support note-taking activities while reading materials, such as annotations, highlighting, underling, and so on (Bothin & Clough, 2012; Weibel et al., 2011). This type of tool is a note-taking application that supports active reading learning theories. The following section lists some of these existing applications.

DigitalDesk

This work is designed based on the fact that people prefer to use paper for note-taking. This application is designed to enhance traditional note-taking with computation technology instead of replacing paper and pen. The DigitalDesk was proposed by Wellner (1993), to bridge the gap between the interaction of physical documents in the digital world. DigitalDesk is a physical desk with a computer display and a video camera that points to the desk, which captures the image streams of interactions with paper documents, as shown in Figure 3.9. DigitalDesk includes various tools that facilitate the interaction with physical paper such as paper paint, which allows users to select any part of a paper to be processed as digital documents, a collaboration environment that allows users to view the works of others, and a digital calculator designed to perform digital operations. This application is the first attempt to transport traditional note-taking into the digital form, and provides a new approach to connecting paper and digital devices for collaboration purposes (Wellner, 1993).

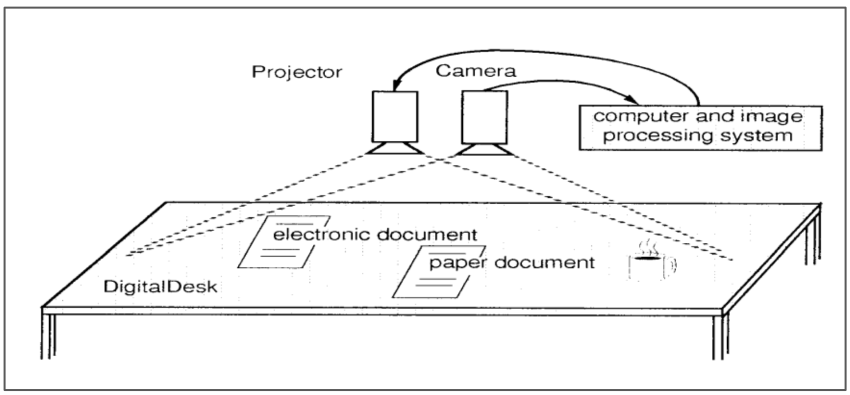


Figure 3.9 Digital Desk system Architecture (Wellner, 1993).

XLibris

XLibris is designed based on tablet PC concepts to support active note-taking tasks, such as underlining, highlighting, and adding comments (Wilcox, Schilit, & Sawhney, 1997). This application is designed to perform note-taking tasks on paper documents, such as annotation, page turning, and handwriting. XLibris uses an active digitizer behind the screen, which is controlled by a small electromagnetic field designed to replace textbooks with EBooks. Figure 3.10 shows the Xlibris System on a Fujitsu Point 510 (Wilcox et al., 1997).

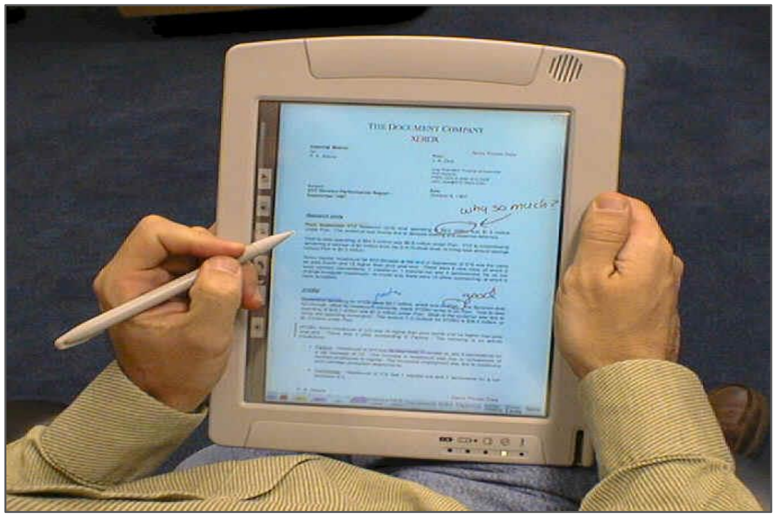


Figure 3.10 XLibris device.

Paper Augmented Digital Documents

Paper-Augmented Digital Documents (PADDs) is designed to fill the gap between taking notes in the physical and digital worlds. Digital pen and paper are designed to connect paper and digital documents. Digital paper is designed as a normal paper with printed infrared dots that are invisible to the human eye. As such, a unique pattern of dots is printed in every three square millimetres of paper. A digital pen has an infrared camera that detects the dot pattern for recording the correct location of the ink stroke. The digital pen is also used to capture and annotate the document. This application is a good note-taker, with its easy navigation, annotation, and discussion on a paper document. Likewise, it allows ease of editing, sharing, and archiving of the digital world, as shown in Figure 3.11 (Guimbretière, 2003).

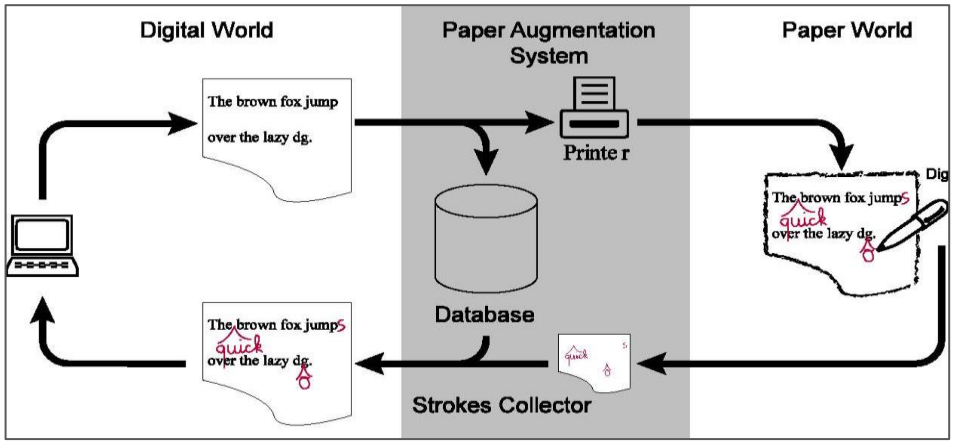


Figure 3.11 PADD systems Flowchart.

PapierCraft

Later in 2005, PADD system was improved to bring more digital power to paper documents (Liao, Guimbretière, & Hinckley, 2005). A digital pen on a digital paper document support direct commands such as copy, paste, email, create a link, or mark for search. Gestured commands are executed to present synchronization process with the computer. These commands can specify digital commands, whereas working in paper expands the range of possible interactions available in the handwriting interface. PapierCraft tools create a novel method for mediation between the subject and the object without changing other elements of the activity, such as community, rules, division of labor, and learning outcome (Yeh et al., 2006).

Sony Reader and Amazon Kindle

These two devices are essentially designed to support active reading by replacing traditional paper, and textbooks with electronic books, respectively. Sony Reader was designed in early of 2006, and the Amazon Kindle was designed in late 2007. Both devices use electronic paper display, comprising two transparent silicone sheets for displaying sheet images. Electric paper can mimic the appearance and functions of an actual paper, such as being easily changed, small power consumption, non-backlight dependence, and the advantages of being environment-friendly. However, these types of devices lack freeform annotation or the ability to write notes. Several differences exist between these two devices. Kindle does not support many file formats, whereas the Sony Reader has no connectivity to the Internet. Moreover, the Sony Reader is simple, clean, looks more similar to a book, and is cheaper that the Kindle (Demski, 2010). Figure 3.12 shows both devices.

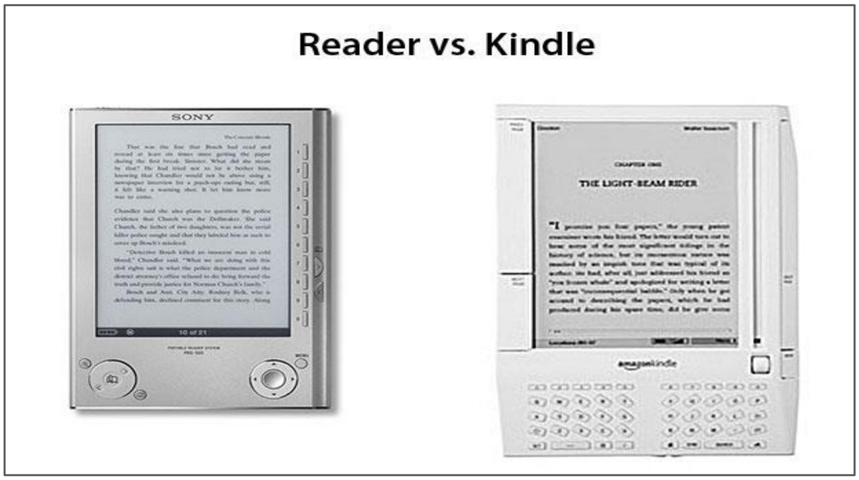


Figure 3.12 Sony Reader and Amazon Kindle Device.

InkSeine

InkSeine is a prototype for ink application developed by Microsoft Research Center. This application works similar to a pen input. Hinckley (2007) explored how tablet PCs can help manage tasks and support creative sense-making while minimizing distractions and maximizing focused attention (Hinckley et al., 2007). The key idea behind InkSeine is to leverage the existing digital ink in the notes to trigger searches for related content. InkSeine is designed with excellent user interface and includes most digital pen functions. InkSeine has an excellent search tool integrated with inking, which is triggered when you draw a circle over the word. In addition, this application automatically conducts a search for a specific word in all documents. This software not tested for learning purposes, but widely used for business meetings, discussions, and other tasks, as shown in Figure 3.13. This application can be used for taking notes, but requires the integration of several tools to support electronic note-taking.

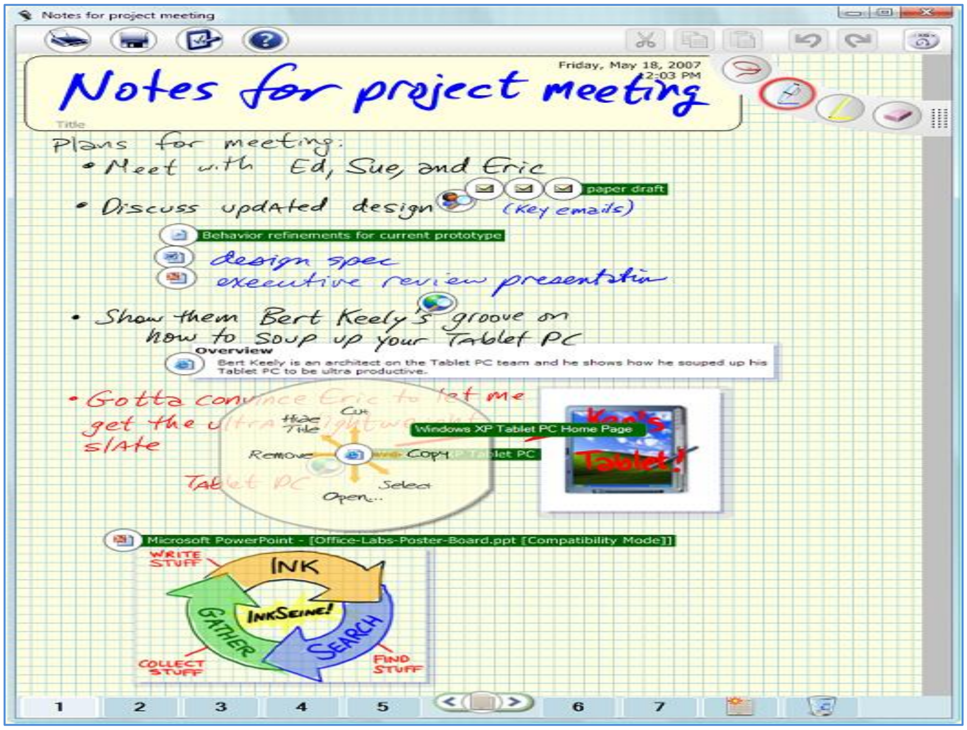


Figure 3.13 InkSeine System Interface.

3.2.3 Note Taking Application for Sharing and Collaboration Purposes

Tivoli

Pedersen et al. (1993) developed a system that supports note-taking in collaboration with a small group by using Xerox liveboard with pen-based interactive techniques. The system includes pen and gestured commands for editing, printing, and importing backgrounds images, as shown in Figure 3.14. This system allows only one user to collaborate at any given time. This application does not constrain the role of users and allows anyone to change the whiteboard contents, which is physically constrained in the classroom (Pedersen, et al., 1993).

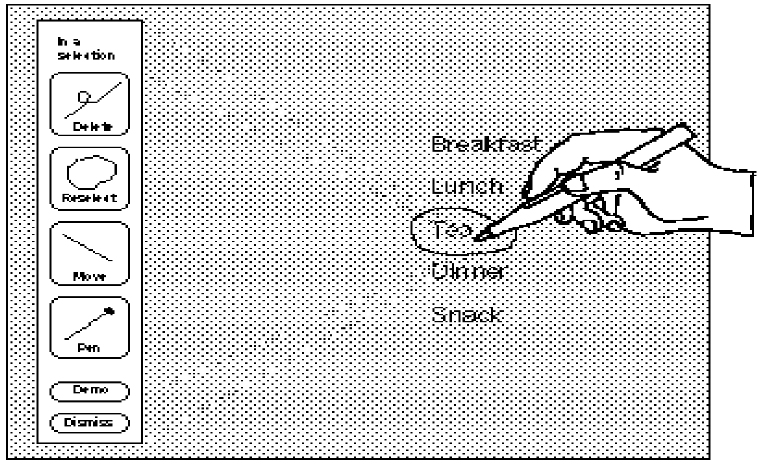


Figure 3.14 Tivoli System Interface.

MicroNotes

MicroNotes focus on informal and personal note-taking, which was developed by Lin et al. (2005). This application was designed for small notes, such as list of topics, an address of an interesting website related to a current topic, question reminders, and pages to read for an exam. This application allows the posting of notable information and receipts between group members using any handheld devices. This system is designed to share special notes between selected group members (Lin, Lutters, & Kim, 2004).

NotePals

NotePals is an application that supports collaborative note-taking for recording and sharing notes (Davis et al., 1999). NotePals allows easy access for notes of group members, where each member can upload their notes in a shared repository. Group members can view the notes of other members by retrieving notes from the repository using topic context. This system is mainly designed to support note sharing during meetings or discussions instead of note-taking to capture knowledge. The main disadvantage of the system is the lack of awareness in student's notes, direct communication is not allowed between users, and the lack of handwriting recognition to parse and search within the notes (Davis et al., 1999).

Group Scribbles

Roschelle et al. (2007) developed Group Scribbles at the SRI International to support interactive learning environments using collaborative capture and computation. This system is designed to work on tablet PC, and provides each student with private and public boards. The private board is used for composing and storing notes, whereas the public board is used for sharing and collaborating notes, as shown in Figure 3.15.

The visual metaphor of Group Scribbles is “tuple spaces” architecture, which supports the three classic operations required by a coordinated written operation, which allows the scribble sheet to be dragged from the private to the public board; read operation, which allows scribble sheets to be viewed on public boards; and take operation, which allows a scribble sheet to be dragged from a public to a private board. However, this tool has no explicit support for management or coordination between users (Roschelle et al., 2007).

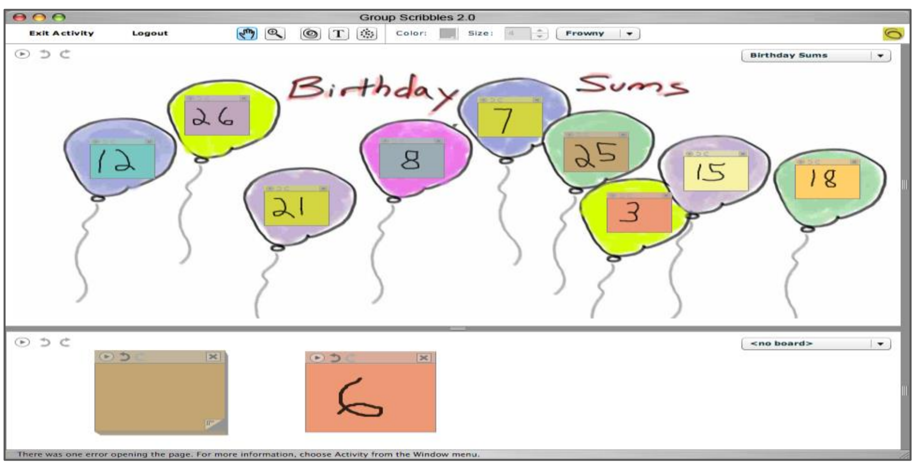


Figure 3.15 Group Scribbles System Interface.

CoScribe

Steimle et al. (2007) performed a quantitative study to derive the implication of the design of note-taking system in E-Learning. They conducted a survey focused on four parts, note-taking behaviour and media, collaboration and team work, course-related information, and personal information. Several key characteristics of traditional notes were demonstrated as comparable with electronic note-taking. No differences were observed between different types of note-taking in review and collaborative activities. Moreover, the E-Learning system must comply with the complex multitude of context dependencies. This study developed a system called CoScribe (Steimle, Brdiczka, & Mühlhäuser, 2009).

CoScribe was developed to support students in making collaborative handwritten annotations on printed lecture slides. The design of this application was based on paper-based sharing and semantic tagging of annotations and slides. This system enables students to create handwritten annotation, to classify notes based on semantic structure, to tag documents for easy access, and to share notes and collaborate with other students. The system interface includes a novel visualization that provides users with two views, namely, single-user and multi-user views. These views control public and private sharing notes (Steimle et al., 2007). The system allows users to make annotations on paper printouts of the lecture slides using an electronic pen, as shown in Figure 3.16. This technique is similar to the annotation in traditional notes, wherein technology remains in the background as much as possible. After annotation, students can use a PC to synchronize their annotations, and store them in a database on a central server. CoScribe is implemented in Java and supports PowerPoint lecture slides. The evaluation indicated that the system efficiently supports student annotation (Steimle, Brdiczka, & Muhlhauser, 2008).

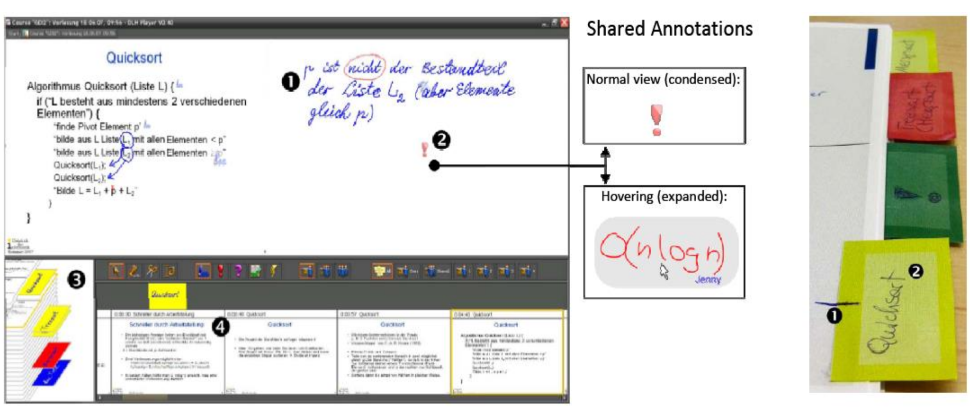


Figure 3.16 CoScribe software viewer, and Digital Paper Bookmarks.

3.2.4 Note Taking Application for Wireless Handheld Devices (WHD)

Technology produced many devices, equipment, and tools essentially used for personal information management (PMI), such as PDA, Smart Phone, iPod, and iPad. Luchini et al. (2002) reported that a tremendous opportunity exists in using these devices with wireless technology in education and learning if a suitable application is rationally developed for educational tasks and activities (Luchini, Quintana, & Soloway, 2003). However, to gain the full potential of these technologies, several issues need to be addressed. Students and instructors of all ages are likely to own WHDs and bring them to class. Thus, these devices provide educators and learners the opportunities to harness the capabilities of such devices in education. As the number of devices rapidly increases and networking infrastructures expand, society moves toward an era of ubiquitous computing with technological advances and personalization of these tools to be used for media-based learning styles. Several tools were developed to support the learning activities on WHDs devices. Most of these tools focused on information annotation, collaboration, indexing, and later access. Thus, these devices have limited capacity storage, and most data are stored in the web server (Cope & Kalantzis, 2009).

Wilcox et al. (1997) designed a system for organizing telephone numbers, tasks, and other information by applying the properties of handwriting and indexing notes using keywords. Their system is more concerned with indexing based on keywords that provide index pages on request. Indexing is conducted based on keywords, and a property is applied to the strokes and provides an index page on request, such as a hyperlink (Wilcox et al., 1997).

Uchihashi and Wilcox (1999) proposed an automatic indexing system of digital data by clustering ink strokes based on a hierarchical clustering approach, where the distances between strokes are calculated using dynamic time warping. These tools focused on searching by matching ink strokes rather than the recognized text. Hence, document search is limited to those stored in the text format.

Sharples et al. (2002) designed a pen-based mobile personal learning organizer that follows socio-cognitive engineering principles by enabling users to capture and recall, integrate disparate sources of information with, and share information on an object.

Luchini et al. (2003) designed a system to support learners in creating concept maps using hand-held devices such as pocket PCs. They reported that the developed systems can address complex learning activities using handheld tools, and it can be used to help students create better concept maps.

Nakabayashi et al. (2007) described the development of a self-learning environment, where both mobile phones and personal computers could be used as client terminals. They extended the system functionality to enable offline learning, sharing course structure, and learner tracking information for learning activities using mobile phones and personal computers.

In 2006 and 2007, Dieterle determined how wireless handheld devices can affect learning and teaching in university settings. Their project focused more on using wireless handheld devices such as communicators, construction kits, information banks, phenomenaria, symbol pads, and task banks in a variety of learning settings. They reported that WHDs devices can enhance learning and teaching activities, and that ideal note-taking and information retrieval environments should be developed (Dieterle & Dede, 2006; Dieterle, Dede, & Schrier, 2007). Varadarajan et al. (2008) proposed an intelligent system with simple interface on PDA devices to allow fast indexing for digital notes in document repositories. Their system supports information query in inter- and intra-document indexing using latent semantic indexing. They reported that the system highly enhanced the student learning experience (Varadarajan, Patel, Maxim, & Grosky, 2008).

In summary, most of these developed tools introduced note-taking into digital media. Some of these tools include specific features and functions, which are considered essential requirements for developing a useful note-taking application. For example, StuPad and CP support individual student annotation on lecture slides. However, LiveNotes allows students to take their own notes and to view the annotations of a small group of their peers without providing an explicit division or management of space conflicts. NotePals allows students to take small notes during lectures, juxtapose these notes with the lecture slides, and share with the entire class. In contrast, students who use LiveNotes and NotePals are unaware of the notes of other students during a lecture, which minimizes space and content conflicts but may result in duplicated effort.

3.3 Analysis on the Current Note taking tools

The note taking systems described in the literature were classified based on user group targets and system functionality. For example, StuPad, NoteTaker, Classroom Presenter, E-Notes, and DyKnow are consider as active learning tools designed to support user activities for taking notes during classroom lectures where developers focus on capturing and recording functionality. While other tools such as DigitalDesk, XLibris, PapierCraft, Paper-Top–Interface, and InkSeine support users for taking notes during reading information resources where annotation, highlighting, and adding comments features had higher consideration for assisting in elaborating resource materials. Furthermore, some tools focused more on the learning gain of collaboration and sharing notes functionality between users such as Tivoli, Livenotes, CoScribe, and NotePals. Finally, several tools were developed for note taking facilities in handheld, and Tablet PC devices perform limited tasks such as creating map concepts, enabling offline learning, annotation, sharing course structure, and semantic indexing. Many research groups were participated to move note taking towards electronic representation, and advised the suitability of using handheld devices, Tablet PCs, and personal computers for note taking activities (Abowd, 1999; Davis et al., 1999; Lin et al., 2004). Thus, current note taking tools were widely diverse in their user targets, functional components, interface layout, and their behaviours in achieving note taking tasks.

Recent studies showed that students still preferred to use the pen and paper method to take their notes instead of demand on the new technology for taking notes (Bauer & Koedinger, 2008; Hsieh et al., 2006; Kim et al., 2009; Reimer et al., 2009). For example, a survey showed that students still preferred to take their notes manually using pen and papers instead of using digital devices (Reimer et al., 2009). Their study showed that people still use the traditional pen and paper for taking notes heavily because a little progress have been made to transfer note taking activities into digital applications.

We performed a systematic comparison between the current tools of note taking to identify their functional requirements, modules, platforms, advantage, and disadvantages as shown in Table 3.1.

Table 3.1 Systematic Comparison of Some Note Taking Tools

Name	Modules	Functions	Platforms	Advantage	Disadvantages
StuPad	Capturing Accessing reviewing Organizing Recording	Handwriting Annotating Highlighting Record Audio and video stream	Windows Whiteboard Pen – based technology Client server Architecture	Support free form Record lecture stream. Used for active learning	Need further developments. Student has access permission only to review lecture contents. Missing most of note taking activities. Suitable for lecturers no students.
NoteTaker	Capturing Reviewing Manipulating	Handwriting Annotation Typing text Drawing diagrams Formatting text Highlighting	Java Platform	Flexibility in using the preferred device to input notes. Handwriting used to draw diagrams, keyboard used to enter text, mouse used to make selection and positioning. Include several note taking functions such as drawing, stretching, copying, gridding, colors, importing images, saving to a file, printing, scrolling, and rudimentary navigation among pages. Optimize selecting and positioning tasks. Support multi language and keyboard directions.	Pop up menu destruct users. Quality of drawing was rated as very bad. Users confuse about the suitable input devices. Using mouse in Selecting process leads to extra wasting time. Ease of use of NoteTaker was rated low (3.9 on average). Cognitive efforts for using NoteTaker were higher than traditional approaches. Contains several implementation limitations in both hardware and software.
CP, UP	Capturing Reviewing Manipulating Sharing	Handwriting Annotating Highlighting Colouring and formatting Erasing Importing Saving Printing Typing text	Windows Client – server architectures	Sharing of digital ink on slides between instructors and students. Integration of digital ink in lecture slides. Import images and PowerPoint slides. Support some learning functions. Support using wireless technology for active classroom teaching. Support interaction during lecture by using any web-enabled devices such as laptops, notebooks, and smart phones.	Does not support digital advantages such as searching, linking, and indexing. Teacher monitor student inputs which effects student freedom. Disturb users via other people feedbacks. Crowded interfaces. Not evaluated yet. Limited functionality for later access and revision of notes. Difficult to use for note taking purposes.

Table 3.1 Systematic Comparison of Some Note Taking Tools

Name	Modules	Functions	Platforms	Advantage	Disadvantages
DyKnow	Presenting, Importing slides Assess and Save notes Monitoring, and Supervise activities Record and Replay Organizing Collaborate and Interact Sharing	Annotation. Embed content (websites, videos, graphs, tables) Content Delivery Share Control for Group Work. Chat, Polling, Screen Broadcast, and Private Notes. Graded Polls, Collect Work, Return Work, Status Request. Replay Content, Record Audio, Access Anytime-Anywhere.	Web based enabled for any devices. Client – Server's architecture.	Support most of note taking activities and functions. Support learning management's tools. Allow wide interaction style between teachers and users. Can be used in any web-enabled device.	Interface is very difficult to learn and use. Disturb users during lecture via chat, pool, and feedback during classroom. Doesn't support Handwriting. Has one interface for the different device types. Support interaction activities more than note taking activities.
Microsoft **Tablet**	Capturing Accessing Organizing	Handwriting Annotating Indexing Drawing Saving Printing	Windows Client only Pen-based technology	Support different platforms such as PC, Tablet, Palm, and Pocket PC. Support free form notes. Easy to use.	Inaccurate handwriting recognition. Crowded interface. Include a lot of menu, commands, and shortcuts which affects the cognitive response of students.
Evernote	Capturing Accessing Manipulating Sharing	Handwriting Typing text Uploading images and different files. Synchronize data Annotating Indexing Web clipper Drawing Formatting text Highlighting	Support most of OS platforms. server-client architecture	All of your notes, web clips, files and images are made available on every device and computer you use. Access anytime, anywhere. Flexibility in information managements. Support different OS and devices. Support some digital features such as linking, tagging, and indexing.	Its design mainly for personal management information. Difficult to use without guidance. Developed without learning consideration. Its commercial software developed without any evaluation of its effect on learning achievements. So much menu and dialogues. Required internet connection to work with workspace.

Table 3.1 Systematic Comparison of Some Note Taking Tools

Name	Modules	Functions	Platforms	Advantage	Disadvantages
		Snapshots Recording audio & video			
E-Notes	Offer an electric form of lecturer only	Annotating Sharing	Windows Client only	Simple and easy to use. Evaluated and got good rating.	Missing essential functions of note taking. Design for lecturer mainly.
Livenotes	collaborative and augmented note-taking system	Annotating Sharing Augmented materials.	Server client architectures. wirelessly connected tablet PCs.	shared whiteboard for taking lecture notes cooperatively on top of prepared instructor slides as well as for real-time discussion among group members	No explicit division provided for labor among the members of the small Group. Support discussion is overload users. Interface is similar for the different devices. Required extra times for using the specific tools.
DigitalDesk	Capturing Reviewing	Handwriting Drawing Annotating	Physical desk Video camera captures image streams	Simplify the process of interacting with documents in the digital world. Flexible to use similar to the traditional note taking.	Didn't explicitly focus on digital note-taking process. Missing digital advantages such as indexing, searching, sharing, and linking. It merges the traditional and digital tools without supporting for transfers the note taking tasks into digital environments.
PADD	Capturing Reviewing Sharing	Handwriting Annotating Sharing Navigation Saving synchronized	Digital paper. Digital pen with infrared camera.	Ease of editing, sharing, and archiving of the digital notes. Similar to traditional tasks.	Expensive. Some advantages of digital note taking note implemented such as searching, linking, and indexing. Additional times required for transferring ink notes into digital devices.
PapierCraft	Its upgraded of PADD	Extra functions includes new commands in the digital paper such as copy, paste, email, create a link, or search.	platforms similar with PADD	Mediation between the subject and the object without changing the other elements of the activities. Includes several digital advantages	Expensive Note evaluated yet. Synchronization process delay the time of real time for note taking. Electronic paper and tablet PCs will overcome difficulties in deployment.

Table 3.1 Systematic Comparison of Some Note Taking Tools

Name	Modules	Functions	Platforms	Advantage	Disadvantages
Sony Reader, Amazon Kindle	Accessing Reviewing	Annotating Underline Highlighting	Electronic paper with two transparent silicone sheets filled with small spheres.	Supporting active reading by using electronic paper. More flexible like paper. Consumes very little power, can be easily changed, and is not backlight like traditional computer monitors.	Proprietary formats and content availability, as well as the lack of freeform annotations for the sake of longer battery life. Most note taking tasks not supported. Limitation of hardware and software.
InkSeine	Capturing Accessing Reviewing	Handwriting Highlighting Searching	Tablet pc with Pen gesture.	Support creative sense-making while minimizing distractions and maximizing focused attention. leverage the existing digital ink in the notes to trigger searches for related content. Support similar interaction with traditional pen and paper.	Managing the various windows is challenging and the interface was cluttered. Interface is fairly complex, which may hamper note taking. Not evaluated.
Tivoli	Collaborative	pen scribbling and gestured-based commands for editing, saving, printing, and importing background images.	Xerox Liveboard, a large pen-based interactive whiteboard, for informal group meetings.	Mediate note-taking in a small group of people Supports multiple users at the same Liveboard as well as multiple users at different geographical locations,	the subject of the activity changes from one student to a group of students, which in turn, changes the division of labor and rules that mediate the relationship between the students and the rest of their community. Most note taking tasks not supported.
NotePals	Sharing Accessing	Typing Annotating zooming	PDA with web enable	Inexpensive and usable everywhere. Flexible to use. Ability to access note from any browser.	It designed for the classroom and focuses mainly on sharing notes as a meeting support tool. The zoom window is shaped to be used for writing text and may actually hinder the drawing of diagrams. Missing most note taking functions.

As illustrated in Table 3.1, most of these systems address new functionality and activities of note taking in the classroom such as audio and video capture, sharing. They also focus on indexing the annotations with the other objects. Current note taking tools included specific modules to support the abstract tasks of note taking process such as capturing, managing, accessing, reviewing, and collaborating notes e.g. (StuPad, NoteTaker, CP,DyKnow, EverNote, E-Note, Livenotes, and InkSeine). Notes are often created in the classroom while listen to the lecture. Sometimes, supplemental materials are available while taking notes such as outline or slides for class presentations. Then, notes can be edited, expanded, or organized to improve their usefulness. In addition, notes can be a comment or highlights on text during reading books or journals. As shown in Table 3.1, a few systems support note management, note use, other than providing some generic search and browse mechanism. Technology changes the note taking tasks and makes some of these abstract tasks easier, while complicating others. For example, the added benefit of having the notes electronically makes it easier to share notes, edit, and organize notes, which are troublesome on paper. However, the way of providing this feature becomes more complicated if compared with traditional paper. Based on the review of the current tools, we identified four abstract tasks that are necessary to any note taking application.

a. Capture

According to a theory in educational psychology, encoding is essential to the note-taking process, which is used to capture information (Kiewra & Frank, 1988; Rickards & Friedman, 1978). Capturing notes involves user's exposure to new information from media, such as reading from a textbook (visual) or listening to a speech or lecture (audio) (refer to section 2.2).

Most note-taking systems are designed to support the aforementioned activities using different approaches, such as handwriting, typing, annotating, and augmenting audio or video materials. For example, Paper-Top Interface (PTI), and DigitalDesk use a projector and a camera pointed at a physical desk to capture and record notes. PADDs, XLibris, StuPad, Tivoli, LiveNotes, and NotePals are supported with mechanisms to connect the notes with a specific document or presented material. Other systems, such as PapierCraft, ButterflyNet, InkSeine, and EverNote, allow multiple documents to be transported as background content any time. The process of capturing and writing notes is considered the core task of the note-taking process (Hartley & Davies, 1978). Existing note-taking systems employ several devices, such as pen-based technology, keyboard, and mouse, for entering note elements (refer to section 3.2). Several studies support the use of pen-based technology in writing notes, especially during class hours (Ward and Tatsukawa, 2003; Kim et al., 2009).

b. Review

According to educational psychologists, accessing note-taking activities is considered as a reviewing process for the note taker (Fisher & Harris, 1973; Peper & Mayer, 1978); it is also defined as the process of storing and retrieving the note product. The process of accessing note-taking activities involves the mechanism used to store, access, and review written notes in preparation for learning (refer to section 2.3). Existing tools include a specific module to support user access to save notes via two access mechanisms, namely, locally (i.e., from storage media devices) and remotely (i.e., via network devices). Existing systems are designed with navigation functions to facilitate user access with varying interface layouts. For example, several existing systems, such as DyKnow and StuPad, are supported with linear navigation only, resulting in slow access activity because the note taker needs to quickly navigate to any note location.

Other existing systems, such as EverNote and LiveNotes, are supported with various nonlinear navigation modules, such as indexing, tagging, and other techniques, thereby deterring user activities. Several other existing systems, such as NotePals, and E-Note, are supported with user structure to control the navigation process, which in turn will provide quick access to relevant contents. Other tools, such as StuPad, NoteTaker, DyKnow, CP, and UP, support note access, including local access, using their own format, whereas others, such as Evernote, E-Note, and PTI, support remote note access using different note formats (refer to section 3.2).

c. Manipulate

The process of manipulation is involved in most activities of note-taking systems, such as creating topics as well as creating, deleting, editing, annotating, and organizing notes. Most existing tools in note-taking applications include different functions to support the note taker in manipulating written notes. For example, InkSeine and LiveNotes provide users with real-time feedback for all manipulation commands, NotePals and PapierCraft provide delayed feedback for several commands, and NotePals and PDA do not give users any feedback regarding any executed commands. Moreover, existing systems have several differences in terms of manipulation functions; for example, searching for relevant content in notes can be performed using keywords, tags, or properties, as in XLibris, Dynomite, and NotePals, or handwriting recognition, as in InkSeine, OneNote, and EverNote. Furthermore, searching for relevant content outside the notes can either be explicit, as in InkSeine, or unforeseen, as in XLibris. In addition, organizing notes can be considered as a manipulating tool designed to organize the various thoughts in written notes within a specific categorization, such as by topic, course, subject, and note purpose (refer to section 3.2).

d. Collaborative

Collaborative note taking can be considered as the interchange and sharing of information with other people during the note-taking process. Research has revealed the importance of collaboration activities among students to improve learning achievements (Geyer & Reiterer, 2012; Steimle et al., 2009; Vega et al., 2007). Furthermore, research on education has found that sharing information enhances the learning process through access to feedback for related information, and enriches the learner's knowledge with extra information on specific topics (refer to section 2.3).

The main considerations of collaboration tools include identifying constraints related to time, people, and location of collaboration. Time constraints involve the availability of tools to support synchronous or asynchronous communication during note taking. People constraints involve user permission for sharing notes. Location constraints involve supporting collaborative activity performed in the same or in different locations. Therefore, many systems are designed to support collaborative and information sharing functionalities. For example, Tivoli, LiveNotes, Group Scribbles, and Evernote support collaboration during note capture with consideration of the time-synchronous process, whereas NotePals, StuPad, and XLibris mostly support collaboration during note access with consideration of the asynchronous process. In addition, DyKnow and DigitalDesk support note collaboration performed in the same place, whereas Evernote, LiveNotes, and E-notes mostly support collaboration between different locations (refer to section 3.2). Additionally, we identified the functional and non-functional requirements of the current digital note taking tools as shown in Table 3.2.

Table 3.2: Functional and Non-Function Requirements of Note Taking tools.

Functional Requirements	Non-functional requirements
Handwriting	Usability
Edit	Efficiency
Search	Performance
Index, Tagging, Linking	Extensibility
Save	Accessibility
Retrieve	Availability
Drawing	Compatibility
Annotation	Portability
Highlights	Legibility
Organize	
Selecting	
Augment materials	

3.4 Review Finding

Based on the previous review of the traditional note taking practice and the current digital note taking tools we summarized our finding as follows:

1. Note takers may be overloaded with multitasks to capture, understand, select, and rewrite knowledge. They may also have different knowledge, skills, capabilities, and styles that affect their behaviour during the note-taking process. Note takers essentially need an effectively adapted note-taking system to optimize their cognitive overload, to become deeply involved in the note-taking system, and to increase their learning achievements with minimum effort by using an electronic note-taking system.

2. Current note taking application designed for different purposes such as personal notes, collaborative notes, and included limited functionality such as annotating, highlighting, and indexing.
3. Necessity of transferring note taking into digital era is become more importance due the widely increasing of information resource while manual note taking become insufficient to process these huge amounts of information. Challenges on the usability of traditional notes clearly appear via information management tasks because of the pervasiveness of current digital technology. Furthermore, people are expected to manage a large amount of information with different formats and from varying resources to complete their academic tasks. Traditional note-taking was unable to meet these challenges and encouraged the development of electronic note-taking applications. Moreover, the digital document is not seen in the physical world, but has more advantages compared to paper documents, such as storability, transportability, computability, reproducibility, legibility, search ability, and extra functionality such as ability for indexing, linking, and information extraction.
4. There are two types of note taking tools in terms of note creation, either linear or free form tools, both types are contains specific functions that impact learning.
5. There are four types of note taking in terms of user targets, active learning, active reading, collaboration, and WHD tools. Additionally, those types of note taking were designed with different functions to serve the user targets.
6. Previous research had identified the necessary functional and non-functional requirements as listed below in Table 3.2. Most systems of note-taking applications do not specifically attempt to make the note-taking process more effective and efficient for meeting learning criteria and hypotheses.

7. Previous studies have often focused more on the design of the note-taking interface instead of the benefits of traditional note taking, thus leading to various note-taking interfaces without satisfactory research on their behaviours and educational outcomes.
8. In other words, if a note-taking application is developed for educational purposes, it should be designed to at least maintain learning benefits achieved through traditional note taking.
9. Most of the existing note-taking tools fail to represent the tasks of traditional note-taking. Such systems also fail to satisfy the requirements of the note taker because they do not significantly change embedded note-taking practices and existing classroom dynamics, support pedagogical practices, and consider student perspectives.
10. Moreover, common note-taking software does not only fail in supporting full note-taking functions, but existing tools suffer in usability, mentality, knowledge capture, negative impact learning, as well as difficulties in retaining and retrieving information. The current application not only fails to support all note-taking functions but also has several major learning deficiencies that negatively affect the learning process which will be described briefly in next chapter.
11. Existing software does not fully support the critical note-taking tasks because of the lack of adequate software tools and difficulties associated with the implementation of general note-taking application due to the limitation to cover the related area involved in the design of such system.
12. Several studies delivered one or several tools, whereas others developed specific application with limited functionality. Extensive studies were conducted on the function and behaviour of note-taking, while others were developed to support note-

taking applications without practical implementation. Other studies focused more in developing the common functions that required in note-taking applications with limited functionality for individual tasks of note-taking application.

13. Several systems have been developed for note-taking applications, but most of these applications do not improve note-taking efficiency because they fail to meet the relevant theories, criteria, and hypothesis of learning process.

We used these finding to achieve the first objective by addressing the current issues of digital note taking applications which are described in more details in next chapter.

3.5 Chapter Summary

In the previous chapters, we have looked at two different scopes of note taking.

- Traditional note-taking process and its effects in enhancing learning and cognition.
- Progress and achievements of technological research on note taking during the digital age.

To aspire to these scopes, different studies on note taking were performed to explore note taking activities and the note taking process.

Traditional note-taking tasks, behaviours, styles, and activities was investigated previously to explore the functional requirements of digital notes that need to be implemented such as focusing, encoding, elaboration, and external storage. We found that the tasks and activities of note taking can be used to deliver the user requirements for digital note taking application; however the developer should be aware about the learning gain during transferring these tasks digitally. Hence, each learning objective of traditional note taking is represented by a set of activities and tasks accomplished during the note-taking process, so note taking is not a single tool or a simple application that can be developed easily, but is a complex human process with numerous criteria, properties, and constraints that must be transferred effectively into digital media. Figure 3.17 represents the investigated area of traditional note taking performed.

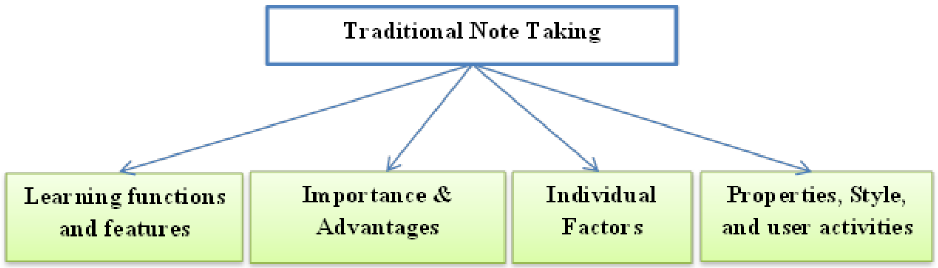


Figure 3.17 Traditional Note Taking Investigated areas.

In section 3.2, we conducted an extensive study on current tools of note-taking applications to further investigate the advantages of digital notes such as searching, editing, indexing, and portability features. We also listed the disadvantages of these tools in learning prospective such as user distraction, interfering, confusing, and mishandling issues. Furthermore, we categorized the types of tools that support note-taking applications into four groups include active learning, active reading, collaborative, and handheld device tools. We also investigated the relative effect of designing a note-taking system on learning and the relationship between note-taking system components and metacognitive knowledge. Then, we summarized our finding about the main issues of current applications and why most applications fail to convert the note-taking process into digital format. Figure 3.18 shows the investigated area of digital note taking performed in this chapter.

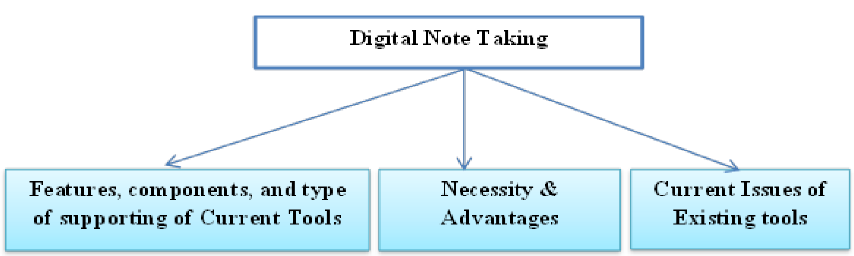


Figure 3.18 Digital Note Taking Investigated areas.

Accordingly, we explored the benefits of converting the note-taking process into the digital format for assimilating different types of information resources, and summarized essential functions and requirements of current tools which proof its suitability in adapting specific tasks of note taking such as handwriting, selecting, highlighting, and sharing tools. Moreover, we elaborated on problems of note-taking applications with regard to the learning process that may occur as a result of the conflict between the tools developed based on learning theories and the overlapping of advantages of traditional and digital notes. In addition, we summarized the advantages and disadvantages of traditional and digital note taking approaches as shown in Table 3.3.

Table 3.3 Comparison of Traditional and Digital Note taking.

	Traditional Note Taking	**Digital Note Taking**
Advantages	- Simple and easy to take note - Learning gain is higher. - People can use it without any guidance. - Style, behaviour, and activity are not constrains. - User has the freedom to enter any type of information with less effort. - Tools used are cheaper.	- Efficient to assimilate several information resources and formats. - Easier for searching, editing, sharing, accessing, and sharing features. - Supports new features such as indexing, linking, and extracting information. - Environment friendly.
Disadvantages	- Difficult to assimilate huge resource of information. - Has short life cycle. - Sloppy - Difficult to access, share, and search. - Has problematic issues in readability, and edit ability.	- Difficult to use for taking notes. - Impacts learning gains. - Users need specific guidance about using tool features. - Users are constrained by several limitations of system functions. - User mostly requires extra efforts to create efficient notes. - Electric device and software are expensive compared with pen and paper.

4.0 RESEARCH PROBLEM AND PROPOSED SOLUTION

The fundamental idea behind this research is to investigate how technology can be used to improve learning outcomes by facilitating the note-taking process in a digital environment and by determining the steps required to convert traditional note taking into the digital format. Few studies delved into the impact of developed systems on learning outcomes for digital note taking. Our present review of the existing systems, illustrated that although note-taking software has increased over the last decade, only a few applications can be classified as a note-taking system, and most of the developed tools only provide some functionality for individual note-taking tasks.

4.1 Research Problem

The development of a successful note-taking application with currently available technology is very challenging. Based on the aforementioned review findings in chapter 3 (refer to section 3.4), we categorized the problems of current note-taking tools that prevent note taking from being converted into the digital format into four main critical issues as shown in Figure 4.1.

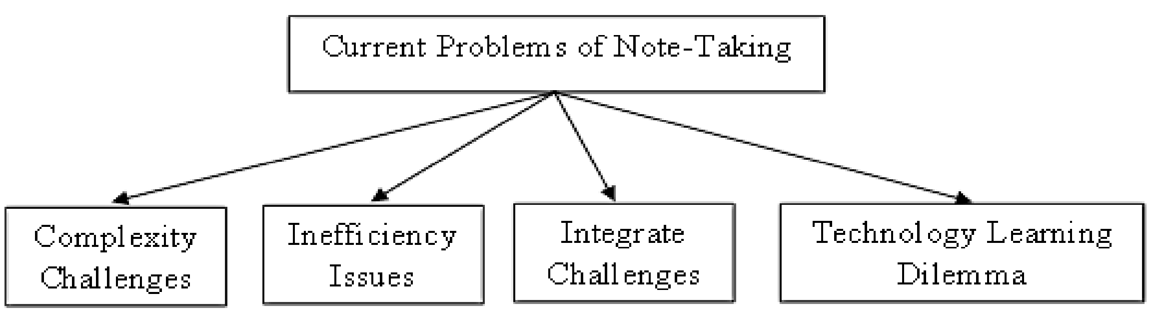


Figure 4.1 Main problems of Digital Note Taking.

4.1.1 Complexity Challenges

The term *complex challenges* encompasses different types of note-taking issues, such as complexity in selecting appropriate tools based on learning theories and in implementing these tools and their interfaces. Note taking developers facing complexity challenges because of several factors. The first difficulty is in transferring complex realistic tasks into the digital worlds. The second difficulty is the complexity of note taking tools development. The last difficulty is the limitation of current technology for implementing these tools. The complexity challenges are shown in Figure 4.2.

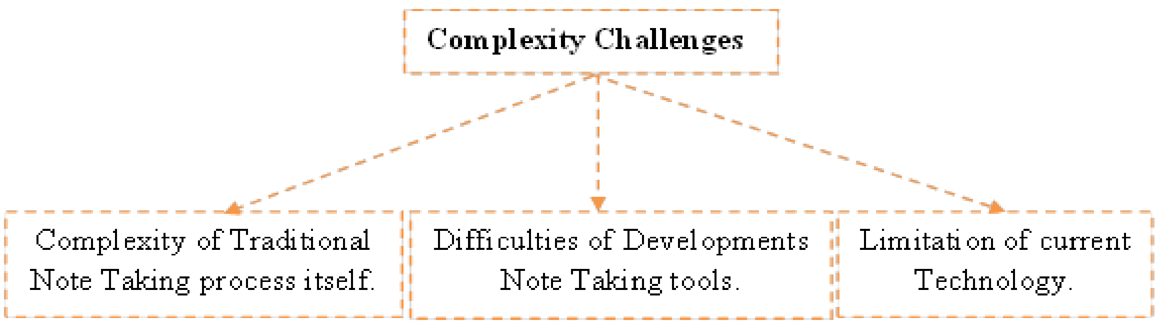


Figure 4.2 Complexity Challenges Cause Factors.

a. Complexity of the Traditional Note Taking

Note-taking activity is considered as a complex process because it needs several steps from comprehension and selection of information to written production. Note taking is a complex activity in terms of its functionality, components, and effects on learning behaviour and outcomes as discussed in section 2.2. Difficulties in representing traditional note-taking tasks as digital functions or note-taking applications are major challenges because of numerous theoretical constraints, such as functional requirements, abbreviation procedures, strategies, and working memory of note taking, which aim to improve theoretical and practical understanding of note-taking activities (refer to section 2.2.3). For example, comparative data for note taking demand more effort than those for reading or learning. However, note taking requires less effort than a creative written composition of an original text as discussed in section 2.3.4. Thus, a complex traditional activity is more difficult to be represented in the digital world because the complexities in transferring traditional tasks into an electronic system are increased.

b. Complexity of Development

Several challenges are faced by developers during the development of note-taking tools such as analysing the traditional note taking tasks to select the appropriate tools. These challenges occur during the development process of such an application from the initial stage of identifying system requirement to the last stages of evaluation and obtaining user feedback. These challenges exist because note-taking tools are not accepted unless they satisfy user requirements at the very least and are implemented with special consideration to the pedagogical practice and the educational benefits of note taking. Challenges increase during the evaluation of these tools because no standard has been developed to describe which parameters should be included in the evaluation process. No research has yet discussed the evaluation criteria approaches of developed tools. Moreover, evaluating individual criterion, such as learning outcomes, student behaviours, student achievements, and performance is difficult (refer to section 3.3).

c. Limitation of Current Technology

Limitation of current hardware and software tools in mimicking the note-taking process, along with economic and social issues, increases the complexity of developing a note-taking application and prevents the adoption of electronic note taking as described in section 3.3. The complexity of using a computing device for a note-taking activity can be cited as a reason for the limitation of electronic systems in note taking (Kim et al., 2009) (refer to section 3.4). However, digital pens, digital paper, handheld devices, laptops, smartphones, and other devices can be used for note taking if an application that facilitates the note-taking process without affecting learning exists. A number of constraints and limitations on functionality, availability, and performance for developing a suitable application for electronic note taking have been observed as discussed in section 3.3.

4.1.2 Inefficiency Issues

Inefficiency of digital note tools is one of the main reasons for keeping to traditional note taking. Based on investigation of the current note taking tools, we found that the current tools of note taking are inefficient and inadequate to take notes in digital devices because of their linearity, limitations of the free form tools, and weak design of their interface issues as mentioned in section 3.3. The inefficiency issues of current tools are illustrated in Figure 4.3.

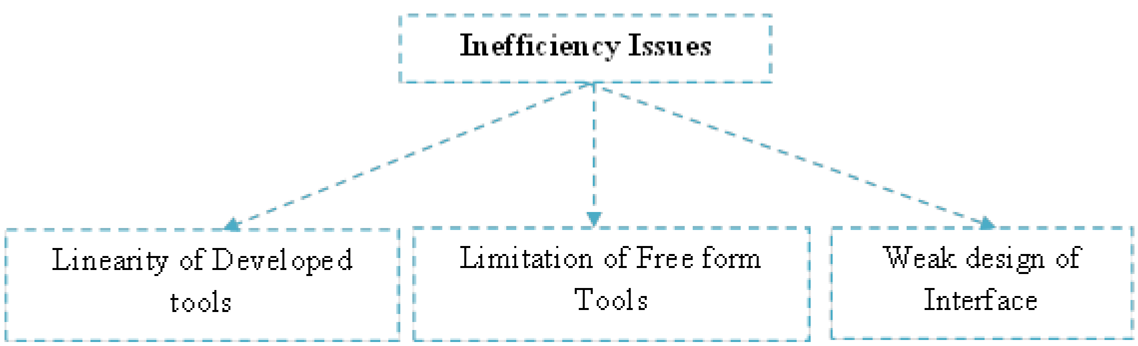


Figure 4.3 Inefficiency Issues Cause Factors.

Time consuming and cognitive overload are the main factors that produced inefficiency issues in current note taking applications. If we consider the theory of cognitive load of the note-taker with a tight time constraint, the current note-taking tools remain insufficient for taking notes in the digital form. Most existing note-taking tools are still inefficient in the digital form because of the amount of time and activity required for the note taker in performing several tasks, such as adding, editing, and modifying information (Vega et al., 2007).

a. linearity

Based on our review in section 2.5, notes are mainly taken without linear consideration, and are written on a different page area with different position without limitation or linearity. However, most note-taking tools are designed to use text editors for creating and editing notes as a digital document (refer to section 3.3). As a result, most delivered digital notes are sequential and follow the analogy of a typewriter. For example, digital documents in English follow the left to right, top to bottom order, which can change based on the writing language. Actually, linearity has broken the role of free form traditional notes where linear tools exhibit efficiency in editing text without freedom option (Ward & Tatsukawa, 2003). Most of the existing note-taking systems use the keyboard for typing notes, which is recommended because the use of keyboard for text input is faster than handwriting (Ward & Tatsukawa, 2003). However, several studies reported that using the keyboard and mouse to input notes is a waste of time due to the extra time required for selecting the tool, choosing the font type and colour, and selecting the desired location for typing (Bauer & Koedinger, 2008). Moreover, recent research reported that the use of input device can affect the note-taking function and strongly impact the learning cognition (Reimer et al., 2009). This limitation of linear representation for current note taking tools makes users prefer the traditional note taking instead of switching to digital notes. Other effects of linearity include its tendency to allow text editors to insert whitespaces between the end of words, sentences, or documents and the user-selected position. Note takers reported that linear application is considered useless during the note taking process (Nakabayashi et al., 2007;

Schilit et al., 1998). Developers reported that free form tools are a challenge they face during the development of note-taking application (Kam et al., 2005).

b. Limitation of the current free form tools

A few systems were recently designed to support note takers in adding information in a nonlinear form, and several tools have tried to implement note-taking with free-form canvas such as OneNote, NoteTaker, and LiveNotes (refer to section 3.2). User feedback on some nonlinear tools such as Microsoft OneNote is generally positive. However, most existing systems that are designed to allow nonlinear form has increased the note taker cognitive loads, so the processing time during the input of information remains inefficient (Crooks & Katayama, 2002; Katayama & Robinson, 2000; Makany et al., 2008; Moos, 2009). For example, users of nonlinear applications should perform several steps before drawing diagrams by specifying the area for drawing, selecting drawing tool, moving the mouse to the desired area, and clicking the mouse to start drawing. These steps require extra time, which creates a critical learning problem for the note-takers. However, the free form tools are recommended by other research to support users write their notes in a flexible and efficient matter (Mitsuhara et al., 2010; Reimer et al., 2009). In general, existing note-taking tools encounter problems in balancing time efficiency and the freedom to enter information, whereas linear tools are reported as efficient in editing text but without the freedom option.

c. Weak Design of Interface.

Designing an appropriate interface for note-taking tools is considered as one of the main critical factors for the successful development of a note-taking system because the note-taking interface is usually constrained by time and cognitive effort. In addition, interface design plays an important role in converting the note-taking process into the digital format. Each note-taking tool can be designed with various interfaces, which results in the accomplishment of tasks in various steps. However, variations in interface design confuse the developer with regard to appropriate design for each note-taking tool. Our investigation of current tools for digital notes showed that the interface components distract users, reduce their attention and focusing. For example, students found that the select tools from the system menu increase their cognitive load and reduce their attention span (Ward & Tatsukawa, 2003). Under time constraint and cognitive load, traditional note taking is difficult to support with technology to enhance learning substantially. In addition, note-taking tools are classified into different types of supporting-activity tasks such as classroom interaction, collaborative tools, outside-classroom tools for material review, and automated computer tools for monitoring and controlling events. Each category of tools varies in terms of functionality and learning support, thus leading to different types of interfaces within a single note-taking application. Overlapping mostly occurs among note-taking functions increasing difficulties in developing an efficient system that combines all tools as a simple interface (refer to section 3.4).

4.1.3 Integrability challenges of Note taking

According to learning theories, note-taking applications should include several components, features, and functions to work as a single unit and should be integrated into a single application for better learning (refer to section 2.3 and 2.4). There is a need to develop several note-taking tools to implement all traditional note-taking activities. Several tools have been developed to achieve various note-taking functions; however, most of these tools have been built with individual functionality (Gathercole & Alloway, 2008; Kim et al., 2009). Integrability cause factors are illustrated in Figure 4.4.

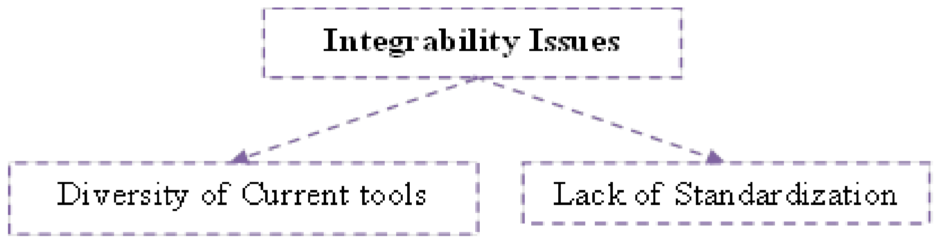


Figure 4.4 Integrability Cause Factors.

a. Wide Diversity of Current Tools

Existing tools are diverse in interface components, system platforms, hosted devices, and programming language implementation. Thus, a number of note-taking tools are currently available with several functions, but system has yet been designed to integrate these tools to develop note-taking applications because of diversity in interface, implementing language, and system platforms. However, existing tools are insufficient for supporting note taking and other tools need to be developed and integrated into a single application for electronic note-taking. Table 4.1 shows examples about these wide variations of current tools of note taking. By contrast, numerous tools and functions can be derived for note-taking applications (refer to section 3.3).

Table 4.1 Examples for diversity of Current Digital Note taking

Hardware Devices	**Platform OS**	**Coded Language**	**Supported Tools**
Laptops, Tablet PC's, Smart Phone, iPad, Digital Pen, Digital Paper.	Windows OS Apple OS Android OS Linux OS	C#, C++, Visual Basics. Web Based HTML, PHP, MonoDev.	Capturing Recording audio & video. Selecting, Indexing, Highlighting, Sharing, Tagging

Integrating all existing tools and developing other note-taking tools are considered as challenges. All these issues regarding the integration process must be addressed to develop a typical note-taking application for adapting traditional note-taking activities into the digital age. Furthermore, this challenge is increased because various note-taking systems have been built using different techniques without learning consideration, in which several techniques consider specific functionality, whereas others consider certain tools, thus leading to variations in tools, functions, and target groups (refer to section 3.2).

b. Lack of Standardization

In our investigation of the existing note-taking systems, we note that various developed tools and systems were designed to work with different platforms to support note-taking in certain digital devices as discussed in section 3.3. Overall, numerous tools need to be developed, different criteria need to be considered during selection, various disciplines should be involved during the development process, a number of platforms and devices should be considered, and numerous constraints and limitations need to be sufficiently addressed. However, there are no systems or studies that describe the roles and identify any standard principle for the development of a typical note-taking application. No research has yet investigated, defined, or suggested any typical application or designed standard guidelines to assist developers to transfer the note-taking process into digital media and facilitate the process of taking notes with digital equipment and existing technology. Thus, there are no guidelines that simplify the process of developing a note-taking system based on the characteristics of the note itself. Moreover, combining the designed tools and integrating them with the note-taking system have not been attempted yet. No generalization form has been built for identifying the complete architecture of the note-taking system.

4.1.4 Technology learning dilemma

Education researchers have reported that using technology to support learning affects learning behaviours, styles, and outcomes (Makany et al., 2008; Zhai, Kristensson, &

Smith, 2005). Researchers on note taking have agreed with the proposition that using technology in inappropriate ways has negative impact on the learning process (Bauer & Koedinger, 2008; Bauer & Koedinger, 2006). Numerous tools and systems have been developed to facilitate the learning process in different areas. However, some of these tools are not designed efficiently and are not appropriate for achieving learning goals (Grabe & Christopherson, 2005b; Morgan, Brickell, & Harper, 2008). Furthermore, several challenges exist in using technology to support note-taking activities. This problem is considered as an important reason why note-taking is not performed in digital devices. In this research, we addressed these problems as one critical issue, which we called the "technology learning dilemma." We categorized these issues as shown in Figure 4.5 into three critical problems: (1) the negative effects of the developed tools or their deficiency in terms of learning behaviours, functions, styles, and outcomes; (2) the conflict between the benefits of using technology tools and learning theories; and (3) the current tools were unexamined well with learning aims.

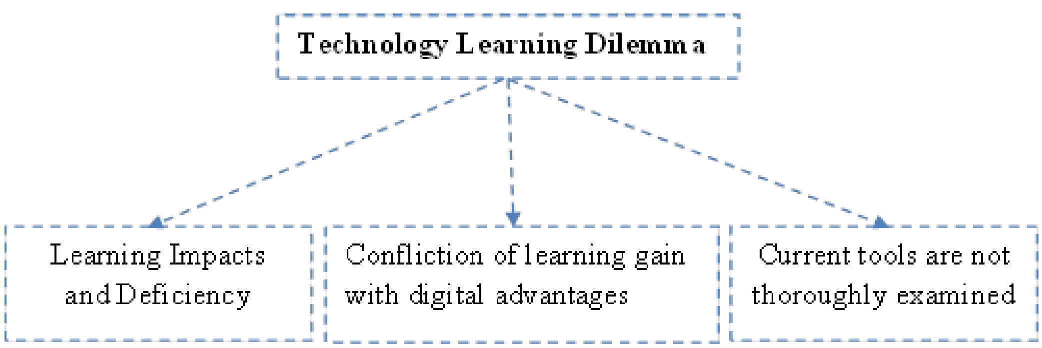


Figure 4.5 Technology Learning Dilemmas Cause Factors.

a. Learning deficiencies

According to our investigation of the current note-taking systems, several note-taking tools have one or more learning problems (refer to section 3.4). For example, a copy–paste function has a negative effect on learning because it allows the note taker to copy the text without reading it. Using the copy–paste function on note-taking applications decreases the ability of the learner to memorize knowledge. The copy–paste function produces verbatim words more than other methods of note-taking. However, this function promotes less retention than other note-taking methods. In addition, the copy–paste function reduces note-takers retention because it allows them to recode notes without reading them or focusing on what they have recorded (Bauer & Koedinger, 2008). As such, this function should be excluded in the design of note-taking applications (Morgan et al., 2008). Another example of learning deficiency is sharing ability, which when included, can change the behaviour of note takers and sometimes, can cause them to depend on the notes of others instead of writing their own. Education research revealed that sharing function affects the encoding function of the note-taking process and exerts negative influence on learning outcomes (Badger et al., 2001; Crooks & Katayama, 2002). In addition, several developed systems allow students to compare notes during class and provide them with the possibility to discuss and post questions (refer to section 3.2.3), which however, can negatively affect user concentration on the presented material (Kaptelinin & Nardi, 2006). We noticed that only specific tools have negative impacts on the learning process, where the way of using tools can lead also to this deficiency.

b. Confliction with digital advantages

As discussed previously, linearity and free form options lead to conflictions issue between the gain advantages of traditional and digital note taking (refer to section 4.2.2). This confliction occurs because the linear systems support the advantages of digital notes; however they impact current user practice, and increased system inefficiency. Vice versa, users are habitually taking notes in a free form approaches which afford learning features by reducing user time and cognitive load, and also support user familiarity, however free form tools is caused to loss the advantages of representing note digitally (Larson, 2009). In contrast, this confliction in selecting the main tool for creating notes leads to delay in transferring notes into digital forms, and cause most developed applications to fail to represent the note taking activities digitally. In addition, a learning dilemma happens when several note-taking functions conflict with some advantages of digital notes, such as the handwriting function conflicting with the ability to edit and search digital notes. The handwriting function is an essential function for note taking because it supports learning by graphic familiarity and free form. Most note-taking applications prefer the use of the keyboard for taking notes because of difficulties in developing handwriting tools and the advantages of electronic notes. However, graphic familiarity and free form as gain factors for note taking as a learning tool are lost if the keyboard is allowed to be used for the creation of note (Hsieh et al., 2006; Kim et al., 2009; Marton & Tsui, 2004). Table 4.2 shows a comparison between advantage and disadvantages of linear and free form note taking tools.

Table 4.2 Comparison between Linear and Free form tools.

Type	**Advantages**	**Disadvantages**
Linear	Easy in developing. Support digital advantages. More legible Easier for deleting and modification.	Increase overloads cognition. Loss familiarity of handwriting. Time consuming Tendency
Free Form	Support realistic behavior. Increasing the efficiency in note processing. Reducing cognitive overload. Support familiarities.	Complexity in developing Loss Digital feature advantages. Less legibleability. Has some limitation and constrains.

The learning dilemma can exist in many circumstances with different scenarios of using technology to support learning. We argue that research groups focused on gaining several feature advantages without considering other important factors, such as those of learning.

For instance, the first group that supported note typing using a keyboard considered acquiring the advantages of the digital notes feature in terms of text typing (Crooks & Katayama, 2002; Kim et al., 2009; Ward & Tatsukawa, 2003). However, this group neglected the note-taking constraints of free form as well as the learning role of the cognitive load and note familiarity. The second group gave a high priority to learning advantages instead of focusing on gaining the powerful tools of technological improvements (Bauer & Koedinger, 2006; Kim et al., 2009; Reimer et al., 2009).

c. Existing note-taking tools are not thoroughly examined

Technology learning dilemma happens because most note-taking tools are designed without considering learning theories. As such, tools are developed without experimentally evaluating their effects, and design decisions are mostly made by software engineers or developers who are not well-versed in educational theories (Vega et al., 2007; Wirth, 2003). Most existing note-taking tools are not examined in terms of their effect on the behaviour and cognitive effort of the learner. Only a few studies have systematically evaluated the effect of note-taking tools on behaviour instead of concentrating on satisfaction and motivation (Bauer & Koedinger, 2006; Berque, 2006). In other words, if a note-taking application is built for educational purposes, it should be designed to maintain the learning benefits achieved through traditional note-taking, wherein each tool must be examined to ensure its suitability for educational purposes. Each tool requires evaluation study to obtain user feedback on the usability of the selected tool and its impact on learning outcomes.

Most developed systems fail to satisfy note-taking tasks because they did not significantly evaluate the embedded note-taking practices, existing classroom dynamics, support pedagogical practices, and consider student perspective (Chiu et al., 1999; Geyer & Reiterer, 2012; Reimer et al., 2009). This finding may be attributed to the limitation of studies performed to evaluate note-taking behaviours systematically, instead of concentrating on user satisfaction and motivation. Several learning theories constrain note-taking application, such as encoding, reviewing, focusing, and elaboration, which should be evaluated for developed tools.

4.2 Research Problem Summary

In table 4.3 we summarized the current issues of note taking tools with the explanations.

Table 4.3 Issues of Current Tools.

Problem	**Caused**
Complexity	- Difficult to mimic the realistic tasks of note taking. - No guidance about development process based on learning theories. - Limitation of current technology to support note taking.
Inefficiency	- Effects of developed tools on time and cognitive constraints not emphases well. - Roles & constraints for proper interface need to be set.
Integrability	- Lack of Standardization - Diversity of user and functional requirements of Note taking applications. - Technology role and responsibilities are not identified yet.
Technology Learning Dilemma	- Design Decision made by Developer who do not understand the education theories well. - Developed tools are not examined well. - There are no roles for evaluation criteria of developed tools.

4.3 Proposed Solution

Proposed solution was developed to solve the major problems described in the previous section. We attempted to initiate essential guidelines required in developing a successful note-taking application to introduce major requirements for the successful adoption of a digital note-taking system.

In table 4.4, we illustrate the proposed solutions linked to the problems discussed in section 4.2.

Table 4.4 Proposed Solution based on Reasons of Current Issues.

Problem	**Proposed Solution**	**Actions**
Complexity	**Complexity Reduction**	- Reduce Complexity by dividing tasks into small units. - Facilitate Modular Engineering for developments. - Identifying the learning role, and theory of note taking. - Initialize Development Guidance.
Inefficiency	**Set Standardization**	- Identify the roles of interface design. - Constrain developers by time and cognitive factors during designing interface. - Keep current practice unchanged and minimize user action as much possible.
Integratability	**interoperable** **technology**	- Identify the role and responsibilities of current technology. - Set constrains for the device physical factors such as shape and size. - Identify standardization development process.
Technology Learning Dilemma	**Free of Learning Dilemma**	- Set specific criteria for evaluation tools. - Evaluate each developed tools. - Use technology to solve the confliction issues between learning and digital advantages. - Adapt the realistic tasks of traditional note.

Additionally, we proposed a guideline that needs to be considered during the design process of an electronic note-taking system, as required by note-taking developers which will be described in the next chapter.

4.3.1 Complexity reduction

Note taking is a set of features, functions, and tasks that need to be implemented as components of tools for developing a typical note-taking application. A note-taking application is a collection of those tools and functions that work together to achieve note-taking tasks and activities. Thus, to develop a successful note-taking application, the complexity need to be reduced by deploying each tool separately as a single unit or module to make note-taking application development and evaluation processes easier, more effective, and efficient. Moreover, to reduce the complexity of developing note-taking tools, we suggested that each activity of traditional note-taking should be classified under the aforementioned learning functions (refer to section 2.3). However, all these tools must be designed within essential constraints to achieve learning goals, facilitate educational activities, and reduce cognitive and time loads during the note-taking process through a special interface.

Thus, complexity reduction extents to divide the traditional note taking activities into specific layers such as learning theories, developments guidance. Then, modular engineering process can be used to implement these tools separately with specific roles and guidance for development and evaluation process. A number of steps need to be accomplished by the developer of the note-taking application to ensure that the developed tools will satisfy user requirements, are associated well with traditional tasks, have a good interface to reduce cognitive and time constraints, and have a positive effect on the learning process.

We categorized note-taking tasks into four main activities: capturing, accessing, manipulating, and calibrating (refer to section 3.2). Each of these activities consists of a collection of several tools and functions. Thus, note-taking applications should be divided into several modules, each of which should include one or more note-taking tools. In addition, the process of dividing note-taking tools into small units or components facilitates, simplifies and supports modular engineering, interchangeability, and integrability; and accelerates the evolution process of the note-taking system in terms of deployment, customization, integration, and distribution. In practice, when note-taking tools are developed separately, the processes of development, evaluating and obtaining learner feedback are easier. Additionally, facilitating modular engineering for note-taking tasks overcomes difficulties in developing note-taking applications, reduces overall complexity faced by the developer, and simplifies the process of converting note taking into digital media.

A major implication of note-taking system requirements is constructing based on capture and access modules, in which the encoding function is represented by the capture module and the reviewing function is represented by the access module. Separating note-taking modules has three benefits—it allows different modules to evolve independently, thus giving users the opportunity to use appropriate tools and access suitable data. This process can assist developers in simplifying and accelerating the development of note-taking systems. In addition, separating note-taking systems into independent modules can accelerate and simplify development for each module. Separated note-taking modules also increase the flexibility of developers during system construction and of users during note taking.

4.3.2 Set Standardizations

People write notes in different styles, such as in two-columns, Cornell, and outline methods refer to section 2.4. Note takers have different learning styles and practices; thus, we cannot constrain them to use one type of note-taking application. No single style or strategy can satisfy all practices or learning behaviours of note takers. For example, some note takers who can write fast develop a strong sense of paraphrasing and organizing, whereas those who write slowly rely on providing clarifications and other useful annotations when taking notes. Note takers can also use different styles depending on the course content. For example, note takers prefer to use the Cornell method for language courses and graphical representation for math or science courses. Hence, it’s difficult to identify a principle to standardize the note taking tools in terms of interface, functions, and target users. However, it is important to identify specific roles, constraints, and responsibilities for note taking components and categorize the similar attributes in individual layers.

Interface design for note-taking tools needs special consideration with specific constraints to reduce time and cognitive load of note-taking activities (refer to section 4.2.2). The interface mainly affects the cognitive load of note takers and is responsible for reducing time spent for note taking. To avoid these problems, we proposed guidelines to standardize the interface of note-taking systems without affecting the consistency of the note-taking process. Thus, note-taking application interface must be designed to minimize perceived changes in traditional note taking with existing practices. Furthermore, the technology introduced to the note taker should be designed with a simple interface without significant changes to his/her natural behaviour and styles. The interface should also be designed with reduced cognitive load and time for accomplishing tasks. The interface developer should be constrained by this role when designing a simple, user-friendly, and learning-conducive interface for each tool. The interface should also support familiar interaction between note takers and their environment. Using a familiar interface in designing note-taking tools can assist users in quickly familiarizing themselves with the interface system, and thus, using it efficiently.

Thus, standardization should be involved in learning theories, development roles, interface design, and technology roles. With the standardization, the developed note-taking application will be more flexible for users and can motivate them to take notes using the digital format. Note-taking tools should be organized, implemented, and integrated with specific global standards, thus allowing implementation of all tools in one system with various platforms to support note taking.

4.3.3 Ensuring Interoperable Technology

Technology constantly changes and always introduces new hardware and functions in different areas related to the note-taking field, such as new Tablet Pcs, smartphones, the iPhone, the iPad, etc. Thus, the proposed system must be designed to adapt to the changing functional and hardware requirements of new technological advancements.

Many note-taking applications vary in functionality and components. No typical system has been designed to include all note-taking features because current tools of note-taking applications need to involve various areas for an efficient design, such as physiology, education, artificial intelligence, and human–computer interaction (HCI).

For efficient design of note-taking tools, different areas need to be involved, such as education theory involved in several technology areas. All available tools cannot be combined or integrated in a single application because each developed tool is designed to work with different platforms and coded with a unique programming language. This problem will be solved if the kernel system for note-taking applications is designed with the ability to integrate various note-taking tools in a single application. However, designing a new prototype system that will work with various technology platforms, then either integrating or recoding current tools for them to work in the proposed system, is easier. Note-taking system developers should also be sufficiently aware of the architecture and components of the proposed system.

The proposed system should also be designed to allow integration of user-requested features and learning features as requirements for note-taking systems. As technology advances and new products emerge, several components of note-taking systems can be simplified and improved using such new tools. For example, handwriting recognition tools have become accurate enough to be included in note-taking systems. Data visualization is a new technique that can be used in note-taking systems to improve the encoding process. Semantic knowledge representation is also a new field that can be used to enhance note taker background.

Using the power of technology in related note-taking tools introduces new tools and techniques to facilitate and improve note-taker learning and also simplifies note-taking development. Allowing powerful technology to be used in developing note-taking systems can guarantee an effective representation of traditional activities in the digital format. We can also support note-taker learning practices with special functions not included in traditional note taking, which encourages people to use the electronic note-taking system rather than take notes traditionally.

4.3.4 Developing Free Learning Dilemma Tools

Developers promote new technology in note-taking applications to replace traditional note taking. However, introducing the benefit of technology must be achieved without affecting the nature of note taking or the behaviour of note takers.

To solve technology learning dilemma in the note-taking applications, we proposed two methods for each type of existing problem. The first method was proposed to solve the negative effect of several note-taking tools by enabling the developer to test the effect of the selected tools on learning criteria and to evaluate learner feedback before integrating the tools in the proposed application. Thus, the decision of including each tool in the system will be based on the suitability of the tool and its impact on learning. Tools with a positive effect on learning are included, whereas those with negative effects are excluded. In addition, the effect of selected tools on learning must be measurable because technology solutions for note-taking tasks often change the nature of the task itself. Thus, note-taking systems must be evaluated to enable observation of the effect of the system on lecturers, presented materials, learners, and notes taken. The second method proposed to solve the conflict of obtaining technological benefits and achieving traditional note-taking tasks is to develop mediation tools that combine both advantages of electronic tools and traditional tasks. This is introduced in the next chapter. Thus, the decision for developing tools is dependent on the ability to develop mediation tools to achieve both advantages of traditional and electronic notes. This problem can be solved if both advantages of using technology and keeping traditional tasks without changing them are gained. If these two advantages cannot be combined, we recommended adapting the activities of the traditional notes because it is a more important factor in the learning process than the advantages of electronic notes.

4.4 Design decision

We introduce our solution to solve each individual problem separately as discussed in section 4.2. Two main solutions for the current problems are presented in Table 4.5. These two solutions are the theoretical framework, and the mediator techniques for note taking applications. The framework is used here to fill the requirements of standardization for digital note taking, to identify the solution components for the individual issues of current problems such as complexity, inefficiency, and integrability. The other solution of mediation approaches is designed here to settle the confliction of using technology in learning developments.

The framework establishes the necessary methods for identifying the process of developing a typical note taking application. Also, the mediator is a combination of methods and process applied to implement specific activities of note taking in special forms to adjust the traditional activities of note taking. Then the two solutions are integrated together to achieve the thesis objectives as illustrated in Table 4.5.

Table 4.5 Framework and Mediator Solutions for Current Issues of DNT.

Practical Solution	Actions	Frame work Components
Theoretical Framework for Digital Note	- Identify the learning role, and theory of NT. - Keep current practice unchanged and minimize user action as much possible. - Select tools based on learning functions.	Learning Layer
	- Identify the roles of interface design. - Constrain developers by time and cognitive factors during designing interface.	Interface Layer
	- Identify the role and responsibilities of current technology. - Set constraints for the device physical factors such as shape and size, with logical factors such as Platforms.	Technology Layer
	- Identify standardization development process. - Facilities Modular Engineering for developments. - Initialize Development Guidance. - Set specific criteria for evaluation tools	Deployment Layer
	- Facilitate note management and assimilation. - Control the dataflow of information.	Data service Layer
Mediation Techniques	- Adapt realistic Tasks of Traditional NT. - Use the powerful of technology to solve the confliction issues between learning and digital advantages.	Note Mediator

Based on our observations of note-taking problems and justifiable solution points, we designed a solution for our research problem with two main design decisions, framework and mediator approaches as described in the following sub-sections.

4.4.1 Framework for Note taking Application

The framework is proposed to identify the most critical implications of the note-taking process. Similar components of the note-taking elements were isolated in a single layer to represent them in a higher-level synthesis of these layers for the development of a note-taking system. In this research, we proposed a framework for note-taking systems as a preliminary solution to solve existing problems including complexity, inefficiency, and integratability issues. Although our findings have an extensive scope, we attempted to summarize major findings of these studies within the proposed framework. The framework is built as layers to separate the similar action of solutions, and to identify the role, constraints, and responsibilities of each layer.

The framework is designed to guide developer generate ideas for designing tools, to design tools with appropriate method, and to obtain user feedback for evaluating from different perspectives of learning targets and usability verification. Then, we can come up with an efficient and effective note-taking application. Therefore, we proposed the framework by carefully considering the process of merits each new note-taking tool. Framework architecture for note taking should be defined to manage the implementation of this point and control the flow during system development. Framework components, architecture, roles, and layers are described in more detail in the next chapter.

4.4.2 Mediation Techniques

Existing applications suffer from the technology learning dilemma (refer to section 4.2). Thus, current tools are insufficient to represent traditional tasks of note taking. People also react differently to note-taking applications when their current practices are not sufficiently supported. Even though several features, such as reorganizing, colours/styles, and annotation, are well supported in an electronic medium, they are not commonly used during traditional note taking. Hence, mediation introduced as a novel solution for the technology learning dilemma, and to adapt the realistic tasks into the digital format. Mediation tools work as a bridge connecting traditional and digital notes without affecting learning gain. Developing realistic note-taking applications without using special tools like mediator is complex. Furthermore, usability must be a major priority in developing interactive systems to support note-taking applications, in which mediation tools can keep the context of traditional note taking unchanged, thus making the action of taking notes more realistic in electronic forms.

Mediation tools are identified as the combination of physical and symbolic tools designed to form the human experience (Bernhard & Sanit, 2007). Limited research on education theories and psychological science discussed the role of mediation tools within the philosophy of technology, such as the technological effects of the existence of human activities and their relationship with the world as well as the technological advancements in producing, transforming, and incorporating human knowledge (Cole, 1996; Mitcham, 1994; Norman, 1993). Research on the socio-cultural theory of learning developed by Vygotsky and his co-workers reported that concepts of tool and mediation are key factors in enhancing the development of human psychological processes that offer more powerful and functional approaches (Cole, 2005; Kozulin, 1998; Kozulin, Gindis, Ageyev, & Miller, 2003; Vygotsky, 1987). Technology can offer a possible form of mediation that assists in shaping the character of human world relation (Verbeek, 2005). The problems reported about several educational applications of technology occur because theories of mediation and the role of instruments are neglected or not understood well (Ihde, 1991; Jay, 2005). Other research works tried to incorporate theories of mediation derived from the ideas of Vygotsky in developing a number of learning tools (Engeström, Miettinen, & Punamäki, 1999; Miettinen, 2001). Accordingly, as note taking is a thinking process related to capturing and transferring knowledge, and as note is considered as text that draws a relationship between knowledge, knowledge and thinking are considered as modes of world experience. Technology can place mediation tools within certain aspects in the foreground or background to simplify the interaction of human process during their thinking and capturing knowledge activities. Historical overview of current note-taking applications shows that mediation tools are never mentioned as essential to technological experiences that support user behaviour toward performing tasks. Hence, incorporating mediation tools into the development of computer-based educational systems is necessary to bridge the gap between user activities and their environments. Mediation tools offer the ability of keeping user activities unchanged during note taking where technology advantages are still available for supporting user's behaviours. Table 4.6 shows how the tasks of note taking diverse when mediation approaches are used. Developments of mediation tools are described in more details in Chapter 6.

Table 4.6 Examples of Note Taking Tasks with Mediators.

Tasks	**Current System**	**Mediator Approaches**
Selecting	Several steps to select item including choose the selection icons, move to desired area, press mouse and keep it down during selection.	Selection with mediator is similar to the traditional way. Just use the pen to select any items directly.
Highlighting	Required extra efforts similar to selection process in choosing the icon or commands, and moving to highlight desired area.	Highlighting is performed similar to the tradition way. Just use the pen of highlighting to highlight the desired area.
Searching	Current systems does not support searching functions.	User allowed searching for specific words in a free form mode.
Annotating	Annotation available with limited functionality.	Annotating available with full functions similar to TN methods.

4.5 Chapter Summary

In this chapter, we analysed the various problems that prevent note taking activities in digital media. We found that there are several issues involved that can be categorized into four main aspects: complexity, inefficiency, inerrability, and technology learning dilemma. Then, theoretical and practical solutions are proposed to resolve these issues. This chapter discusses briefly the research statement and our proposed solutions.

5.0 A FRAMEWORK FOR DIGITAL NOTE TAKING

The main objective for proposing the aforementioned framework as a solution is to guide developers for developing an efficient and effective application for digital notes (refer to Table 4.4 in section 4.4). The proposed framework was also mainly designed to facilitate and accelerate the conversion process from traditional notes to digital notes by achieving the following sub-objectives.

- To simplify the process of selecting tools that promote and motivate learning practices.
- To facilitate deployment and integration of digital note systems. To help accelerate the deployment of digital notes and solve major problems of current digital note systems.
- To identify a typical architecture for digital note systems and organize different components of functional and non-functional requirements.
- To identify necessary procedures for validating and evaluating the developed tools of digital note application.

Prior work on electronic note-taking applications and early designed tools confirmed the necessity of special requirements for developing note-taking systems that support learning hypotheses and satisfy user requirements and tasks when taking notes. We proposed our solution based on the literatures, as well as on the studies that addressed the current note-taking practices and the perspective of note takers on how note-taking systems support tasks and their attitude toward the importance of note-taking systems. We proposed this solution to help researchers enumerate potential elements that should be represented in designing note-taking applications that support digital media. Furthermore, previous studies provided us with bases for high-level components of note-taking systems, which allowed us to initiate the solution and identify its elements under a proper context structure. Then, we made the decision regarding current problems and how to adopt the framework to solve critical issues in electronic note-taking systems.

5.1. Digital Note Taking Framework

Although our investigated study are diverse and have an extensive scope, we attempted to achieve the main objectives of this thesis by summarizing our major findings in the previous chapters within a standard framework for digital notes. The framework was proposed to identify the most critical implications of the note-taking process and isolate each similar component of digital note areas, such as learning theories, data flow, and technology afforded in a single layer. Thus, each similar component of note taking is categorized under a single layer. Each layer included identical elements, properties, and users. Then, we represent higher-level synthesis of these layers to build the framework solution. Our design decision for the smart note-taking application is undertaken during the analysis of specific requirements of digital notes to assist in implementing the framework in actual applications. According to our review of note taking from the educational perspective and in the digital age, along with the results of the previous studies which evaluation of the current systems, we determined several number of scopes, constraints, and limitations requiring special consideration during development. These issues could be solved only if rules that control the development process of applications exist. Our research confirmed the finding of previous studies that a system for digitally representing notes should be developed. Then, the framework was designed to categorize the type of support that technology could offer to design a successful application for note taking based on layer components. We proposed the framework as layer to separate the similar components, and to make the interaction process between the layers more simple. The layer architectures are used to simplify and facilitate the communication process between the different components of the proposed framework. Recently, architecture domains as layers are common in representing the components that execute processes and offer service to the other layers. In each layer, the components, the processes, and the services identify the layer entity which decomposed into small unit to reduce the development process. The framework was designed to be fully explored with a multidimensional scope for note taking. It is characterized by component architecture with five essential layers: interface, technology service, learning and note-taking theories, deployment and integration, and data and information content layers. These layers are considered as the main kernel architecture of the proposed framework, as shown in Figure 5.1.

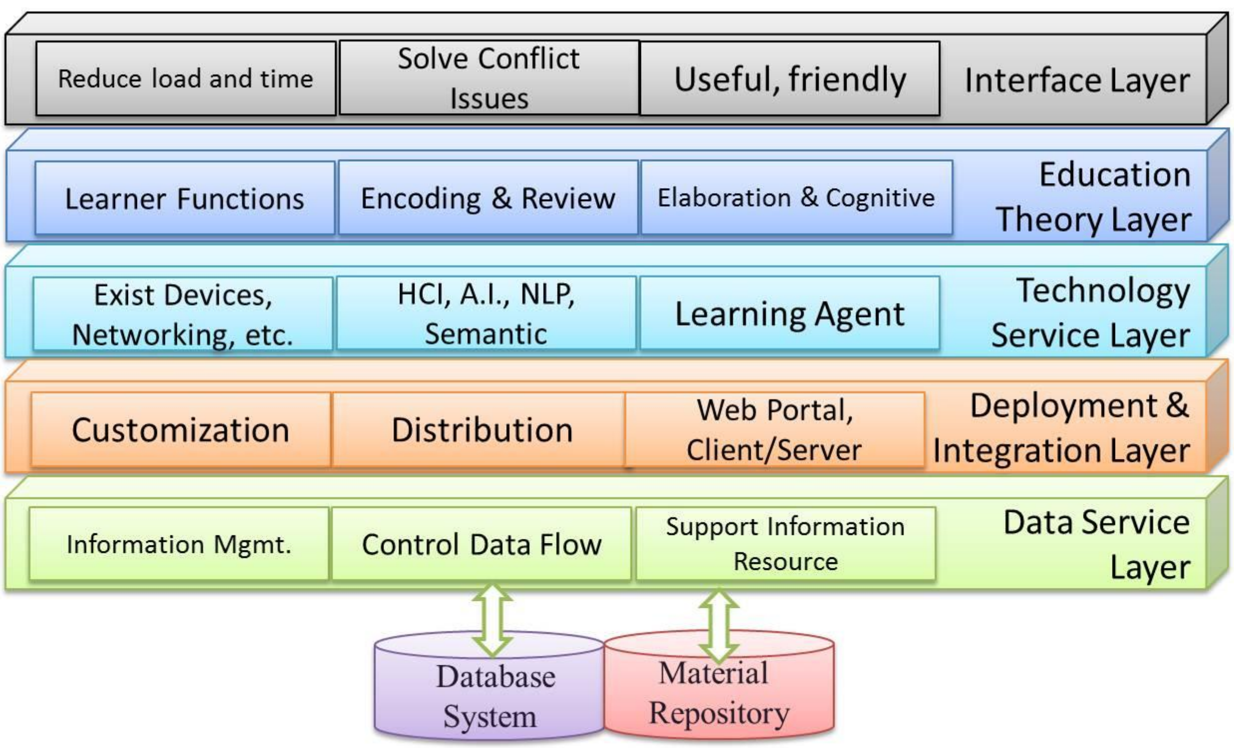


Figure 5.1 Framework Architecture for Digital Note.

The five layers were designed to help developers in constructing note-taking applications. In this chapter, we presented an overview of the responsibilities and components of each layer. Our aim for designing the framework was to minimize the amount of changes in traditional note-taking behaviour and allow transfer to occur easily between digital and traditional note taking. The framework layers involve the developer and researcher during the integration of traditional notes into digital tools. The proposed framework was designed to facilitate the implementation of pedagogical practices as well as learning and cognition theories, without affecting the functionality of traditional notes. In addition, student perspective was considered by enabling the framework to control note-taking constraints by sustaining attention, maintaining interest, providing motivation, minimizing distractions during lecture, and reducing additional cognitive load.

The proposed framework was designed to assist in selecting the proper tools to implement traditional tasks, ensure that the chosen tools support learning during the note-taking process, and satisfy user requirements with special consideration for the negative effect of tools on learning activity. The framework was also designed to provide a uniform platform for multiple note-taking tasks, allow both developers and note takers to spend less time and effort on creating and setting up note-taking tools that are similar across various note-taking applications, and focus more on the specific objectives of learning support by establishing appropriate rules for developing digital note systems. Based on the framework architecture, functional requirements are divided into small incremental units to build the framework layers. This process was repeated until the final framework architecture was created. The design approaches for the framework provided a better understanding about system criteria and effectively described the interaction between various system components and the communication approach between the layers. In addition, de-composing the framework into several layers supported the ability for decoupling independent components of note-taking functions. In the next sub-sections, we will describe in more detail in the proposed framework layers.

5.1.1. Interface Layer

The interface layer is the top layer of the framework that interacts directly with users. This layer provides a simple, easy-to-use, useful, and friendly interface to users. Developers and researchers are responsible for designing an appropriate interface for note-taking functions with specific requirements and constraints for digital notes. An inappropriate interface is considered as one of the most important issues that make most existing systems fail in representing note-taking tasks in the digital age (Bauer & Koedinger, 2008; Kim et al., 2009). Thus, an inappropriate interface design of a note-taking system leads specially to major learning problems, such as learning deficiency, tool conflict, and cognition overload, which are described previously.

By contrast, the importance of the interface caused us to isolate it as a single layer of framework component listed below.

- Special consideration for interface is required for transferring the note-taking task into digital media.
- Interface object should be designed with learning and cognitive theory constraints.
- User interface should be designed with a similar view as that of traditional note taking.
- Interface should reduce time of capturing, writing, and manipulating notes as well as overloading of working memory.

The interface layer is responsible for the smooth transition from traditional note taking to a digital interface without major changes that can disturb or confuse users. This layer is found between the note taker and the digital environment, describing how traditional tasks should be represented, how users act with digital tools, and how interaction between the system and the users occurs. Thus, the interface plays a major role in developing successful note-taking applications. Most actual note-taking tasks and activities require a special interface to mimic user behaviour and note functionality in the digital form, especially those designed to simulate cognition and learning practice (Anderson et al., 2007; Bauer & Koedinger, 2005a; Cope & Kalantzis, 2009; Lin et al., 2004).

In our proposed framework, the initial design for the interface was suggested based on previous assessment tools and functional requirements (refer to section 3.5), that prove its suitability and efficiency in performing certain tasks for digital note taking. Therefore, for each traditional note-taking task, various objects must be implemented to design their interface entities in the digital environment while considering note-taking learning constraints, such as cognition overload, visualization interference, usability, and manipulation of time to run the task. The boundary of what technology can afford to build a successful note-taking interface which can map the note-taking functionality of user behaviours and transfer user behaviour to similar interface tools, while keeping in mind learning practice requirements, should be explored to satisfy educational goals. The HCI field should be actively involved in designing the interface layer for further digital note applications, and extra focus should be given to provide designers with essential guidelines for developing usable computer learning tools. However, complexities on human information processing in understanding the relevant context of the interaction are the main challenges during the implementation of the system interface.

Furthermore, several devices that support digital note taking, ranging from electronic pens and paper tablets to handheld personal digital assistants to electronic pen computers designed to look and feel like a student notebook, are available. These devices have various interfaces for the same tool, for example annotation designed for PC should be different with the annotation interface designed for Tablet Pc Devices because of their physical properties, such as size, shape, view, features, and resolution. Thus, we recommended identifying transparency as an essential non-functional requirement for further refining the design of the interface of digital note tools. Transparency describes how much the user consciously perceives, understands, and interacts with the interface for tools that are conceptually separate from the note-taking tasks. Thus, the interface layer must be designed with both syntactic and semantic transparency roles to provide users with appropriate tools in completing note-taking tasks and with the ability to allow certain system tasks to be achieved easily or automatically. Syntactic transparency is proposed to relieve user tasks that are introduced by the system itself, such as explicitly saving a file, organizing the material in data context, and scrolling windows in a graphical user interface. Semantic transparency refers to the ability of the system to anticipate user intent and to perform their tasks, such as automatic sliding, faster response, as well as indexing and sharing information. In addition, based on the recall problem in augmenting real-world devices with capture technology for note-taking systems, the technology is embedded in everyday tasks to make the interface as transparent as possible. In this research, we focus more on proposing note-taking systems which not only use the interface tool to perform note-taking tasks, but also provide more natural and transparent interfaces for technology-enabled devices to achieve learning. However, a number of note-taking tasks, such as inferring user attention, promoting and motivating users to take notes, and simplifying ideas via visualization, cannot be derived as a function and cannot be implemented as a tool component or interface entity. Thus, we proposed a special solution for such functions, which would be described in the next chapters.

If the design of the digital note system has interface transparency, then users do not have to be trained and can become more familiar with using these tools. System developers are also focusing on designing system interfaces mainly to satisfy user requirements through a friendly, interactive environment. However, for note-taking applications, developers also need to consider other design factors, such as satisfying educational requirements. The interface layer should have a number of responsibilities and constraints to develop a useful note-taking application, introduce traditional note-taking tasks to a user level of electronic note taking, design note-taking tasks with as much transparency as possible, satisfy user requirements, minimize time of task achievement, reduce user cognition effects, and ensure ease of use. For the system design of this layer, developers can minimize inference and user cognitive load by developing component tools with an appropriate and friendly interface. Framework interface layer is identified the roles, constraints, and responsibilities for developing interface layout and actions of note taking tools as shown in Table 5.1.

Table 5.1 Constraints, Roles and Responsibilities of the Interface layer.

Constraints	Role and Responsibilities
- Reduce cognitive load. - Reduce time of task achievements. - Keep current practice unchanged as possible. - Mimic the note taking behaviour, and styles. - Reduce visualization interference. - Minimize usage actions	- Friendly interface, simple, easy to use, and useful. - Transferring the traditional view of note taking smoothly into digital form without major changes that disturb or confused users. - Syntactic and semantic transparency interface. - provide more natural and transparent interfaces of technology enabled devices for learning purposes

Constraints term describes the restriction and limitation features that developers should be aware during development processes, while the role and responsibilities identifies the target decision that developers are required to follow for achieving layer features.

5.1.2. Learning and Note Taking Theories Layer

Theories of cognition and learning, such as activity theory and social constructivism, can be considered as the essential principles for designing and implementing any learning system with available technologies to achieve learning gain. Theories of cognition and learning can provide greater insights into the means and resources of how the new technology can be used to improve learning processes. In addition, technology provides learners with unique functionality that increases learning ability and performance. A note-taking activity is mainly conducted as a learning task, and is used extensively to process learning materials for summarizing ideas and maintaining knowledge. Based on the literature, the process of note-taking has been comprehensively explored from the perspectives of psychology, pedagogy, and learning theories. Thus, research has summarized the two main functions of learning theories in the note-taking process as encoding and reviewing processes. Various activities are performed by the note-taker to achieve learning in both dimensions. Encoding or reviewing is a combination of several tasks that must be performed to improve the ability for learning, integrating, and capturing knowledge with new information (refer to section 2.2). Encoding function (the process) supports learning by affecting the nature of cognitive processing during reading or listening to presented materials. External storage (the product) constructs a repository of information for later review. In addition, education research has shown that focusing increases the encoding process because it increases student attention on the learning material (Benton et al., 1993). In other words, note-taking systems should be designed to encourage the learner to pay more attention to the presented material or to process it more deeply. Thus, tools that support focusing must be included in this layer to increase the focusing process in digital environments. Furthermore, research has shown that the elaboration process can promote learning when it is conducted as a generative activity that connects multiple knowledge components. When the elaboration process is an ability of the learner, it can actively relate a material to existing knowledge, which may involve generating links to prior knowledge, or even connecting distinct concepts within learning materials (Bauer & Koedinger, 2005b; Bauer & Koedinger, 2006; Marton & Tsui, 2004).

These two functions, focusing and elaborating, can be considered as other functional requirements that should be included in learning layers. Thus, this layer has constrained developers to deliver only tools that support learning functions or promote learning practices. We drew our conclusion to include education and learning theories of note-taking as one-layer component in the proposed framework because any developed tool for note-taking applications must be designed based on research theories about gains of learning and cognition. This layer is considered as the base kernel for technology-assisted learning systems because people require technology to support their learning activities. In addition, this layer communicates with both interface and technology layers. Furthermore, the note-taking education layer is designed to support pedagogical approaches and promote principles of constructivist theory, along with collaborative and active learning. In addition, we noticed that most existing note-taking systems are designed based on survey studies on analysis of user requirements without considering learning function requirements. Most developed tools are designed based on the traditional function of the note-taking process without considering the effect of learning theories on note-taking applications and how their new functions should be designed. In the proposed framework, we delivered the digital note taking features from learning function that can be supported by note taking, user requirement functions, along with the new facility function offered the advantages of the digital application.

Following investigated studies on the learning functions of note-taking applications, we determined that a number of tools can be designed to provide the note-taker with useful learning functions for digital notes such as: (1) aiding memory and recalling, (2) understanding the organization and structure of presented topics, (3) identifying important information from lectures, (4) maintaining learner attention, (5) collaborative note-taker behaviour, and (6) navigation, access, and direct feedback of note takers. However, most of these functions require comprehensive consideration before similar tools that imitate them in a single system application can be designed. In addition, not all these functions can be implemented directly; guidelines in designing digital notes during the development of these tools are provided.

The initial functions selected to design the learning and note-taking theories layer were encoding and recording processes, reviewing and organizing notes, student prospective for motivation and concentration, supporting different note-taking styles, and working memory enhancing tools. Table 5.2 provided developers with constrains, roles, and responsibilities of each layer. Furthermore, this layer was proposed in our framework to facilitate pedagogical practices such as activity theory and social constructivism, where this layer must be implemented without significantly changing inherent note-taking practices and existing classroom dynamics while carefully considering student perspective requirements.

By contrast, this layer is responsible for identifying critical learning functions needed by our proposed system based on the learning perspective. We proposed three types of activities to guide developers when designing proper education tools: nomination, designing, and evaluation processes. The nomination process aims to assist developers in selecting the proper tools based on note-taking theories. The designing process guides developers on the proper approach during tool development. Evaluation criteria of designed tools help developers determine whether the tools have achieved their learning target.

Table 5.2 Constraints, Roles and Responsibilities of Learning and note-taking layer.

Constraints	Role and Responsibilities
- Tools must support main note taking theories of learning including Encoding, Reviewing, Elaboration, and Focusing. - Must assist in aiding memory and recalling. - Maintaining learner attention. - Motivate user to be active learner. - Enforce learner to pay more attention to the presented material. - Neglect the tools that have negative impacts on learning process.	- Develop system functionality that increases user learning ability and performance. - Improve the ability of learning, integrating, and capturing knowledge. - Identify the critical learning function to deliver only the tools that support learning functions or promote learning practice. - Support student prospective for motivation, styles, behaviours, and concentrating. - Support pedagogical approaches and principles of constructivist theory along with collaborative and active learning.

In addition, the learning and note-taking theories layer describes the specific design of each tool, wherein the researcher suggests the learning tool that supports the educational purposes of note-taking functions, and the developer designs the tool following layer constraints. Finally, the tool is evaluated by target users to ensure its usability in the note-taking application.

5.1.3. Technology Service Layer

Technology is involved in everyday life and is extensively used to help people improve achieving their tasks and activities. Technology offers certain approaches to support note-taking in digital environments. However, technology has not adapted well to digital note-taking. In this research, we isolated technology as a single layer to provide developers with an opportunity to adapt available technology in developing the functional requirements of digital notes. This layer was proposed in our framework to serve both categories, including physical equipment and information technology tools. Physical devices are involved with hardware equipment that can be used to perform note-taking tasks, such as digital pen and paper, smartphones, notebook computers, and Tablet PCs. However, computer technology also involves advancements that facilitate implementation of traditional note-taking tasks such as image recognition, voice recognition, natural language processing, visual representation, handwriting reorganization, voice recognition, ontology and semantic rules, and intelligent learning agents. With our proposed technology layer, we attempted to combine several technologies that support computer-aided education, including the use of technology to adapt note-taking tasks into digital notes. In addition, during the design of a useful note-taking system, possessing a clear understanding of the planned pedagogical objectives is critical, as well as determining technology approaches to employ.

The technology service layer is the layer that assists in transferring note-taking functionality into the digital age using the best available approaches. Understanding the use of existing technology to create a feasible adoption application for note taking can be considered as a central objective for this research. The main objective of this research is to shift the note-taking process forward for more interactive note-taking applications by using existing technology. The technology layer is the service layer that selects appropriate technology tools for designing note-taking functions. It also identifies physical and application tools for electronic note systems. The technology layer was proposed in this research to process and manipulate the information stream, and to organize different requirements for note taking in a standard format.

People currently use various computing devices in their daily lives, including smartphones, tablets, and laptops. These devices can be used for note-taking if applications are developed efficiently. Physical equipment is also an important dimension that can be used to facilitate note-taking practices and tasks. In designing this layer, special consideration was given to the properties of available devices such as size, shape, and weight of the hardware used to carry out note-taking tasks. The device operating system, compatibility issues, and the platform language required to develop the right application were also considered. Physically, the note-taking process is primarily constrained by limited space, which must also be considered in our design. The physical factor can be used to improve available technology or even design new equipment for note-taking to replace traditional tasks. Available computing devices have different physical and logical variations, which led us to consider each device as separate models during development. For example, the note-taking application for laptops should be designed with a different interface from that of smartphones or other media with the same functionality in our proposed framework. In addition, the performance of computing devices such as network connectivity, power consumption, physical space, and device portability should be considered during design process for optimal adaptation. The technology service layer designs the appropriate tool interface and the layout of the note-taking application for different available devices. Furthermore, it responsible to innovate the future devices for replacing the traditional note-taking tasks.

In addition, we introduced powerful technology to achieve our objective of reducing the complexity that occurs while designing specific note-taking tools. Several fields in computer science are involved in developing traditional note-taking functions; technology can improve the note-taking process in digital environments without affecting learning behaviour and performance, while considering advantages in functionality of digital notes such as accessibility, searchability, legibility, index ability, and portability (refer to section 3.1).

The learner usually acquires knowledge and information from different resources in various forms, such as video, audio, e-books, slides, and ink. Each information stream requires certain technology for successful implementation. Different technology fields are involved in this layer to manipulate the aforementioned information resources. For example, a pattern recognition field can be used to implement handwriting tasks of note taking, whereas natural language processing can be used to analyse information, context, automatic correction for syntax errors, and other note-taking advantages, such as searching and indexing. Furthermore, network technology can be used to facilitate sharing and collaborative processes of note-taking tasks. Table 5.3 presents certain note-taking tasks with our proposed technology, which are appropriate for the development process.

For example, the note taker usually has a cognitive load because of the speed of the instructor and the material; if the voice of the instructor could be converted into text, then it would reduce stress on the learner. In addition, image processing should be used for annotation purposes; semantics and ontology should be used for enhancing background; natural language processing should be used for abbreviation, misspelling, and auto correction; and networking tools should be used for collaboration and sharing.

Table 5.3 Note-taking Tool with Technology Services

Note taking Tools	**Appropriate Technology Employed**
Handwriting	Pattern recognition
Auto correction, abbreviation, glossary, translation, extraction and summarization.	Natural language Processing
Augmented video and audio	Multimedia Authoring, Voice Recognition
Annotation, highlights, selecting	Image processing, NLP
Auto- Enhancing of knowledge	Ontology and Semantic
Visualization concepts	Human Computer Interaction, diagrammatic and graph representation,
Lecture & learner feedback	Intelligent learning agents
Sharing & Collaborative	Networking, Internet, webs
Manage, organize, and store information resource.	Database, repository, metadata

In Table 5.4, we list the most important constraints, roles, and responsibilities of the technology service layer.

Table 5.4 Constraints, Roles, and Responsibilities of the Technology Service Layer.

Constraints	Role and Responsibilities
- Physical properties such as size, shape, view, features, and resolution. - Adapt device platform, operating system, compatibility issues. - Adapt device for network connectivity, power consuming, physical space, and device portability. - Supporting computer aided education. - Keep functionality of digital notes edibility, search ability, legibility, index ability, and portability.	- Select the appropriate technology tools for designing note taking functions. - Identifying Hardware and software components for electronic note system. - Shift the note taking process forwards for more interactive note taking application. - Adapting the available technology to serve in developing digital note functional requirement. - Innovate future device of digital notes.

5.1.4. Information and Data Management Layer

The data management layer is included in the proposed framework to control the direction of information flow relative to the lecture, the presented material, and the note itself. Traditional note-taking is used to transfer information and knowledge from inside the classroom to outside. This process involves transferring information and knowledge from the lecturer, as well as the presented material, into the note takers. Students usually capture information during the lecture and review it later outside the classroom. Another possible flow of information may occur from outside the lecture, such as when students read the textbook prior to the lecture and use it as a reference during class, or when the lecturer delivers materials to the student prior to class and the student uses it for annotation. Furthermore, information can flow from student to student within a lecture. Several information resource materials and different flows of information occur during the note-taking process. Thus, we proposed this layer in our framework to organize, manage different information resources, and control variant flow of information content.

The information and data service layer is responsible for manifesting, organizing, manipulating, and storing different information resources of the learning material. This layer includes information architecture, metadata considerations, and information content. Furthermore, it provides the note taker with the ability to support information service capability (which is critical for supporting shared data), the ability to integrate similar information, the ability to define metadata shared across the framework layers, and the ability to secure and protect information. In addition, the information and data services layer provides developers of note-taking applications with extensive capabilities to support information services. It also provides a uniform method of representing, accessing, maintaining, managing, analysing, and integrating data and content across heterogeneous information sources.

The information stream of note-taking activity generally has different resources with various stream types. Thus, we proposed this layer to control the traffic of information flow, organize different types of data, control the sharing of information and secure data, and manage the process of certain events, such as polls, quizzes, and interactive flow. In addition, this layer is used to assist developers with important capabilities such as the ability to expose data as services; to add, remove, and manipulate data entries in the other service components of the framework; to handle data representation from various data sources in a unified data format; to record event logs of users; to transform and map data of different formats; to manage hierarchy and relationship among data entities; and to validate and enforce data quality rules.

The information service layer should be designed to integrate and manage the information stream of material resources. The functionality of this layer should be able to provide the user with the following specific functions:

- The ability to extract relevant information from resources, transform the information into appropriate integrated forms, and load the information into the target repository.
- The ability to perform access capabilities, such as the ability to retrieve, query, and search for information.
- The ability to perform data standardization and understanding, including semantic reconciliation and ontology knowledge representation.
- The ability to manage and maintain metadata in a common metadata repository. The ability to capture, aggregate, and manage unstructured contents in a variety of formats such as images, text documents, Web pages, spread sheets, presentations, graphics, e-mails, videos, and other multimedia.
- The ability to author, configure, manage, customize, and extend metadata repository. The ability to handle access privileges of various data users and control access on individual data items.
- The ability to receive the requests from the interface layer and obtain events from the integration layer. The ability to review and assess inbound service activities in the form of event information and determine responses or issue alerts/notifications.
- The ability to define vocabulary, glossary, terms, and data entities. The ability to define a common information model as leveraged, such as entity relationships, logical data model for information repositories, and message model for service definition and specification.

This layer is proposed in our framework to achieve a solution for reducing complexity during organization and for managing flow of data and information. We summarized the most important roles, constraints, and responsibilities of this layer.

Table 5.5 Constraints, Role and Responsibilities of the Information and Data Layer.

Constraints	Role and Responsibilities
- Identify information architecture, metadata considerations, and information contents. - support information services capability - support a shared data, - ability to integrate similar information - Define proper metadata that shared across the framework layers. - Ability to secure and protect information. - Uniform the data for representing, accessing, maintaining, managing, analysing, and integrating data and content across heterogeneous information sources. - Handle access privileges of various data users, and control the access on individual data items.	- Control the direction of information flow relative to lecture, presented material, etc. - Identify the strategy to store different material resource. - Manage transferring of data, information, and knowledge. - Manifesting, organize, manipulate, and store the different information resources of the learning material - Ability to extract relevant information from resources and transform the information into the appropriate integrated form. - Load the information into the target repository. - Ability to perform access capabilities for retrieve, query, index, and search process. - Ability to define vocabulary, glossary, terms, data entities, entity relationships, and information repositories.

5.1.5. Integration and Deployment Layer

A set of guidelines for the development of student-oriented technologies and their successful adoption in note taking have been described in the previous layers. These guidelines include various technological capabilities that support the note-taker with tools similar to those for traditional note taking. This layer was proposed to guide the developer during the development of note-taking functions for designing appropriate tools and solving conflicts occurring among certain note-taking functions. Moreover, this layer provides guidelines for verifying and evaluating the developed note-taking functions before it is integrated for use in the proposed note-taking application. Lastly, the integration and deployment layer tests the proposed tools and integration in an appropriate form of note-taking application. The proposed framework architecture was designed based on user requirement specifications and educational target function requirements. System functional requirements were then categorized into layers with small incremental units to support developer module engineering, thus leading to greater ease and flexibility during validation. In the deployment layer, we proposed an algorithm to guide developers from the early stage of system analysis until the final system was achieved Figure 5.2.

In the deployment layer, we proposed three level architectures for developing the proposed framework: layer, client-server, and repository models. This layer is responsible for guiding developers on the appropriate approach used to develop a digital note system based on the proposed framework. The deployment and integration layer was designed with the incremental model to guide the developer during selection, design, and evaluation of different note-taking functions.

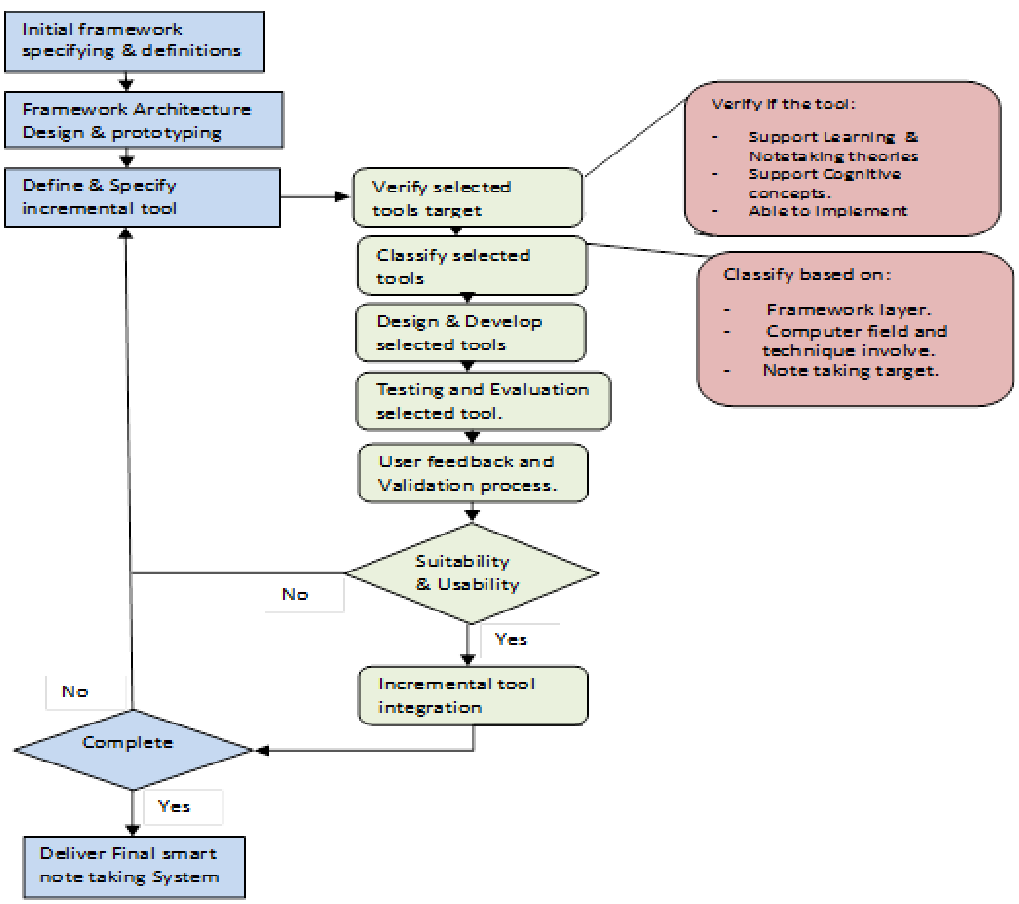


Figure 5.2 Flowchart Guidance of Incremental Model for Development Process

The main task of this layer is to constrain developers during the development process for each note-taking tool used in developing the final digital note system. Developing the entire system of note-taking, as well as all tools for the proposed framework, in a single study is difficult owing to limitations in scope, time, and effort. Each proposed tool for the note-taking system must be analysed, designed, and evaluated prior to integration in the system. Thus, each tool must be designed and developed separately; only after the evolution process can it be integrated into the proposed system. In this study, we focused on roles and constraints in developing successful applications for note-taking by analysing and designing framework architectures to describe the functionality of each layer component, identify note-taking functional and non-functional system requirements, and develop the initial note-taking system prototype. In Table 5.6, we summarized the roles, constraints, and responsibilities of this layer.

Table 5.6 Constraints, Role and responsibilities of the deployment & integration layer.

Constraints	Role and Responsibilities
- Constrains by other framework layer (interface, learning theories, technology, and data layers) - Constrains developers to use development guide approaches. - Follow the step of designing tools and systems. - Use increment model for delivered digital note applications.	- Develop proper interface tools. - Develop proper tools for supporting note taking learning. - Improve implementation for the available tools of note processing. - Develop proper tools for solving learning dilemma. - Validate and evaluate properly developed tools

5.2. Framework Evaluation criteria

Difficulties occur in the evaluation criteria for the efficiency of designed tools because the developer is required to test learning outcome and student performance for the proposed system. In this framework, we suggest evaluation criteria based on the previous assessment studies to guide developers in suitable approaches for evaluating note-taking tools. These criteria are listed in the following sub-sections.

5.2.1. Note Quality

Note quality is a good indicator of the ability of tools to support users with appropriate functions to capture and record notes. The appearance of digital notes is generally improved over traditional notes, because digital note applications contain rich tools for processing textures and graphical elements with easily editable properties. Developers can use the quality of notes in evaluating overall system performance and learning achievement, where several studies found a positive correlation between quality of notes and learning (Fisher & Harris, 1973). Quality of notes is an important factor that leads users to take notes using digital media if the functionality of the system assists them in producing organized, recognizable, and consistent notes.

5.2.2. Note Contents

Notes usually contain text, shapes, and graphical information. Note contents are represented by the captured information which indicates whether the user found it useful for the encoding and reviewing processes. Researchers can collect user digital notes during lectures and compare it with the objective of the lecturer to evaluate the influence of the system in the learning process. Note contents can be used to evaluate the usability of the system and the ability of the system to reduce load cognition. Fewer notes indicate that the system interface is inappropriate or presents usage difficulties. However, note contents are also affected by individual factors, such as age and gender, which were discussed in Chapter 2.

In addition, researchers can use wordiness to evaluate overall system transparency, friendly interface, and system usability. Wordiness is a numerical calculation for the total number of recorded words in a note divided by the total number of recorded ideas. Wordiness can be indicated by the time spent rehearsing the recorded idea. The researcher can use it to evaluate the efficiency of tools in reducing time of note capturing and recording, as well as system efficiency for reducing cognitive load. Early studies for evaluating note-taking efficiency in lectures found a significant positive relationship between the wordiness of notes and recalling learning function (Fowler & Barker, 1974). However, wordiness remains unclear for reviewing processes or reading materials; little work has addressed this issue. Thus, wordiness can also be included to evaluate the tool interface used for capturing and recording notes.

5.2.3. User Feedback

Researchers primarily consider user feedback for evaluating system usability, efficiency, and performance. In our framework, gathering user feedback was considered as necessary for evaluating digital note systems and tools. Developers are required to perform evaluation experiments to collect user feedback on the developed tools. Developers must design an experiment for participants to use their tools, and then collect user feedback via interviews and meetings. In this study, this approach is compulsory for evaluating overall system functions, including usability, efficiency, and performance. Involving users in evaluating digital note systems is essential to measure whether system functions satisfy user function, whether the interface is appropriate and useful, whether the tool optimizes the time required to perform note-taking tasks, and to ensure that tools do not disturb or confuse users. We recommended that developers should encourage users to obtain their feedback by designing specific survey and/or interview experiments for evaluating each system component of a digital note application.

5.2.4. Assigned Assessment and Exams

Much research in note-taking has designed experiments to evaluate system influence on student achievement and learning outcome by using assessment methods such as quizzes, tests, and exams. This approach is considered as the best available means for evaluating system efficiency in supporting learning criteria and increasing student performance (Bauer & Koedinger, 2008; Dieterle & Dede, 2006; Ward & Tatsukawa, 2003). Improving student learning performance using digital note applications is one of the main objectives of this research. These assessment methods vary between short-term assessment and long-term assessment. Short-term assessments are performed in short periods such as one lecture or one week of class. Long-term assessments are performed over long periods such as one semester or one year. In both assessment methods, students used the developed system to perform note-taking tasks, and then, tests, exams, or quizzes were given to measure their learning outcomes. This method is identical to evaluating system effects on learning and cognitive theories. In addition, we recommended the inclusion of a log event for digital note applications to record user activities. This log should be used to compare student achievement results with their actual activities. This measure is a good indicator of system efficiency for learning.

5.2.5. System Functionality

Evaluation of system functionality is a critical evaluation approach, conducted by the developer to verify that the system works correctly for achieving the proposed tasks. The developer must use this approach to ensure that the system achieves user functional requirements. By using this approach, the developer ensures that no learning conflict occurs among system functions and that the system gains the advantages of digital note applications. This method of evaluation is popular among system developers.

5.3. Roles and Responsibilities of the Framework

In this study, we proposed a framework solution with a five-kernel layer to address our problems. Our framework was proposed to produce a prototype of the final version of a smart note-taking application. The proposed framework performs several functionalities of note taking. The following is a list of the overall framework responsibilities.

- To improve learning accessibility by making digital note taking easier for students, and by mimicking traditional note taking.
- To ensure that developed tools are appropriate to be used in the note-taking system.
- To simplify and accelerate the development process of the final system of digital notes, and to improve the progress of movement into digital notes.
- To control the quality of developing note-taking tools and systems.
- To build tools that assist users in taking notes with the advantages of both traditional and digital notes.
- To support users in producing notes that is high in quality and quantity, and to assist them in organizing their information materials efficiently.
- To improve user ability to capture, manipulate, and access different materials via the proposed system, such as classroom presentations, e-books, and wikis.
- To help users capture specific knowledge more easily and increase their attention and absorption of topics.

- To develop a friendly interface with an interaction model that provides users with non-functional requirements such as usability, efficiency, and portability by facilitating the development of a simple, easy-to-use, useful, and ease to learning for note-taking.
- To develop smart tools that increase user focus in controlling their own learning experience, and to motivate users to take notes in digital media, as well as to develop expert tools for helping them become active learners in the classroom.
- To help researchers and experts select note-taking learning functions that need to be developed.
- To guide researchers and designers in developing note-taking functions, and in clarifying user and educational requirements for note-taking applications.

5.4. A set of Design Principles and Guidance

In this research, we proposed a framework to be used as a preliminary solution to guide developers and researchers during the nomination process, designing, evaluation, and integrated tasks of note-taking tools. The framework is mainly designed to guide researchers on the steps and approaches required to be used in designing a digital learning note-taking system. This proposed framework is responsible for guiding developers from the early stage of selected tools until the evaluation and gathering of feedback from users. From the previous research, successful development of digital note applications involves numerous difficulties because an extensive range of user skills and capabilities need to be engaged (refer to section 3.5). In addition, note takers perform multitasking activities with limited time and cognition. Thus, we introduced the following important guidelines for the successful adoption of the digital note system.

- Nominating appropriate tools to implement one or more traditional activities and tasks based on one of the three criteria: (1) user requirements for achieving note-taking tasks and activities; (2) note-taking functions that support learning and cognition theories approved by education researchers; and (3) tools that improve the behaviour and styles of the note taker or facilitate management and organization of digital notes.

- Selecting the appropriate transparency interface for nominated tools which should be simple and accessible as much as possible; and ensuring that the interface satisfies time and cognition of user constraints.
- Attempting to sustain the current practice of traditional processes as much as possible to maintain environmental constraints without significant changes in natural user behaviour, and to make the tools familiar and easy to learn.
- Drawing the appropriate user layout for the system with the limitation of target devices such as physical shape, size, platform, and resolution. The framework is designed to generalize the process of note-taking on a collection of history-preserving devices such as laptops, tablets, and smartphones.
- Choosing the proper technology field in terms of hardware, programming language, and technology to design the nominated tools. The increment model will be used to develop each tool separately, and then, the tools will be integrated within a single system in the final phases of system deployment.
- Using the powerful technology to implement tools that resisting the conversion process into the digital format, or the tools that have conflicting issues between traditional and digital notes.
- Ignoring or minimizing tools that disturb users or force them to change their behaviour, and reducing tools that induce learning diffusion, such as the copy-paste function or the auto-summarize tool.

- Offering useful tools that promote learning, thus encouraging users to transit toward digital notes. These tools can be designed to support a wide variety of user note styles and their context behaviour.
- Identifying strategies used to control data context and interaction flow for resource materials of selected tools as well as for system interaction.
- Following the deployment algorithms proposed in the deployment and integration layer to ensure the optimal path for developing digital note systems.
- Obtaining user feedback to validate and evaluate nominated tools based on the framework evaluation criteria model. The developed tool is integrated into the proposed system; overall system usability and performance are evaluated.

5.5. Chapter Summary

In this chapter, we addressed necessary factors in our framework that should be used to guide developers during their creation of digital note systems. We identified essential components of framework layers and described the roles, constraints, and responsibilities of each layer. We then described the framework evaluation criteria used to evaluate the developed tools and the overall system. We proposed a set of guidelines to assist developers during the design process. Finally, we summarized overall framework responsibilities for developing the proper tools in creating efficient and usable note-taking systems.

6.0 SMARTINK DEVELOPMENT

The lack of adequate software support for note taking is due to several issues, including implementation difficulties associated with developing note taking applications, complexity of performing traditional tasks using digital tools, inappropriate design of interface layout, and insufficient studies that could help evaluate the developed tools along with its impact on learning. Previously, we found that among non-functional requirements, both usability and support of learning objectives are given the highest priority in the development of interactive digital note applications. Previous analysis on the existing note-taking applications, their functionalities, and their impacts on the learning process provided us with a picture of the main issues that prevent the development of a useful note-taking application that satisfies user requirements and improves learning. In addition, we comprehensively discussed the digital learning dilemma of note taking applications that can be observed among several educational technologies.

In this research, we proposed two individual solutions. A framework is developed as a primary solution for simplifying the development process and for assisting the developers by providing them with a set of guidelines designed for note-taking applications. A meditation tools are introduced as an instantiation of the framework l solution for the digital applications, to deal with difficulties in implementation, for adapting the activities of traditional tasks to solve the digital learning dilemma.

In this study, a prototype framework is used to build a smart note taking application that increases the effectiveness and efficiency of the note-taking process during learning. A framework architecture, layers, roles, and responsibilities described in previous chapter are used in this chapter to design the prototype for digital notes. Given the limitation of the research scope, the proposed SmartInk prototype with mediated tools is designed as a limited solution for the current problems in developing a note-taking system. In fact, a comprehensive note-taking application is beyond our research and requires more than just one research, as several studies are needed to design, evaluate, and integrate the proper tools for typical note taking application. A great deal of time and effort is thus necessary. Therefore, the final SmartInk system cannot be delivered as a single delivery product in one study. As discussed previously, several architectural frameworks, models, and functional requirements must be implemented during the development and integration of the proposed note-taking system.

Despite such limitations, the SmartInk reveals the key technical problems associated with the note-taking software implementation. The proposed SmartInk system is used as a case study to validate the proposed solution, to ensure the successful integration of the critical requirements, and to test the robustness of the system for future experimental evaluations.

6.1. SmartInk Prototype

Prior to the design and implementation of the SmartInk application, we conducted a study on some similar system requirements as described in Chapter 3. The current chapter presents the digital note-taking functions of the SmartInk system to attain the sub-objectives of the fourth objective of this research. The sub-objectives are:

a) To design a diverse system of components for digital note taking.

b) To combine the advantages of traditional and digital note-taking features.

c) To describe the implementation process of digital note applications.

d) To address the steps required to solve current issues and problems in digital notes.

e) To liken the digital note-taking process to the traditional approach for an easy transition from traditional notes to digital notes.

In addition, SmartInk is designed to resolve three main concerns: the problems reported for previous note-taking tools and applications, satisfying the learning objectives of users, and fulfilling the requirements of note takers in terms of activities and behaviours.

6.1.1. Analysis of System Functional Requirements

Based on the note-taking theories mentioned in Section 2.3, we classified note-taker activities into its constituent parts of encoding and reviewing, with additional features derived from existing tools to support learning.

Furthermore, note-taker activities in digital media are classified into four main replicas to determine the computing technologies that support such activities (refer to section 3.4). The SmartInk requirements are derived from the four replicas of an abstract note-taking task (i.e., note creation, note management, note content access, and collaborative notes), as shown in Table 6.1, wherein each model represents one abstract task of digital note taking.

Table 6.1 Replicas of Note taking Essential Tasks

Abstract Tasks	**Process Description**
Capture	Writing note from source material or lecture. This process included the listening, concentrating, understanding, extracting idea, and summarizing it before writing it. This model used to create and record notes.
Access	Using created notes, type of access, reviewing process.
Manipulation	Editing and organizing notes. It included drawing object, visualizing idea, and many more tasks.
Collaboration	Sharing the notes between peoples. It included information assimilation, cooperation, and group effort.

The functional and non-functional requirements of the SmartInk system are identified based on the previous tasks, in which each abstract task is used to provide the designer with a specific description of the system components (refer to Table 3.2). The analysis of note-taker activities on current note-taking system reveals the importance of including those tasks, either in partial or in full forms. Prior to the early design and implementation of a similar note-taking system, we extract several essential tools that are proven usable and efficient for our system through testing and evaluation. The SmartInk prototype is designed with these compulsory functions at the early stage of system development. In the next section, we classify the requirements of the SmartInk system into five modules and discuss the inclusion of these components in the development of SmartInk functions.

I. Capture Module

We propose a system function for capturing process in SmartInk based on our proposed framework principle of keeping pedagogy practice unchanged, thus allowing users to use our system for note taking just as they would on natural paper (refer to section 3.4). Pen-based technology is proposed as the primary device for entering notes during capture mode, whereas other devices, such as keyboard and mouse, are allowed to be optionally used during review mode. Writing notes on a computing device using handwriting inputs is advantageous because of ease of use. Users can start using the system without disrupting their thinking process. The proposed functions for entering notes in SmartInk are presented in Table 6.2.

Table 6.2 SmartInk user functions for the Capture Module

Functional requirements	**Specification Context Description**	**Capture Mode**	**Review Mode**
Input Notes			
Write notes	Using handwriting for writing notes	+	*
Handwrite drawing	Drawing diagrams and shapes	+	+
Type text notes	Using keyboard to insert text notes	-	+
Draw diagrams by mouse	Using mouse to draw diagram	-	*
Annotation notes	Using handwriting to annotate material	+	*

Note: "+" means supports full functionality, "-" means does not support functionality, and "*" means supports full functionality but with constrains.

As shown in the table, several functions related to entering notes are selected for implementation in the SmartInk system. During capture mode, users may use the handwriting approach for writing notes. However, such approach is limited during review mode if users accessed the system without devices that utilize pen-based technology. On the contrary, during capture mode, users are prohibited from using the keyboard for entering text notes. Nevertheless, they have the option to select their preferred input device during review mode. This setup is followed to maintain the traditional practice of note taking for users, to reduce the required time in switching between input devices, and to preserve note familiarity. The capture mode of SmartInk involves several functions to enhance encoding activities, such as handwriting, annotating, tagging, and indexing.

II. Access Module

The SmartInk system is proposed to serve as a data repository for notes and learning materials, which can be accessed remotely (refer to section 3.3). We incorporate several functions to allow users to display saved notes using control navigation, thereby making user access simple and easy. In addition, SmartInk offers several system functions for browsing and navigating saved notes during review mode, with several constraints during capture mode, such as multipage views that reduce user attention as presented in Table 6.3.

Table 6.3 SmartInk User Functions for the Access Module.

Functional requirements	Specification Context Description	Capture Mode	Review Mode
Access Notes	Each user has account and data storage space.		
User Login	It's a function of user authentication	+	+
Access, Brows , and Navigate Notes	Functions that support user to open specific folder, subject, and page notes to brows note contents. Also, Its functions that facilitate note browsing through multi page views, and display the suitable view for user requests.	+ *	+ +
Access resource material	It's the ability to access related resource information materials.	*	+

+ means full functionality support, while * symbols means support with constrains.

III. Manipulation Module

The SmartInk prototype is design to support the users by providing several functions for manipulating and organizing notes (refer to section 3.3). Adding, deleting, selecting, and highlighting note elements are examples of note manipulation functions, whereas creating, naming, as well as removing subjects and pages are examples of note organization functions. We select specific functions for manipulating and organizing notes to be included on SmartInk as listed in Table 6.4. Please note that the '-'indicates that some functions excluded from capture mode because its overload user time and cognition.

Table 6.4 SmartInk functions for Manipulate Module.

Functional requirements	**Specification Context Description**	**Capt.**	**Rev.**
Manipulating Functions			
Add annotation, Comments	Add notes, comments, and annotations note elements.	+	+
Select note elements	Select specific note elements.	+	+
Delete note elements	Delete word, sentences, and diagrams.	+	+
Move note elements	Change the location of word, sentences, and diagrams	+	+
Highlight note element	Highlight specific note elements	+	+
Search notes	Search for specific note elements by contents or creation date.	+	+
Index, and linking notes	Index or linking notes with other items.	*	+
Query	Query about specific information	*	+
Import lecture slide	Include lecture materials for annotating and write notes	+	+
Organizing Functions			
Create new subject	Create subject folder to categorize note.	+	+
Remove subject	remove subjects with its all note pages	+	+
Name subjects & pages	Assign specific names for each created subject and page notes	+	+
Create new note page	Create new page notes	+	+
Save note page	Save notes	+	+
Delete note page	Delete notes	+	+
Process multiple page	Browse and open multi note pages	*	+
Separate and move pages	Move and organize multipage subject.	-	*
Backup & Restore Data	Export & import all user work space for export and import purposes	-	*

IV. Collaboration Module

In our system design, we provide support for collaborative function during review mode to reduce user disruption during capture mode. Correspondingly, users are allowed to access the shared material from different locations, in which users are constrained by specific permissions and roles for accessing and collaborating with others. We select three types of information collaboration between users as shown in Table 6.5.

Table 6.5 SmartInk Collaborating Module Functions.

Functional requirements	Specification Context Description	Capture Mode	Review Mode
Collaborate Notes			
Share notes	Share user note with specific people, or sharing other materials.	-	+
Ask questions	Post questions with user group.	-	+
Answer questions	Answer the asked question.	-	+

Note: "+" means supports full functionality, "-" means does not support functionality.

V. SmartInk Internal System Functions Module

Several functions are developed to assist in the integration of the SmartInk prototype. These functions are designed to improve and facilitate user interaction with the system. Their functions and contexts are listed in Table 6.6. All SmartInk functions are presented in Appendix A.

Table 6.6 SmartInk System Function.

System Functions	Specification Context Description	Cap.	Rev.
User authentication	User name and password required for login	+	+
Update Information	Modify user profile	-	+
Response System notification	Read, response, for system notification such as error, warning messages	-	+
Change interface components	Add, remove specific interface components	-	+
Change note styles	Change page view style	+	+
Record users activities	Recording user activities for creating, accessing, reviewing, modifying notes	+	+
Detect access location	Ability to detect user location from intranet or internet.	+	+
track user note style	Ability to monitor the preferred note styles	+	+

	that user used mostly		
Interaction with user	Communicate with users by identifying errors, warning, and message notification control	*	+
Interact with Data Repository	Automatic communicate with the data repository in creation, modifying, and deleting contains	+	+
Create and organize User Groups	Classify user groups based on subjects, and class.	-	+
Attach date and time about create, access, and modify notes	Assign date and time for users activities.	+	+

Note: "+" means supports full functionality, "-" means does not support functionality, and "*" means supports full functionality but with constrains.

6.1.2. SmartInk System Architecture

SmartInk is proposed as a prototype solution for developing digital note applications. We use the proposed framework comprising kernel layers to initiate the system prototype for producing the final draft system of digital notes. Here, we describe the SmartInk architecture that is built by associating the proposed framework layers into the components of the system classes. SmartInk architecture is described here to simplify the implementation process and to provide interested developers with the necessary information. To satisfy the role, constraints, and objectives of the proposed framework, we use three different architecture for designing the SmartInk system, namely, client–server, data and repository, and evolutionary. The three architectures are described below.

I. Client-Server Architecture

The client–server specifies the higher level of system abstraction for addressing the interaction process between the user interface and the data repository layer in the server side. We identify the client side here as the note-taker devices, whereas the server side represents the data service machine that contains the learning material, user notes, and lecture slides. This architecture is proposed to simplify the syntax and semantic specification for each request as well as the response between the user and the data layer, as described in the proposed frameworks. The users are requested to perform tasks via interface layer functions. The SmartInk system then responds to achieve the task or operation through interaction with other layers, such as the data repository layer. Hence, the data service layer designed to store all necessary learning materials gives users specific privilege to access, manipulate, organize, store, and calibrate notes. Moreover, the client–server is proposed here to manage the information flow between the user and the data repository; it allows the user to save, search, query, and retrieve specific information from the shared server of the data repository. The client side of the SmartInk system is designed to assist users in taking notes during class hours and in reviewing those notes outside the classroom. In addition, the client side represents user access to the SmartInk system using available technology devices.

In accordance with the proposed framework, we classify the learning layers of note taking into two individual parts, namely encoding and reviewing, based on an education theory regarding note taking. These parts have considerable differences in terms of tasks, components, and functionality. Even encoding and reviewing models that represent note-taking tasks have many differences in their roles, constrains, and responsibilities, as mentioned previously. Thus, SmartInk is designed with two client interfaces for supporting note taking, namely, inside the classroom (capture mode) and outside the classroom (review mode). The capturing interface mode is proposed to allow the user to take notes inside the classroom using pen-based technology on a tablet device, whereas the reviewing interface mode is proposed to facilitate the process of accessing notes from any other location.

This distinction is made to increase the user flexibility of SmartInk such that it works well with different client models and to implement the traditional method of note taking without changing current user practice. Furthermore, this decision is made to satisfy the roles indicated in the framework by maintaining user attention and focusing on the lecturer as well as by reducing user dispersion and cognitive overload during class hours. The SmartInk system includes another interface for the review mode that allows users to retrieve notes without constrains and with full functions for note-taking activities. This distinction can be considered as the most difficult and interesting technical challenge in the development of the SmartInk prototype system.

Accordingly, both proposed client modes are designed with great diversity in terms of their components and functionality and with a few differences in their communication methods with the server side. In addition, the client–server model of SmartInk is designed to support parallel interaction with data repository for multiple users simultaneously. The SmartInk system architecture is shown in Figure 6.1, in which the data repository and its supported tools are implemented in the server side, whereas the client mode is implemented in the client machine with its component tools.

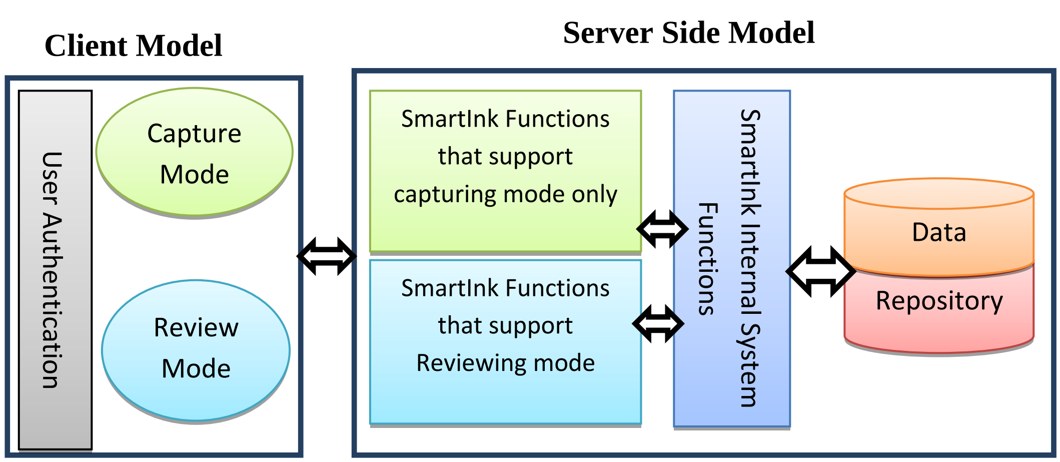


Figure 6.1 SmartInk Client-Server Architecture

II. Data Repository Architecture

As revealed in our analysis of the SmartInk prototype system, a large amount of data needs to be represented, including user information scheme, user notes, lecturer's material, and electronic resource material with its various formatting. Thus, in the data repository introduced for the implementation of the SmartInk prototype, information is stored in a central data repository to allow users to access, control, and maintain their own data schema. This feature facilitates the process of passing data explicitly and exchanging data between other system components. The data repository architecture is basically designed to store and organize different types of information during note taking. The proposed system is developed mainly to create and store user notes; however, some information, such as data entities, user information, documents, forms, queries, and transactions, must be included in the system data layer. Therefore, we design SmartInk to handle all of these metadata objects that are created and used frequently by system users. These metadata contents vary widely in terms of a few properties; nevertheless, they have several common properties. For example, they tend to have similar hierarchical structures, they are modified regularly during the normal course of a system's lifetime to derive many versions, and they have some relations when connecting between documents. We include generic tools in the SmartInk prototype to process these metadata that are considered highly important issues. This inclusion ensures the consistency of our proposed system over time.

The data repository model is constructed with two main constituents, namely, the database structure and the metadata objects as shown in Figure 6.2. The database structure is designed to store user information, user authentication roles, and user activity events, whereas the metadata are designed to represent the properties and attributes of notes, form layout, and user note documents in XML schema.

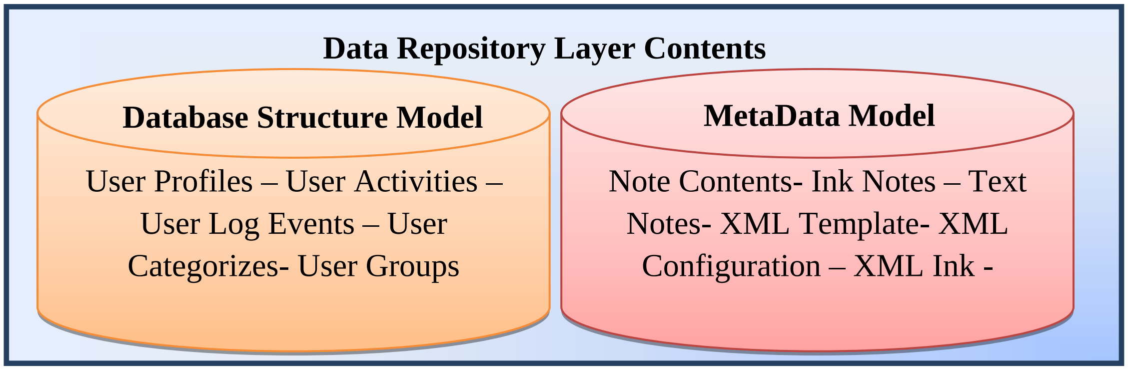


Figure 6.2 SmartInk Data Repository Architecture

In addition, the data repository architecture is designed to describe the tool and process used for creating, managing, and storing the different document formats. Another objective for the design is to address the data structure and data entity for the metadata repository of the SmartInk prototype as listed in Table 6.7. Furthermore, the data structure of the repository is designed to manage the space storage and to assign the appropriate roles and permissions to system users.

Table 6.7 Data structures, Data entities, and Metadata of Data Repository.

Data Kind	Description
Notes	The created notes can be text, image, diagram, audio, and video
Form layout	Screen interface, coordinates, orderings, and customization options
Lecture material	It's the data about presented material, accessibility, and ability to include it in note taking process.
User information	It's about user name, authentication methods, passwords, permission, and prevailing.
User Activities	It's a data about user event recorded in the system such as user who created and accessed to notes, and time of accessing, sharing notes, and user activities for modifying documents.
System message for index query, search, notification, and transaction.	It's about system Errors, warnings and other user messages, types of queries, and attributes which can be queried, and parameters, entities involved, records locked, and user processing.
Document type, index, linking	It's about categorization of the document types and generation of the index and linking with other resource material.

Microsoft SQL Server 2008 is used to implement the XML schema for data repository because it contains a number of classes and tools that can be easily integrated with the SmartInk prototype. In the data repository model, which involves a semantic approach for the embedded language data, powerful tools can be designed to represent, manipulate, and display the different data types of note structures. The sample template for the embedded XML used to describe note document structures for creating XML schema is presented in Figure 6.3.

```
<?xml version="1.0"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema">
<xs:element name="note">
  <xs:complexType>
      <xs:element title=" topic" type="xs:string"/>
      <xs:element date="Created Date" type="xs:date"/>
<xs:sequence>
      <xs:element name="body" type="xs:string"/>
      <xs:element text=" words" type="xs:string"/>
      <xs:element graph="diagram" type="xs:image"/>
</xs:sequence>
  </xs:complexType>
</xs:element>
</xs:schema>
```

Figure 6.3 Example of Data Repository XML Schema for SmartInk Document

Microsoft SQL metadata service is an object-oriented repository technology used to store, manage, and integrate the SQL metadata components. MS SQL is used to design the SmartInk system because it contains enhanced features; for instance, it supports a wide variety of standards, such as COM-based interface and XML encoding, supports user-defined metadata for the creation of metadata-based applications through the OIM, provides a repository engine that stores, consolidates, and retrieves metadata in repository databases, and supports various repository API, which can be used to expose repository engine functions and information model definitions through COM interfaces.

III. Evolutionary Architecture

According to the design guidelines of the proposed framework, the evolutionary architecture is selected for implementing the SmartInk prototype system because of numerous reasons. For example, this architecture is easier to use in developing rapid applications. It provides us with the ability to develop a system based on an incremental product release, allows the frequent delivery of the system to users, and is able to support the dynamic plane process for system evaluation and modification. In addition, the evolutionary architecture simplifies the contribution of other developers to the integration of other functions on the SmartInk system. To assist in the release of the final application, an initial outline of the specifications with high-level functional requirements, as described in system requirements, is used for developing the evolutionary model. The evolutionary architecture is constructed such that it can add new functions and features easily into the final system, as shown in Figure 6.4.

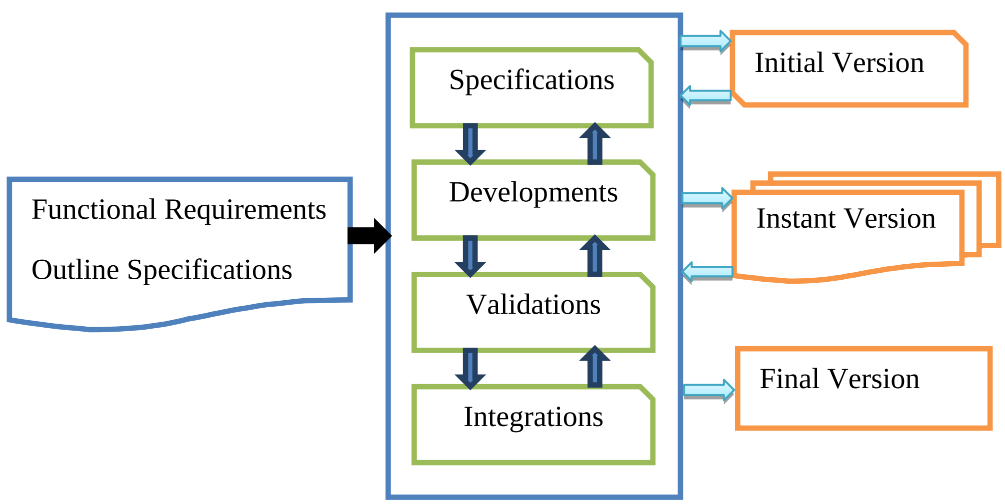


Figure 6.4 Evolutionary Architecture of SmartInk System.

6.1.3. SmartInk Designing and Implementation

As mentioned previously in the thesis objectives, the main goals of SmartInk are to make digital notes exist, to combine the advantages of digital and traditional notes, to introduce the technology of note-based learning, and to quickly transfer traditional note taking into digital forms. To accomplish these goals, we follow a set of guidelines for the framework as discussed in section 5.5.

According to the design guidelines of the proposed framework and to the key design objectives for SmartInk discussed previously, the SmartInk prototype is implemented using Microsoft C#.Net and Microsoft SQL Server 2008. On the one hand, C# is an object-oriented language that includes several built-in classes that satisfy our evolutionary model for developing an application with less time and effort. It is a good choice to build an independent platform that is compatible with several operating systems, Tablet devices, and web technologies. On the other hand, the Microsoft SQL server provides several facilities to represent the client–server model. It facilitates the creation of data repository schemes and includes XML classes to the interaction with our data repository. Both tools are considered powerful in building a dynamic application that allows users to modify their interface and select their preferred functions.

During the implementation phase, several classes are developed for building an efficient note-taking system guided by the framework design guidelines and the SmartInk key objectives. For example, *NoteDocument*, *NotePage*, *NoteElement*, *NoteTransformer*, *NoteViewer, NoteUser*, *XMLNote*, and *NoteAgent* are implemented for the development of the SmartInk prototype system. These classes are provided in Table 6.8 with their descriptions.

Table 6.8 SmartInk Class Names and Description.

Class Name	Class Descriptions
NoteDocument	- The main class or the super class of SmartInk. - Store user information. - Categorize user note with multi pages by subject or topic. - Responsible for adding and removing topics and pages, naming pages, rendering pages, saving and organizing notes. - Track current pages in each document.
NotePage	- Subclass of NoteDocument which used to define the stored information in each page. - Manage page elements, such as text, handwritten, and diagrams. - Responsible for adding and removing note elements, keeping information on page properties (e.g., dimensions, margins, and default page view). - Store related information on page attributes, such as unique identifier, created dates, dates of access and modification, title, users, and sharing attributes.
NoteElement	- Subclass of NotePage which is used to identify the note elements in each page. - Store note element types and properties, such as the location and dimension of each note element. - Record user activities on note element, such as active, selected, highlighted, and element formats. - Process the note elements as individual chunks, whereby each word, sentence, and diagram is identified as one element.
NoteTransformer	- Subclass of NotePage which is used to track the user input and convert the handwritten text into normal text. - Responsible for categorizing note elements into text and diagrammatic components. - Responsible for storing ink notes in the data repository - Transfer the Converted ink notes into associated page text, diagrammatic shapes into an attached image. - Responsible for improving handwriting recognition tools. - Process the system and user dictionaries to select the best matching words by autocorrecting and detecting misspelled words. - Allow user to identify the abbreviated words, keywords, and indexed words. - Update the stored note during activities such as editing, modifying, and deleting note elements.
NoteViewer	- Subclass of NoteDocument which is used to manage interface. - Allow users to select the note entering options, that is, either by using an empty sheet or by importing the slide lecture for annotation. - Contain system menu and functions of interface layout, such as colour, page grid, highlight tools, query and search.

	- Responsible for interacting with the user via messages, notification, and dialog.
NoteUser	- Subclass of NoteDocument which is used to create and manage users and groups. - Identify their roles, permissions, and storage space. - Identify the shared roles for note pages between users and groups. - Records various user activities on the system repository and manages the parallel user sessions.
XMLNote	- Subclass of NoteTransformer which is used to create the XML schema from the converted page text of NoteTransformer. - Convert page text into .XSD file (XLS schema) with suitable format, including XSL-LNK, X-Path, and XQuery. - Convert the XSD file into the appropriate SQL script using the XSLT template. - Create and modify the database repository schema. - Store and the database repository schema automatically. - Responsible for creating, accessing, and manipulating the metadata repository.
NoteAgent	- Subclass of NoteDocument which is introduced to perform special intelligent tasks that assist in improving system functionality and performance. - Responsible for introducing the mediation tools. - Assist in gathering and linking related information of user notes. - Allow developers to develop intelligent learning agents further for better learning achievements, such as linking the information repository using the semantic and ontology approach.

The hierarchical relationships among the designed classes are shown in Figure 6.5.

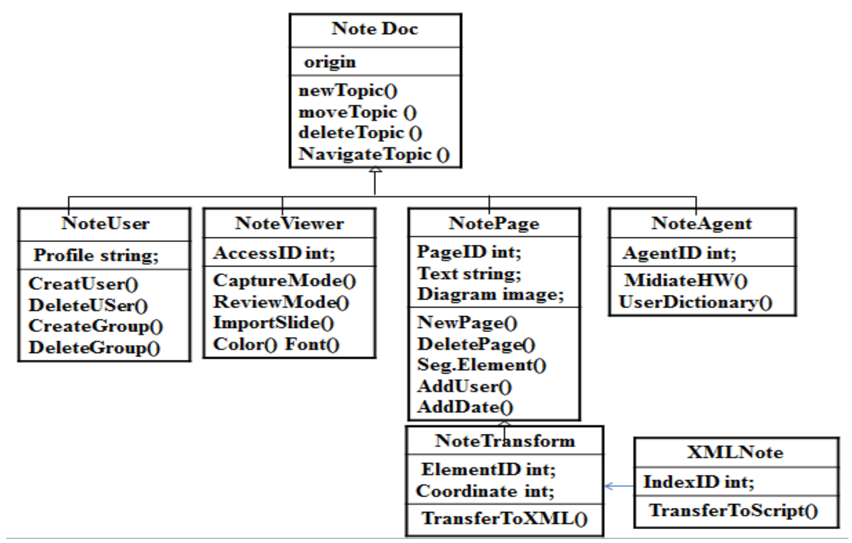


Figure 6.5. SmartInk Classes Hierarchy Relations.

The Language Integrated Query (LINQ) tools are used for the SmartInk implementation. LINQ is equipped with general query capabilities, wherein a single declarative query is provided for any kind of data source, including relational data and XML data. This tool is implemented to update the data repository schema when the users modify their notes. In doing so, the processing time is reduced and the resource efficiency during searching and querying is improved. ADO.Net is used to integrate the LINQ tools in our system for the provision of a high level of data abstraction for XML data and query operation. The primary purpose of using LINQ in the SmartInk prototype is to unify and simplify the delegation among XML tools, such as XQuery, XPath, and XSLT template.

6.1.4. SmartInk Interface

One of the important framework guidelines is keeping the traditional note-taking process unchanged as much possible in designing the transparent interface of the system. Thus, we derive the SmartInk prototype interface from traditional tools to offer the familiarity of the traditional approach, which people still widely demand. This offering will make users more confident and comfortable in taking notes. Similarly, the interface is designed based on the recommendation of many studies to use a pen as a reliable input device and a tablet PC as the paper surface without the crowded elements of a menu or toolbar to allow users to perform actions as quickly as possible (Berque, 2006; Larson, 2009). As introduced earlier in this chapter, two mode views (i.e., the encoding and reviewing models) are designed for client user interface based on the learning functionality of note taking.

These two views are designed with similar interface layouts but with varying embedded functions. Note takers are constrained to perform specific tasks only inside the classroom, and a special interface is necessary to minimize the time and cognitive loads of the users. While note takers are outside the classroom, only a few constraints exist, and an interface with rich tools is needed to perform several tasks, such as reviewing, manipulating, collaborating, and elaborating notes.

The SmartInk prototype system is designed to call specific interface views by detecting user location and accessing requests automatically for displaying the suitable mode view based on user request, either locally via the intranet or remotely via the internet. To achieve the note-taking tasks, the SmartInk prototype is designed to interact with users using specific functions, as shown in the diagram presented in Figure 6.6.

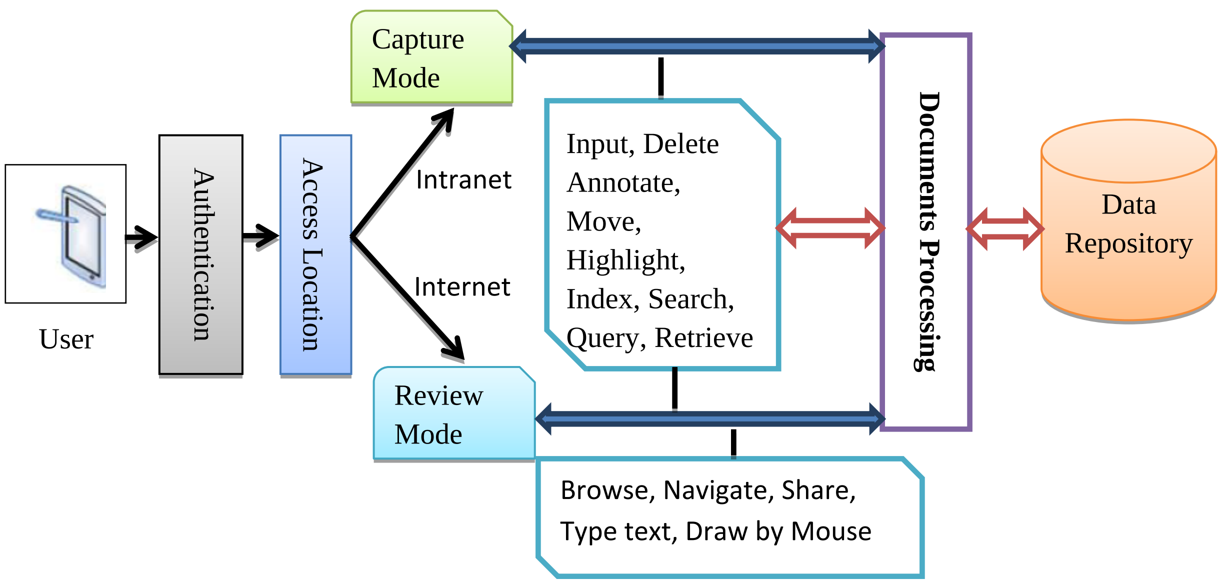


Figure 6.6 SmartInk User Interaction Diagram.

6.1.4.1. Capture Interface Mode

Universities, institutes, and learning organizations are responsible for supporting a learner by providing facilities, equipment, and materials necessary for the learning process. Thus, we assume that the aforementioned institutions offer Tablet devices connected with the internal server to facilitate the note-taking process during capture mode. Universities in the US and the UK have started utilizing Tablet PCs, iPads, and other devices in their classrooms for lectures. The design for the final SmartInk application is a hardware device similar to a Tablet or an iPad that is fabricated for each learner site. The design includes a specific touch screen surface analogous to normal paper and a digital pen for digital note taking. The proposed device aims to facilitate the digital note-taking process by integrating the SmartInk proposed system using technology-based learning. Moreover, this device is designed to enable students to connect with organization networks.

Our SmartInk prototype system is integrated in a Tablet PC device with pen-based technology to achieve our thesis objectives. The capture mode interface of SmartInk for note taking inside the classroom is designed similar to normal paper, as shown in Figure 6.7.

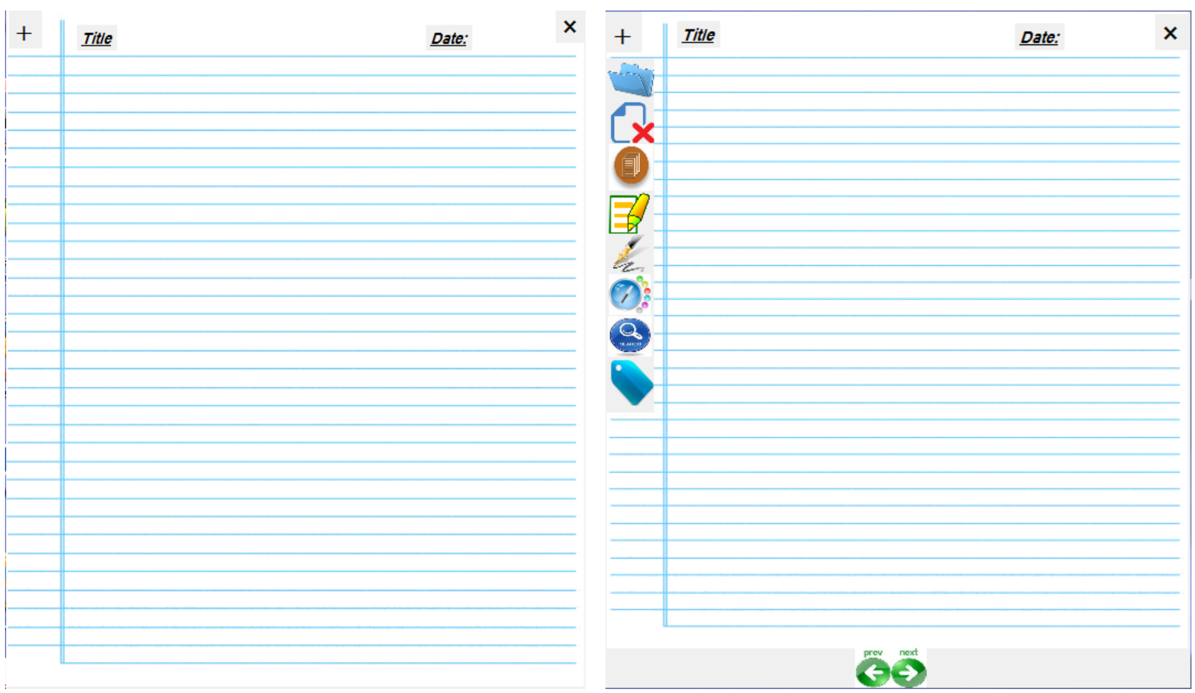


Figure 6.7 Capture Interface Mode of SmartInk.

The interface is displayed when users locally access the SmartInk system from the campus intranet. In this interface, the pen-based input is only the primary input device for creating and annotating notes during classroom lectures. In addition, the capturing interface is designed with specific functions to support traditional approaches to note taking, such as highlighting, drawing, annotating, tagging, as well as changing pen colour and pen tip size. Specifically, the SmartInk prototype is designed based on the suitability of taking notes in the classroom using a tablet PC with pen-based input that has a smoother end than passive devices; the prototype can also track information, such as the pressure and angle of the pen-based input device. The SmartInk interface is designed to reduce the overload functionality of the existing system onto a single input device, which is useful for note taking activities that involve the sole use of pen strokes without any kind of commands included in other systems. For instance, pen-based input is used to write notes, draw diagrams, select and move note elements, highlight notes, edit note elements, and execute system commands.

With the auto hide panel of the capture mode, as shown in Figure 6.7, users can perform default actions related to traditional activities for digital note taking. Using a pen with a tablet device gives users a sense of consistency, considerably reducing their activities compared with existing applications that limit the functionality of the pen, mouse, keyboard to drawing, selecting and positioning, and entering text, respectively (refer to section 3.3). Furthermore, the pen has the advantage of mobility compared with the mouse, which requires additional space and effort to be utilized well. Using this pen-based technique enables users to perform activities more efficiently and with less action. The inefficiency issues avoided here include those that occur when users perform several steps before the actual writing of notes such as selecting a text icon, moving the cursor to a desired area, and clicking the mouse button.

6.1.4.2. Reviewing Interface Mode

The review mode interface of SmartInk is designed to support the user with enhancement tools that allow access to the system from different places using numerous technology devices including laptops, smartphones, and so on. In the review mode, the user can perform several note-taking tasks, such as accessing, reviewing, manipulating, sharing, and organizing notes as well as indexing, linking, typing text, adding resource material, and performing search and query operations. This interface is designed using web technology approaches that support note access anytime and anywhere via the internet using any technological device. In this mode, most users are not under time and cognitive pressure. Therefore, constraints related to user time efficiency and cognitive load are not an issue. Considering this scenario, we allow the operation of other system functionalities to enhance the user learning achievements during the review phase of note taking. This interface is mainly designed to satisfy the necessary requirements of system accessibility and availability for accessing, reviewing, and sharing notes as shown in Figure 6.8.

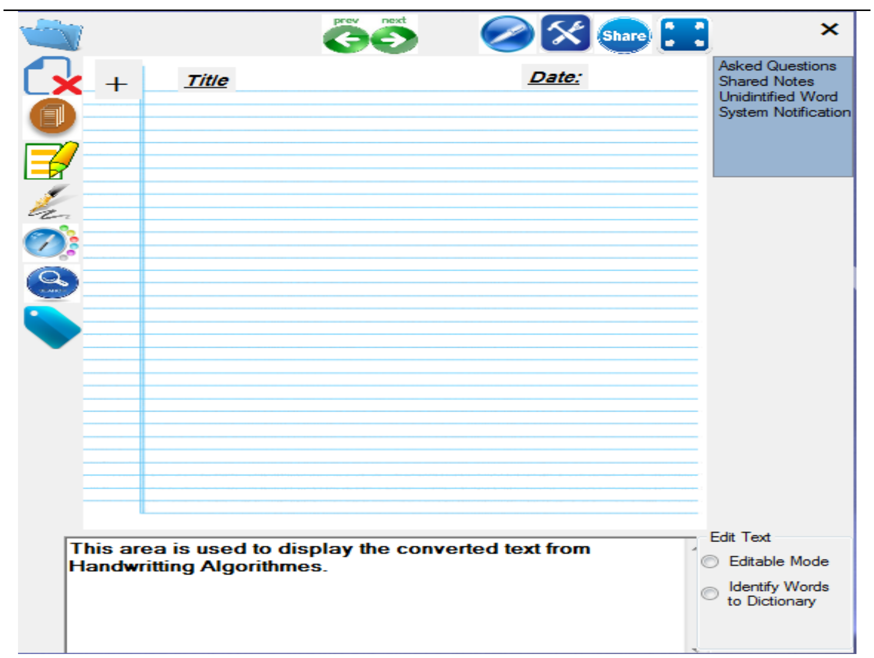


Figure 6.8 Review Interface Mode of SmartInk.

By contrast, interface layout views are implemented as images with a hidden grid of rows and columns that the system uses for tracking, entering, selecting, and annotating notes. In addition, the layout view, similar to a traditional page, includes visible horizontal lines with a small hidden menu that appears only when users move the pen to the left corner edge of the note document. More details about the interface components and context functions are provided in the Appendix B.

The interface layout is implemented such that it interacts with the dynamic modification model, allowing users to change the user interface, including page styles and menu position, and to add or remove specific tools based on their methods of interaction with the system. The dynamic modification model is built in the NoteAgent class with a smart agent that allows the system to detect usual user behaviours, styles, and activities. Subsequently, the system tries to automatically adapt the user's interface view. For instance, the smart agent constantly tracks the user's habitual note-taking styles to dynamically change the interface layout following the user's preferred note styles. Our prototype is named SmartInk because it includes specific intelligent agents embedded in the implemented classes to facilitate the design of mediation tools described in detail later in this chapter. The dynamic adaption model provides users with the possibility of manually changing positions, components, and views of their own interface layout based on their current note-taking practices.

6.2. Note Mediator

As evidenced by current computer tools for note taking, technology has made several note-taking functions both easier and more complicated (refer to section 4.4). The main goals in developing mediation tools are to make the note-taking process more useful and usable by adding new features gleaned from the digital format. As discussed earlier in section 4.2, current application tools suffer from several learning deficiencies, whereas other tools have conflicted issues related to the learning advantages of digital note-taking. Other note-taking tasks remain non-transferable to electronic forms because of implementation difficulties.

Therefore, the current work is a pioneer, particularly because our research proposes to design a novel solution in the form of mediation tool concepts that can be used to solve the digital learning dilemma in note-taking applications as well as to adapt the note-taking tasks. Furthermore, the meditation tools proposed here aim at changing the context of existing system actions. Note mediators offer a new vision in developing appropriate tools to mimic the traditional note-taking tasks.

The main objectives for proposing mediation tools as solutions to digital note-taking are as follows:

- To solve the digital learning dilemma by designing tools that keep the learning advantages gained from traditional note taking and by incorporating such advantages with those of digital note taking
- To introduce the power of technology by mimicking the context of traditional notes and to improve the learning functionality gained by users
- To make the note-taking process in technological devices more realistic and to simplify the transfer of note-taking tasks into digital forms.

The note mediator concepts in our research are proposed to design specific tools for filling the gaps between user tasks and note-taking system functions. Thus, users can still perform their realistic tasks and gain technology advantages at the same time. In this research, we focus more on developing mediation tools that facilitate changes between traditional and electronic notes to maximize the best advantages rather than to completely emulate each traditional task found within the digital-note applications. Below, we discuss several mediation tools for realistic note-taking tasks as primarily solutions to the learning dilemma issues that exist in the current note-taking systems.

6.2.1 SmartInk Mediator

Research on the area of note taking remains inconclusive with regard to the appropriate primary input device (either keyboard, mouse, or pen) for creating notes as previously discussed in section 4.2 and 4.3. The conflict in selecting the main device for note creation leads to the delay in the transfer process of notes into digital forms, thus causing most developed applications to fail in digitally representing note-taking activities. Accordingly, this problem has led to the existence of the digital learning dilemma as described previously in section 4.2. This problem is also one of the main challenges encountered in this research. This problem is considered as one of the critical issues in the note-taking process because it centres on resolving the main functions of entering notes into digital devices.

By contrast, our research objectives are mainly focused on designing technology-based learning applications. We resolve these issues by making design decisions that highly prioritize learning roles and constrains without neglecting the other advantages of digital notes. We took into consideration the existing conflicts of functionality, constraints, and advantages in developing appropriate tools for resolving these current issues. Emphasizing mediation tools in the area of education has provided us with helpful ideas on the nature of tools that can solve the current problems. This new solution is designed to combine the simplicity and flexibility of traditional note taking with the benefits of digital note representation. Special tools for the SmartInk prototype are designed to achieve the advantages of digital notes with consideration of the note-taking learning prospective.

6.2.1.1 Design SmartInk Mediator

We incorporate an intelligent mediator based on XML technology in our system to allow users to create notes using their own handwriting through the pen-based technology.

Simultaneously, background processes are ran to convert notes into digital form. We developed mediator diagram, and specific mediator algorithms as presented in Figure 6.9, and Figure 6.10 respectively to implement our mediation techniques. Note mediator is developed here as combination of methods, process, and functions. The mediator acts in transferring user notes into specific representation using XML schema to facilitate the digital representation of electronic notes. In this section, we describe the development of the mediation approach for our proposed system.

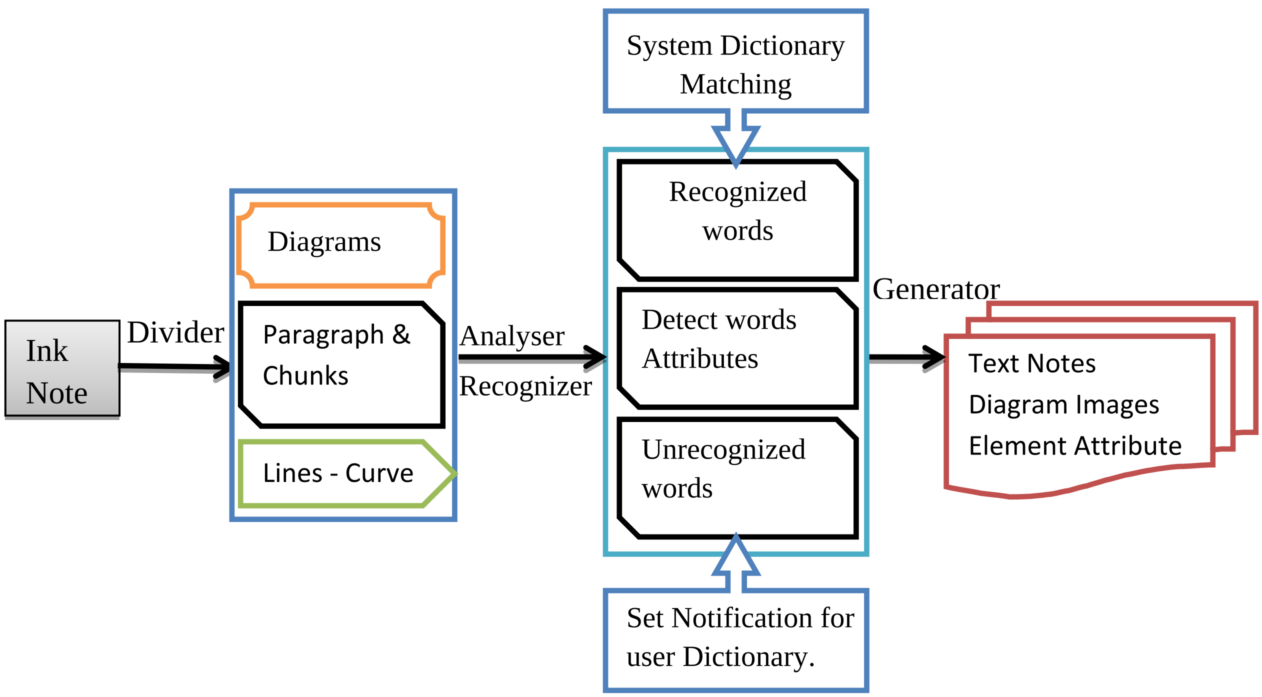


Figure 6.9 Note Mediator Diagram of SmartInk Prototype

The mediator is a process of collecting user handwriting and drawing during input notes and generates the electronic version of user notes. To achieve this function note mediator algorithm is presented in Figure 6.10. Real-time tracking routine is designed in the NoteAgent class to perform the process of pen location observation for handwriting process recognition. The tracking model runs in real-time mode to track the pen stroke movements and to record the note elements as well as its coordinates for the handwriting recognition routine. In addition, mediator is designed not only to recognize handwriting ink but also to classify ink elements, record the coordinates of each word, store element attributes, find the best matched words for chunks, and to notify users on unrecognized words to be later identified using their own dictionaries.

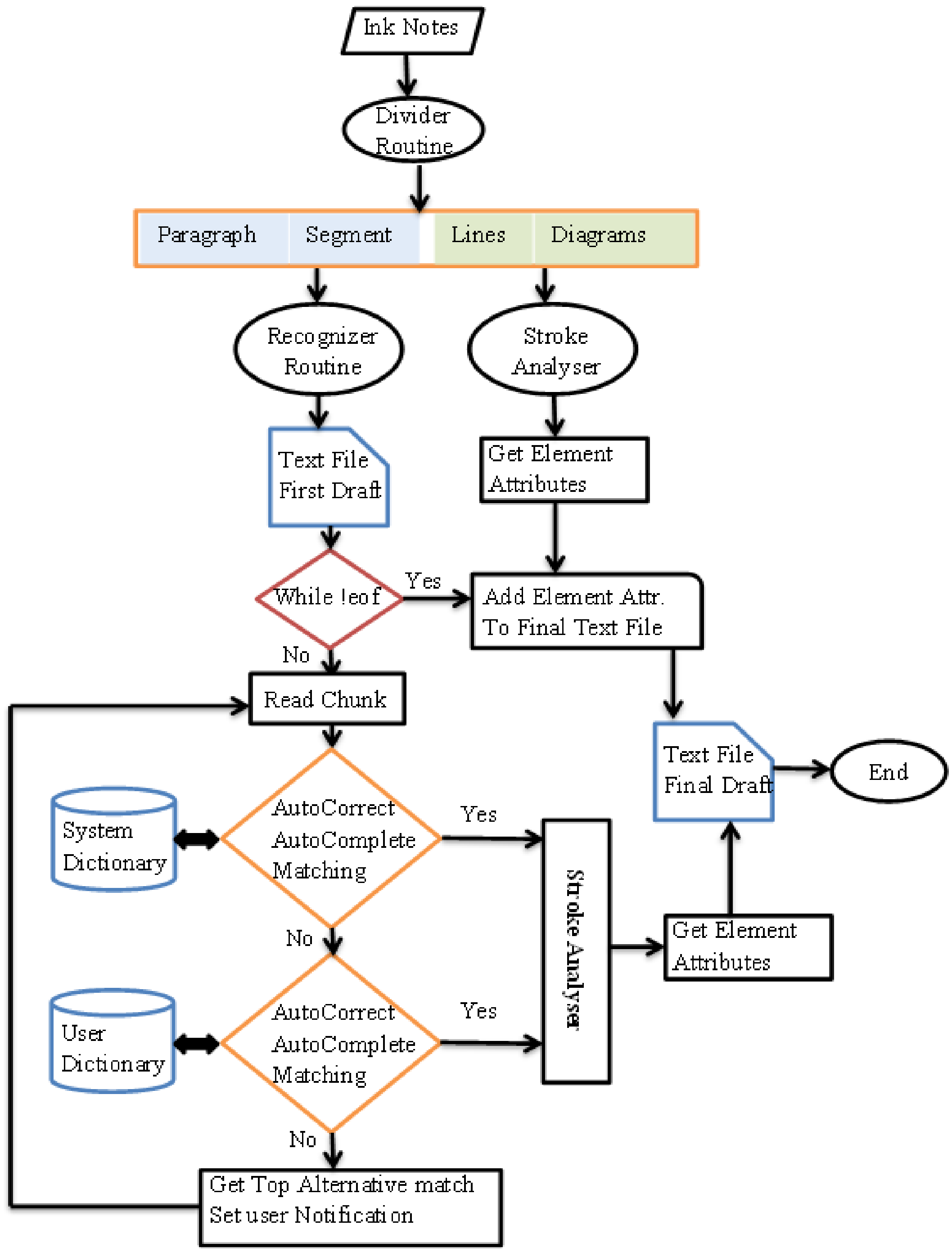


Figure 6.10 Mediator Algorithm for SmartInk Prototype

API functions of the Table PC developed by Microsoft used to collect ink objects from the digitizer, manage the collected ink strokes, recognize ink elements, and convert the elements into other data types such as text.

The InkCollector object is implemented to capture ink input from the system interface with efficient event sink to render this input in real time. An ink object is used as the fundamental data type to manage, manipulate, and store input elements of the InkCollector object by tracking pen strokes. Each pen stroke comprises a set of captured data in a single pen-down, pen-move, and pen-up sequence. Each stroke sends packets of data at every document point, such as coordinates and pen pressure. Then, ink strokes are stored in the associated ink object used as inputs for the recognition module.

We also utilize the InkOverlay object to integrate the drawing, selecting, and editing tools. For instance, InkOverlay enables users to detect note elements within a traced region that returns the strokes collection based on user selection. In addition, the DrawingAttributes object is implemented to include basic drawing properties such as colour, width, and pen tip as well as advanced parameters such as smoothing and transparency variables to improve ink readability. The ink rendering module is implemented to map ink space coordinates into pixel coordinates.

Furthermore, Divider objects are implemented in our system to analyse note elements, classify them into a group of data strokes, and save the results of layout analysis in DivisionResults objects. The implementation of the divider objects is aimed mainly at improving the recognition process of note elements by dividing the elements into several segments and separating the text and drawing note elements. The DivisionResult object is returned in the division unit collection of all structural element types, such as segment, line, paragraph, and drawing note elements as shown in Figure 6.11.

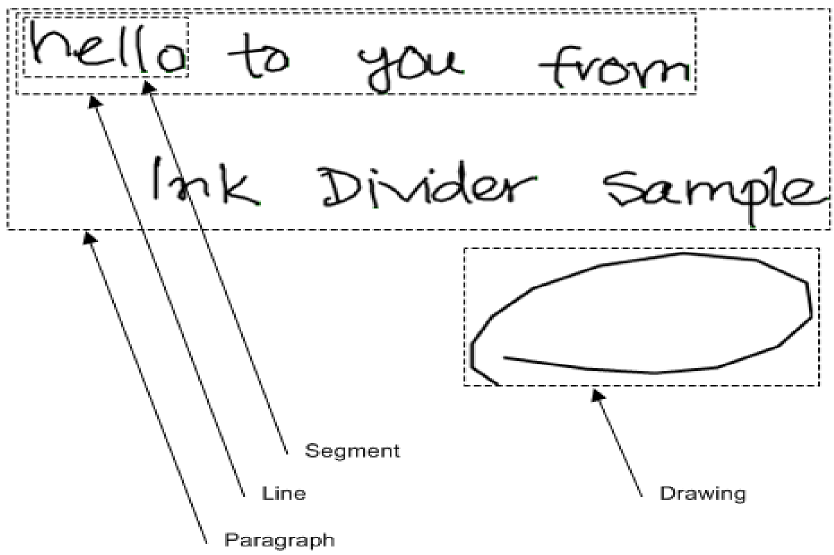


Figure 6.11 Divider Class Process for Sample Note.

After the note elements are classified, we use the available API of the tablet PC platform to recognize text elements by sending the stored collection of strokes for each segment to a recognition engine. The recognition module is currently developed to recognize English language only. It is also implemented to asynchronously run using the RecognizerContext object to recognize a given collection of data strokes.

Two dictionary types are implemented in our prototype system: the Microsoft Office dictionary and user-specific word recognition. Additionally, auto-completion properties are used in both dictionaries for converting the recognized text into meaningful words. However, if the recognized text is not identified in both dictionaries, it is inserted into user dictionaries that notify users, who would then properly identify the word during the reviewing process of notes. The user dictionary is a file in the data repository that includes mainly used abbreviations, shorthand words, and special user glossary words. The user dictionary is designed to allow users to add, search, and delete words. It is also designed to include the special meaning of characters such as “&,” which means “and,” “=,” which means “equals,” “-,” which means “minus”, “+,” which means “add,” and so on.

The user dictionary deals with important issues in the design of our system application because researchers reported that note takers heavily demand abbreviations and special characters during the note-taking process. By using the above algorithms, the SmartInk prototype can accurately guess the best word that possibly matches what the user wrote. It can also break alternate segments into separate words as well as perform autocomplete and autocorrecting for ink notes.

The mediator is designed to transfer the ink notes into uniform data by allowing the digital representation of the various components of ink notes. Using XML technology, the mediator processes user notes with several steps to save notes in system repository. Our approach to metadata repository creation includes the abstract definition of ink notes and the relationship among XML-generated data objects. The XML note template is designed to be used for customizing ink notes and automatically generating XML notes. Furthermore, the XSLT data template is used to transfer the XML note file into the portable SQL script executed to create the SQL data repository schema for note documents. The mediator process of transferring ink notes into the data repository is illustrated in Figure 6.12.

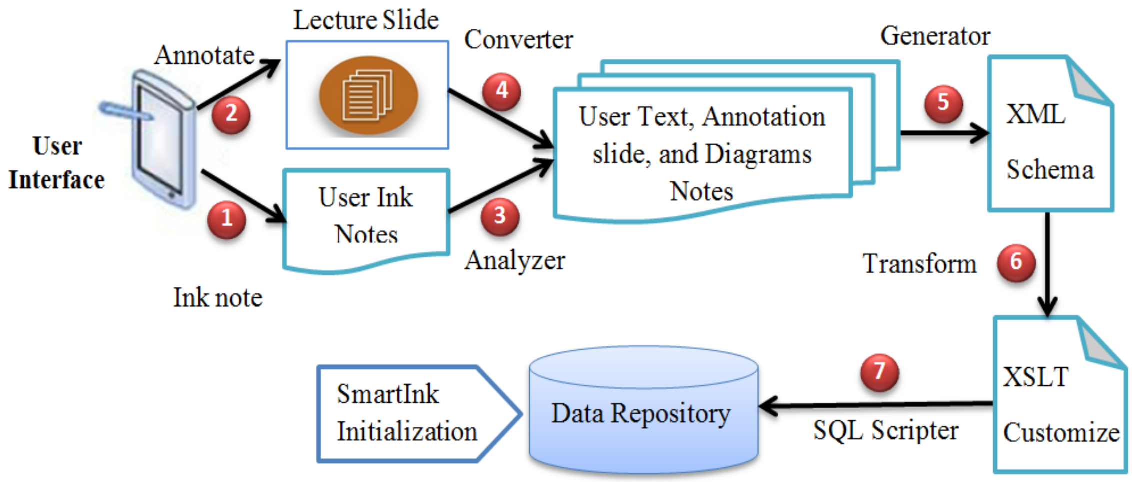
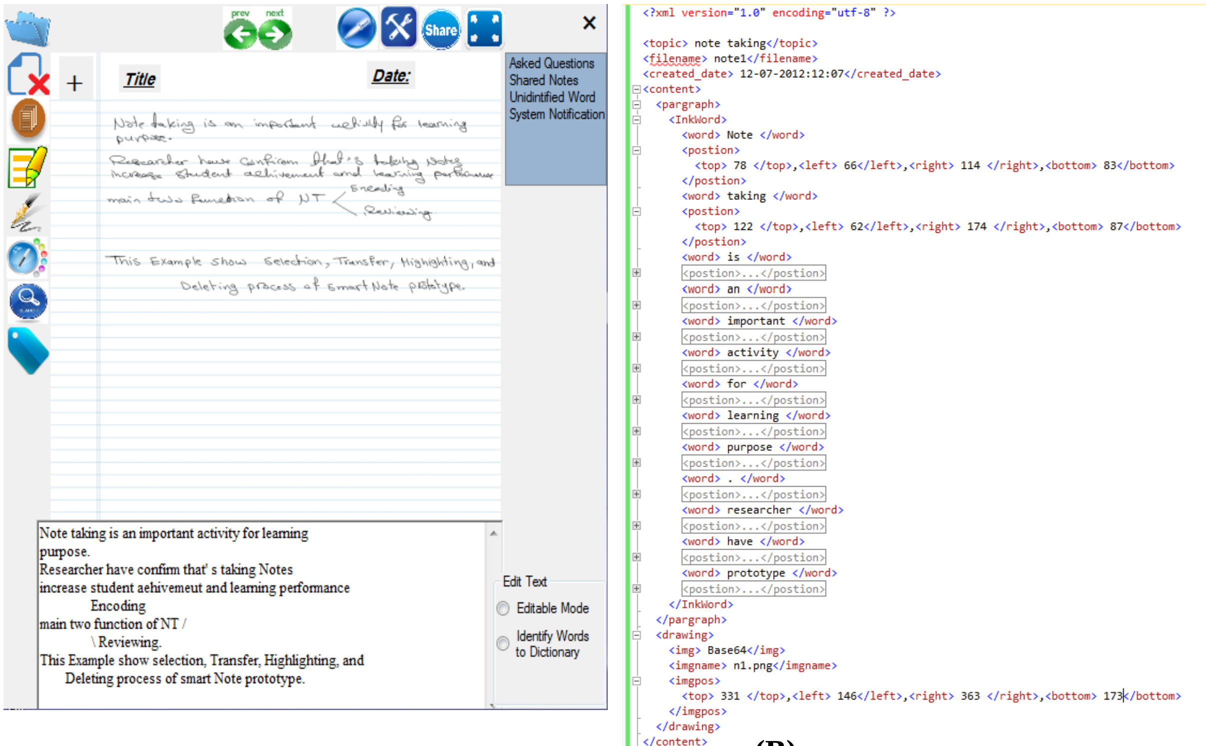


Figure 6.12 Process of Transferring SmartInk Objects into SQL Repository.

The XML schema of note objects is designed to support other XML advantages, such as XSL-LINK for creating links between XML resources, X-Path for accessing specific parts of note documents, and XQuery for allowing the system to represent the embedded query language.

Finally, results of the recognition algorithm are stored in the text file, whereby each chunk is stored as text word with additional XML metadata, such as coordinates as well as highlighted, indexed, and other XML attributes. In addition, both ink page and text file associated with the index value for storing and manipulating every associated text file are considered as an electronic copy of the original ink note file shown in Figure 6.13(A). The generated XML file in the same example is shown in Figure 6.13(B). Additionally, any user operation performed on the original ink file, such as adding, deleting, and transferring ink elements, causes the system to also change the version of its electronic.



(A) (B)

Figure 6.13 Ink notes with its generated text file, and XML file.

6.2.1.2 SmartInk Mediator Functions

This context design of mediated tools allows the user to utilize the power of technology in fulfilling the functionality of electronic notes without losing the consistency of traditional note taking. Some system functions are developed by using mediation approaches to mediate some of user activities during note taking into the digital form, including entering, deleting, moving, highlighting, searching, and querying. Other powerful tools, such as knowledge discovery, semantic and ontology approaches, related to knowledge understanding and transferring, can be implemented in further study based on this technique. The developed tools integrated with the SmartInk prototype are selected based on most previous research that reported the necessity of including such tools in any note-taking applications (refer to section 3.3).

Adding ink notes: SmartInk implements the function of adding notes to allow the user to enter notes using the pen tip device only in capture modes, whereas other input devices, such as the keyboard and mouse, are enabled for entering notes during the review mode. Users are provided with the option of selecting the input device in the review mode as shown in Figure 6.14.

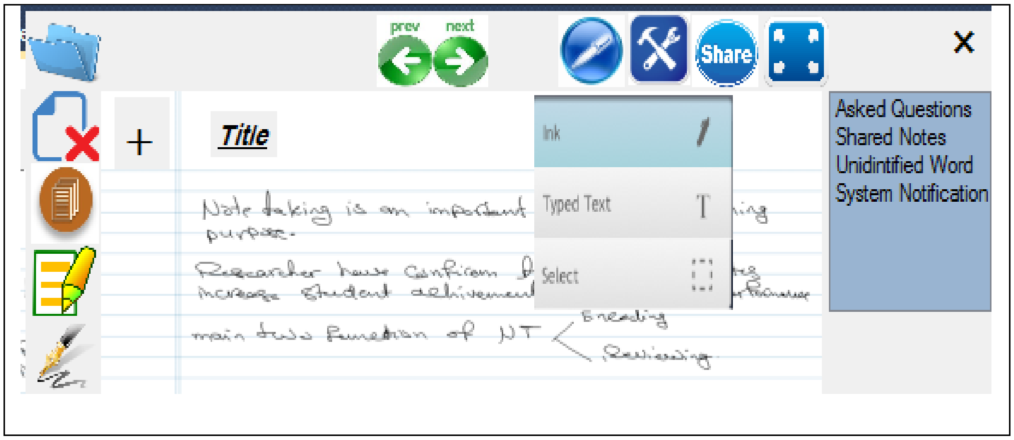


Figure 6.14 SmartInk Input Options in Review mode.

Converting ink notes into text: The free form algorithm implemented in the SmartInk prototype allows the ink note to be converted into the appropriate text file, as addressed previously. This option is enabled in both user modes, whereas the conversion process is automatically executed only when the user enters notes using a pen-based device.

Saving ink notes in data repository: Earlier in this chapter, we discussed the architecture of the data repository with class components and member functions. SmartInk prototype is designed to save ink notes in a database to facilitate electronic document operations such as editing, searching, and querying. On the SmartInk server side, the database is designed to store both ink and electronic notes in two individual tables, namely, **ink_note** and **txt_note**. The ink note database table contains a unique identifier, image data in fortified GIF persistence format, and the length of data array. The associated text note database table contains a unique integer index, ink identifier, ink words in text, and chunk attributes, such as left, top, right, and bottom values of the bounding box. In addition, the developer can implement specific tools to improve the advantages of digital notes in delivering knowledge by including other attributes, such as note keywords, topics, subtopics, word occurrence, and so on. A useful metadata of ink notes are stored in the database tables, including bounding box values, length of ink strokes, and other ink attributes, such as highlighted, bolded, indexed, tagged, and underlined. The metadata represented in our system supports digital user requirements in searching, indexing, linking, and querying the original ink file notes. On the other hand, storing the ink notes, and converting notes inside the data repository support users handwriting format which similar to the pen and paper approach with the digital functionality. As described previously in the data repository model design, the XML schema file is generated from the converted text file using the XML file template. Then, the generated file is used to automatically create the SQL script file using the XSLT designed file template. Finally, the SQL script is executed in the background process to store this information as metadata on the system repository.

Selecting Note element: The selection process is considered as a prerequisite for achieving specific note-taking tasks, such as deleting, transferring, highlighting, and linking functions. The SmartInk prototype is designed to allow the selection of ink elements using pen tips in the capture mode and the mouse cursor in the review mode. The user can select text such as words, lines, and pro-graph of ink notes in performing specific tasks. The selection process is designed to detect pen tips. On the one hand, if a stroke is detected on a blank area, then nothing will be selected. Also, if a pen tip stroke is detected on an inked area, then the selection process is executed by determining the beginning and end of the stroke location. The bounded box then covers the selection area and displays three icons.

These three icons give the user options to perform desired operations, including deleting, moving, and highlighting tasks (Figure 6.15). In addition, if the user changes his mind regarding his selection, he can tip the pen anywhere outside the selection area to cancel the selection process.

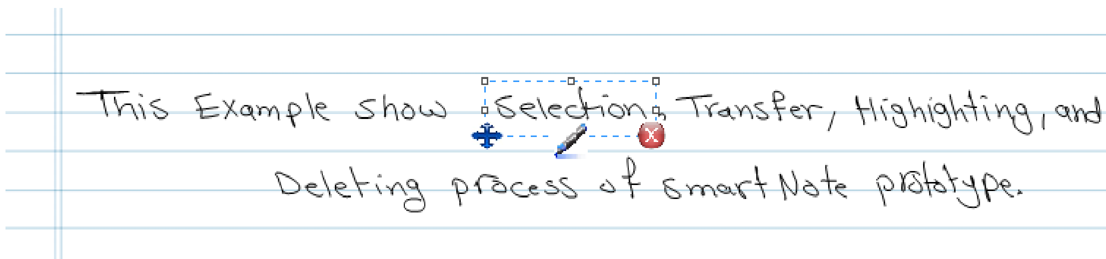


Figure 6.15 Example for Selecting process on SmartInk.

Erasing, Highlighting, and Transferring note elements: The note element can be selected and resized. It can also handle the four corners of the selected elements of the bounded box to perform note-taking activities, such as highlighting, moving, and deleting. After selecting the elements, the user can simply stroke the pen tip over the displayed icons on the selected area to perform tasks. For example, stroking the erase icon deletes the desired note element, stroking the highlight icon highlights the desired element, and stroking the transfer icon using the pen tip moves the note element into the desired location as shown in Figure 6.16. After performing the desired tasks on a selected area, the associated text file is automatically modified based on user choice. For instance, if the user performs the deleting operation, then the deleted chunk is removed from the associated text file. In another example, if the user performs the moving operation, then the word coordinates are changed in the associated text file; if the user performs the highlighting operation, then the value attribute of the highlight is changed to “1” in the associated text file.

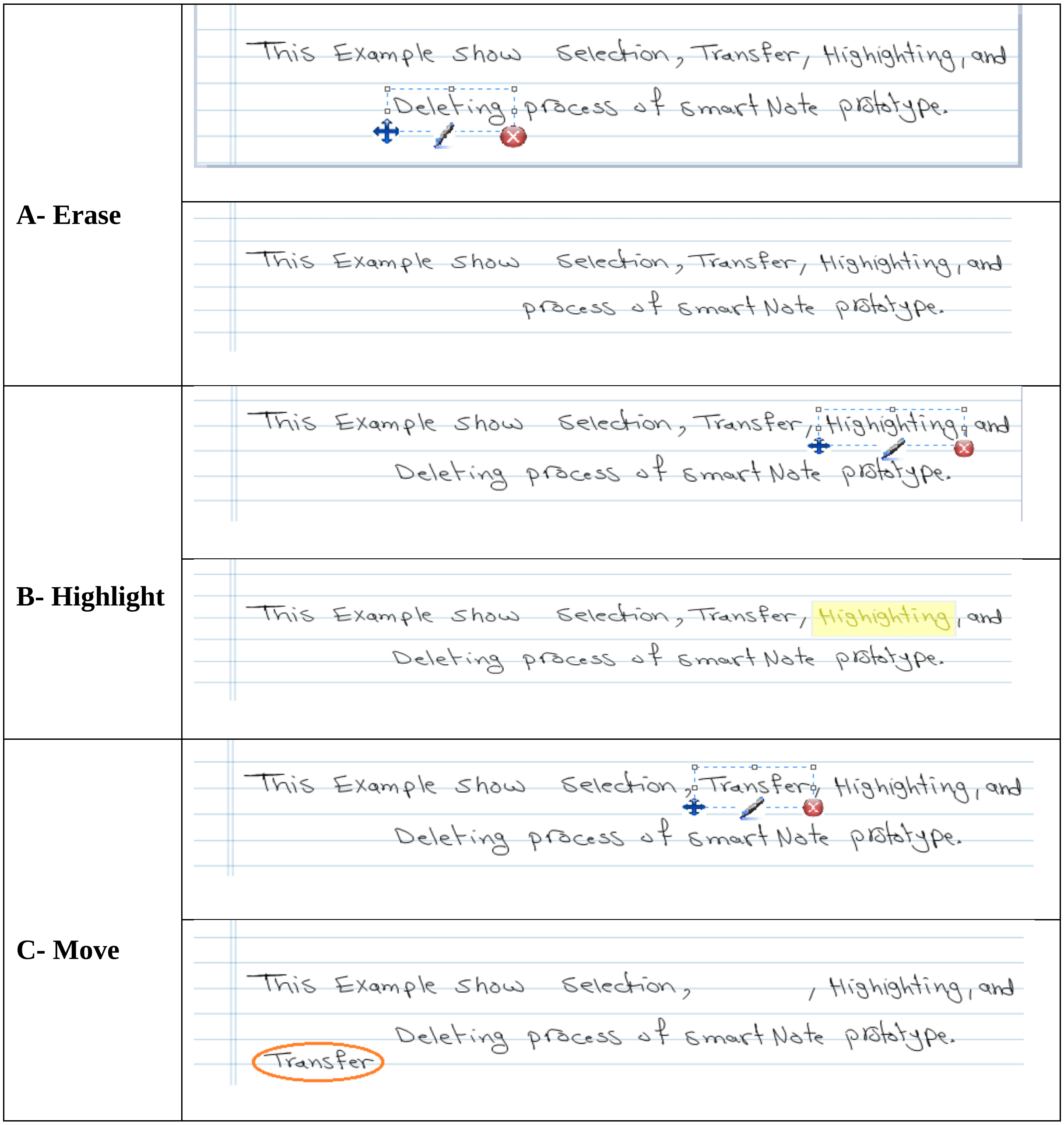


Figure 6.16 Examples for Deleting, Moving, and Highlighting on SmartInk.

Displaying, and navigates Notes: The saving task similar to the traditional task of writing on paper is automatically performed, unless the user decides to remove the ink note document. NoteAgent is responsible for updating the data repository upon any update of or modification on the ink notes. To create or display ink notes, the stored data are loaded into the memory stream. The NoteAgent member functions are used to create or display the ink objects. The navigation interface layout also allows users to switch between different topics and pages.

Searching, and Querying: Searching and querying in ink notes are considered as one of the most fundamental advantages of digital notes. These processes support users in quickly accessing specific information contained in one or more documents. The SmartInk prototype is designed to store ink notes in a database table, as previously discussed in system design. The SmartInk prototype supports users in searching for specific topics, paragraphs, and words, either by their content or by their creation dates. The searching process is designed to allow users to initiate a search or batch search for the purpose of creating a query index of ink notes. Users can simply search a specific context by entering search words or query using their own handwriting in the capture mode or by choosing the option of typing text from a keyboard. By creating tables for ink note and its metadata, the SmartInk prototype can perform searches on the server side to retrieve ink data from the database. A stored procedure is designed to perform the search on the text note table, retrieve information from the matched results, and to display the ink note data files. The stored procedure is named **find_inkin_text**, and its query code is shown in Figure 6.17. The search and query mechanism works as follows:

1- First, the user should input the query or search word.

2- The stored procedure is executed to retrieve matched words in the **txt_note** table.

3- The search procedure is performed in the text table to find all matching words as well as to retrieve matching word information such as file integer index, unique identifier, word bounded box, and word attributes.

4- The information on matching words found in the search process is used to display the associated ink note as a GIF file. Matched words are highlighted based on the retrieved parameters of the bounded box.

```
CREATE PROCEDURE find_inkin_text
 @Words varchar(200),    --Input parameter ,  word search
 @index  int,            -- Out parameter, text note ID
 @ink_identifier int,    -- Out parameter, identifier that likb between ink note and text note
 @MatchedDocID varchar(200), --Out parameter,  Matched file name
 @leftSearch int,        -- Out parameter,
 @topSearch int,         -- Out parameter
 @rightSearch int,       -- Out parameter
 @bottomSearch int       -- Out parameter
AS
   SELECT @matchedDocID = InkDoc FROM USER_INFORMATION_SCHEMA WHERE @ink_identifier = txt_ID IN
       (SELECT Index, InkID, left,top,right, bottom FROM (sys.txt_note)
        WHERE TXt_ID(@index) like '@words' )
       order by Created_date
GO
```

Figure 6.17 Searching stored procedure for SmartInk.

The search procedure is executed to retrieve the index, ink identifier, and matched words from the **text_note** table. Then, the index and ink identifier are used to retrieve the ink document files. Word attributes are used to identify the position of words found in the ink documents. The search results display the ink note files that contain the locations of the searched or queried words as presented in Figure 6.18.

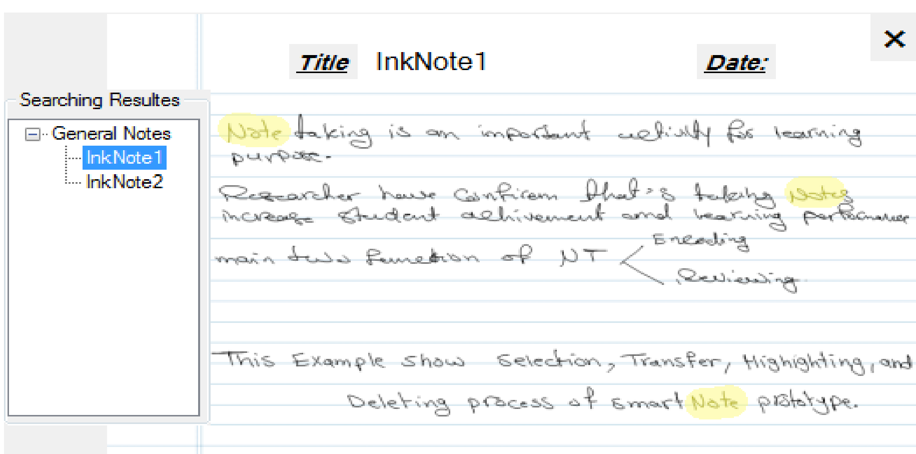


Figure 6.18 Example for SmartInk search results about “Note” word

Sharing Function

Recent research found that approximately 68% of students have borrowed notes from their classmates (Kiewra, 1989). Borrowing notes, a task associated with the traditional note-taking process, is implemented as one of the sharing options in digital applications as discussed in section 3.3. Easier note sharing, as previously described, is considered as one of the advantages of digital note taking. Most conducted systems have integrated sharing abilities in their note-taking application to support the collaborative learning. The SmartInk prototype provides users in sharing their ink notes, associated text notes, or both note files with their classmates and groups. Our design decision considers only note sharing during the review mode, as note sharing during capture mode is considered as a factor that reduces user attention (refer to section 3.2.3).

Sharing notes in the SmartInk prototype is simply performed when users select the share icon. Subsequently, a drop down menu will appear to allow users to choose which note files will be shared and to whom the file will be shared as shown in Figure 6.19.

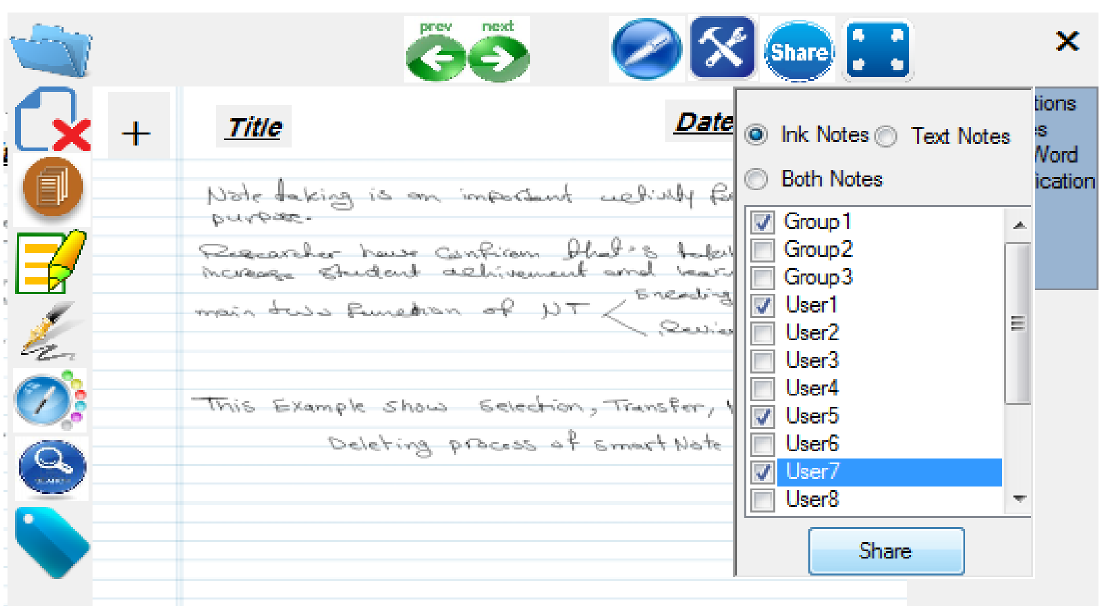


Figure 6.19 Example of Sharing tasks in SmartInk prototype.

Users have three sharing options, namely, sharing their own ink notes, sharing system-generated text notes, and sharing both ink and text notes. Additionally, users are allowed to select a specific group of people to share their notes with, such as classmates and individual users (Figure 6.19).

The SmartInk prototype also has another collaboration option that allows students to ask and answer questions among themselves. Users can post questions to a specific person or to a group of people, while the question asked will appear in the notification area of the selected group or individuals. The selected person or group can then answer the question that appears in their notification area. The previous section presented briefly how we implemented the essential functions of note taking, which were selected based on our proposed framework and on our analysis of the requirements of note-taking applications. The proposed tool is also designed to allow users to take notes in a manner similar to the traditional approach, mediating user tasks for taking notes in digital form. The full guide for the SmartInk prototype system included in Appendix B can be used to guide users about system function description.

6.2.2 Mediated Annotation Task on Lecture Slide

Technology has been widely used in classrooms to support the learning process; lectures are presented on computer slides rather than on chalkboards. The content of lecture slides mostly includes important outlines about the presented topics. Lecture slides are often used to control the flow of the lecture content. Taking notes during class discussions encourage students to be active in following the lecture materials. Below we argue the effects of annotation function in supporting learning to follow the framework development guides (refer to section 5.2).

Recent research found that students in the classroom use different media types for their traditional note taking: 47% take notes using an empty paper, and 61% take notes using printed slides and empty sheets (Steimle et al., 2009). Annotating lecture slides during class discussions is becoming one of the common note-taking activities. Numerous researches have been conducted to enable users to annotate lecture materials such as slides, audio, and videos. An example is XLibris (Schilit et al., 1998), which enables users to create handwritten annotations with a stylus; NotePals (Davis et al., 1999), which enables students to take notes on a PDA device during a lecture and to automatically associate notes with the proper slides; and Classroom Presenter (Anderson et al., 2007) as well as Dyknow (Berque, 2006), which support students in annotating lecture slides using tablet PCs during classroom discussions. Other systems, such as Audio Notebook (Stifelman, Arons, & Schmandt, 2001), A-Book (Mackay, Pothier, Letondal, Bøegh, & Sørensen, 2002), and ButterflyNet (Yeh et al., 2006), support users in using real papers as input medium for digital notes and annotation. Other systems, such as PADD (Guimbretière, 2003), PaperPoint (Signer & Norrie, 2007), PapierCraft , and PaperCP allow users to print documents for annotation purposes (Liao, Guimbretier, & Hinckley, 2005). However, limited studies have explored systems such as CoScripe that would enable users to annotate digital lecture slides (Steimle et al., 2009). By contrast, as described above several research studies revealed that annotation should be offered in note-taking applications to enable users to annotate slide lectures in printed hand-outs or in digital media. As lecture slides are considered professional notes written for lecture, we implement annotating activities in the SmartInk prototype to follow our framework design principles. However, we mediate the annotation tasks to solve the implementation difficulties involved by simulating the traditional annotating tasks in digital media.

6.2.2.1 Design Mediation for Slide Annotation

The key idea behind a design annotation tool is based on the finding that annotation of lecture slides is allowed to establish a direct reference to the lecture context (Grabe & Christopherson, 2005a). Annotation is a particularly important function that optimizes time and cognition of note takers by allowing them to add additional important information instead of writing everything down on a blank sheet. Research also showed that students prefer to create their own note structure if they lack free space on printed slides (Brandl, Richter, & Haller, 2010). Thus, the annotation of lecture slides satisfies our framework principle of meeting learning objectives through the SmartInk prototype system. On the contrary, research found that the annotation of lecture slides alone is not enough for the note-taking activities of students, as they need extra space to create their notes (Steimle et al., 2008). Thus, the interface layout for the annotation task should be designed such that students are provided with free space for their own note taking. This idea indicates combining the lecture slides with free space to separate user ideas from additional information provided by the instructor. In addition, the interface for the annotation tool is constrained by personal annotation styles and the need for an empty space to perform extensive annotation and independent note taking. Difficulties in implementing annotation tools in note-taking applications have been reported in several studies (Steimle et al., 2008) because of numerous issues, including students changing the content of lecture slides during text modification, lecture slides being prepared in different formats (such as PDF, PPT, and other formats that make the integration process more difficult), and annotating lecture notes without allowing the students to write their own notes, which leads to a learning deficiency or to the switching to traditional methods for note taking using a blank sheet.

Our design is guided by the goal of determining an appropriate user interface that will allow users to annotate lecture slides and write their own notes by simply providing them with a copy of the lecture slides similar to the E-note application mentioned in a previous study (Wirth, 2003). In the SmartInk prototype, we offer a new solution for mediating the annotation process by enabling students to annotate lecture slides and by allowing them to write their own notes through the interface layout that is divided into two individual areas: the left area for displaying the lecture slide and the right area for providing users with a blank space to write notes (Figure 6.20).

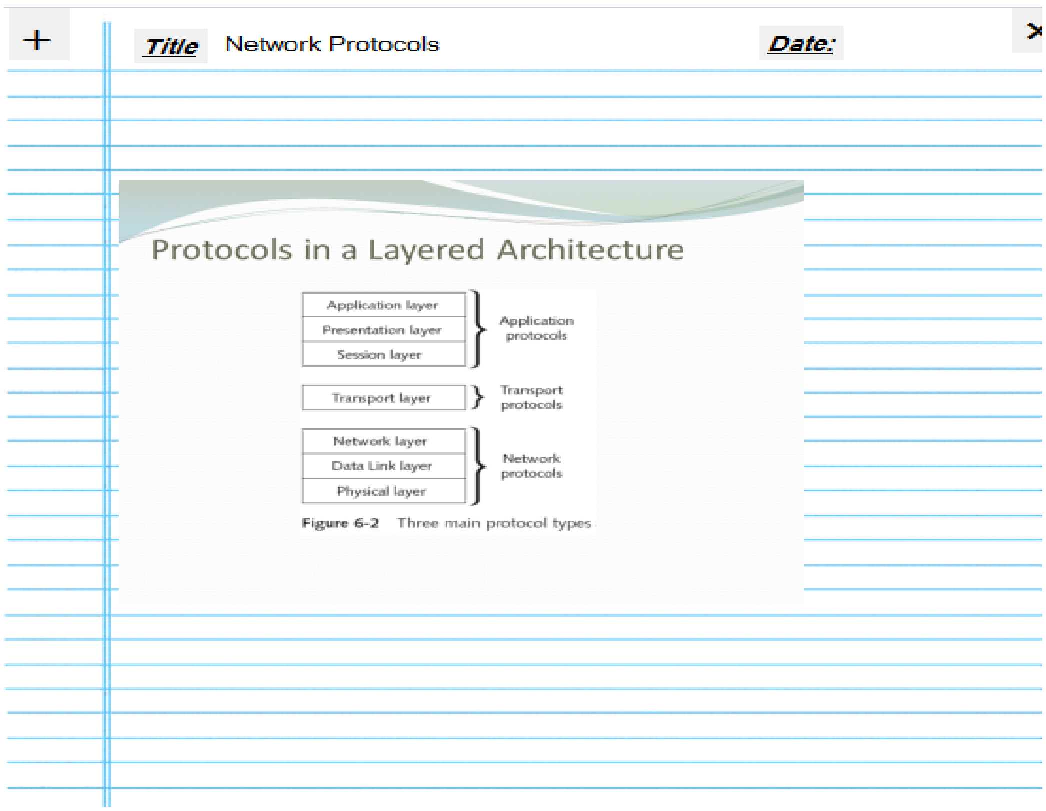


Figure 6.20 Example for Annotating lecturer slides in SmartInk prototype.

The SmartInk system is designed to import all lecture slides as an image displayed in the left area to prevent the user from changing the slide contents and to solve the problems of integrating the different lecture slide formats by making only one data format available for integration. During the importing process, the NoteAgent class is responsible for obtaining the slide contents as text and for converting the slide format into GIF for further processing. Two associated files are created to manipulate the user annotation process. The first file is designed to include the slide text elements and attributes such as annotating, commenting, and highlighting attributes on the slides. The second file is designed to include user ink notes and the related attributes. Furthermore, the lecture slides in the SmartInk prototype are imported from the server side, where each lecture slide is uploaded into the data repository and users are able to select specific lecturer slides in their workspace. Accordingly, the SmartInk prototype supports users by including the lecture slides for annotation and note creation. The imported slides become resource materials for users, with features that allow highlighting, annotating, searching, querying, tagging, and indexing lecture notes.

6.3. Chapter Summary

In this chapter we applied the framework role and principle to design the SmartInk prototype. Functional requirements of SmartInk prototype were identified based on note taking activity and extracted from similar previous system. The SmartInk essential modules, Capture and Reviewing are designed based on the essential function of note taking learning theories of encoding and storage features. SmartInk prototype architecture has been developed based on the framework deployment layer. The implementation of SmartInk prototype is developed to be compatible with different platforms as constraints by the frameworks technology layer. Several mediation tools were integrated with the SmartInk prototype to assist in solving the technology learning dilemma, and to adapt well the realistic tasks of traditional note taking. Three functional requirements of note taking tools (i.e. searching, sharing, and annotation) were provided as examples to illustrate the process of selecting, designing, and integrating these tools in the SmartInk prototype.

7.0 RESULTS AND DISCUSSIONS

7.1 Evaluation of SmartInk prototype

An experiment was initiated with multi-pronged approaches to evaluate usability and effectiveness of the SmartInk prototype, and the efficiency of mediation approach using a combination of different methods including student feedbacks, survey questionnaires, server data logs, and observations. Survey and observation were conducted to collect user feedbacks for measuring system usability, as well as to validate system functionality and effectiveness. The evaluation was conducted for seven weeks during the first semester of 2012. During that period, students from different fields volunteered to use the SmartInk system during their classroom lectures to take notes. A total of 42 students volunteered to evaluate the SmartInk system, 29 of whom were male and 13 were female. The volunteers are students of the International University of Technology Twintech in Yemen, with diverse majors, including Information Technology, Business Information Technology, and Multimedia.

7.1.1. Evaluation Equipment

The hardware devices used for the evaluation of the SmartInk in the classroom were various brands of Tablet devices, including two ASUS EP121 Tablet PCs, two Compaq TC1100 Tablet PCs, and two Apple iPad ver.2. Six tablet devices were used for the evaluation of the SmartInk prototype, which was customized with the MonoDevelop software version 3.0.6 for running on Apple OS. A powerful desktop PC was used to host the SmartInk data repository with built-in stored procedures.

7.1.2. Survey Evaluation Etiquettes

Customized questionnaires for the SmartInk prototype were designed based on the USE questionnaire approach (Lund, 2001). USE approach is a short questionnaire survey used to measure the most important dimensions of usability. USE has proved to be a valuable evaluation tool, being robust and reliable to measure usability. USE has been made freely available for use in usability assessment (Lund, 2001). USE questionnaire is a common approach for testing usability score of the software system, where USE items are built with a specific amount of validity for users (Abdinnour-Helm, Chaparro, & Farmer, 2005). It focused on the measurement of the main usability factors including usefulness, satisfaction, and ease of use. USE approach is selected because its validity and reliability on evaluation the usability dimension of software based on user feedbacks, and also because the items were worded as simple as possible (Andre, Hartson, & Williges, 2003; Donahue, 2001). The questionnaires focused on gathering student attitudes about the important dimensions of the system key objectives, including system functional effectiveness and system usability (such as usefulness, ease of use, and ease of learning).

At the beginning of every week, six students were selected to use the SmartInk system with the Tablet devices to take their notes for the entire week. Volunteers were allowed to choose their preferred Tablet device. They were also informed that they could switch back to their traditional note-taking practice if they felt that SmartInk was inappropriate for the purpose. A 10-minute introduction on using SmartInk with Tablet PCs was given to the volunteers, as well as the volunteers were informed to take their notes using English language only. At the end of every week, students were asked to submit their feedbacks on SmartInk through a web-based survey questionnaire designed (see Appendix (C)). The survey consisted of 24 items and divided into four sections which produced by USE approach. Users were asked to rate their agreement or disagreement with the statements using a rating system that ranges from “strongly disagree” to “strongly agree.” For ethical reasons, the volunteers were informed that their system activities and note contents would be observed as part of the SmartInk prototype evaluation.

7.1.3. Analysis of Survey Results

Of the 42 students who participated, 39 students completed the online survey during the seven-week experimental evaluation. Usefulness, ease of use, and ease of learning made up the three aspects of the survey questionnaires that were used to indicate the usability and effectiveness of the SmartInk prototype. The effectiveness terms is evaluated by the ability of users to complete note taking tasks in flexible matter using the SmartInk prototype. The last section of the survey was used to assess the usage functionality of the prototype and the effectiveness of its features in satisfying users for taking notes. Survey results are provided in Appendix D, and results for each survey section are presented below.

I. Usefulness:

Eight questions were asked in this section to explore the extent of the effectiveness value that students placed on the SmartInk prototype. Students were asked several questions to address their experience in using SmartInk in terms of the usability dimension includes effectiveness, productivity, and usefulness. Figure 7.1 summarizes the responses of the students about the usefulness of the SmartInk prototype.

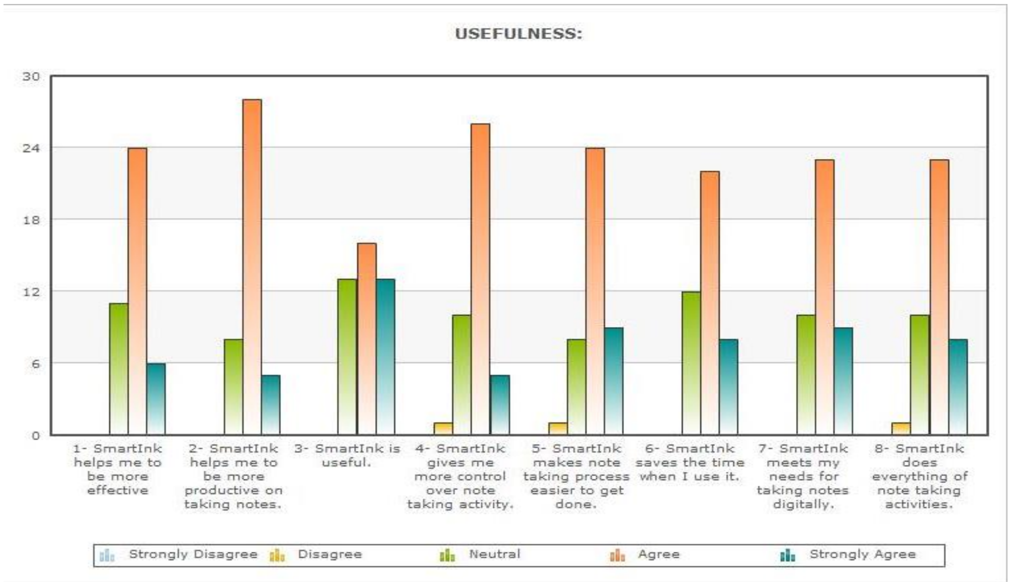


Figure 7.1 Student response chart for Usefulness of SmartInk.

Table 7.1 shows the percentage of students who rated each item with a moderate or significant value, where moderate means students response with "*Neutral*" term, and significant means the students response with *"agree" and "strongly agree"* terms.

Table 7.1 Student Responses for Usefulness of SmartInk.

Item Rated	**Moderate and Significant Response**	
	No. of Answer	**%**
SmartInk helps me to be more effective.	39	100%
SmartInk helps me to be more productive on taking notes.	39	100%
SmartInk is useful.	39	100%
SmartInk gives me more control over note taking activity.	36	92%
SmartInk makes note taking process easier to get done.	36	92%
SmartInk saves time when I use it.	39	100%
SmartInk meets my needs for taking notes digitally.	39	100%
SmartInk does note taking activities.	35	89%

Surprisingly, there were not many places in this section of the survey where student responses less varied greatly, where only a few aspects in this section of the survey highlighted minimal variations in the responses of the students.

II. Easy of Use

Five questions were asked in this section to explore the ease of use of the SmartInk prototype. Students were asked five questions related to the user-friendly interface, simplicity of use, flexibility, and the amount of effort needed in using the SmartInk prototype. Figure 7.2 shows the responses of the students about the ease of use of the SmartInk prototype.

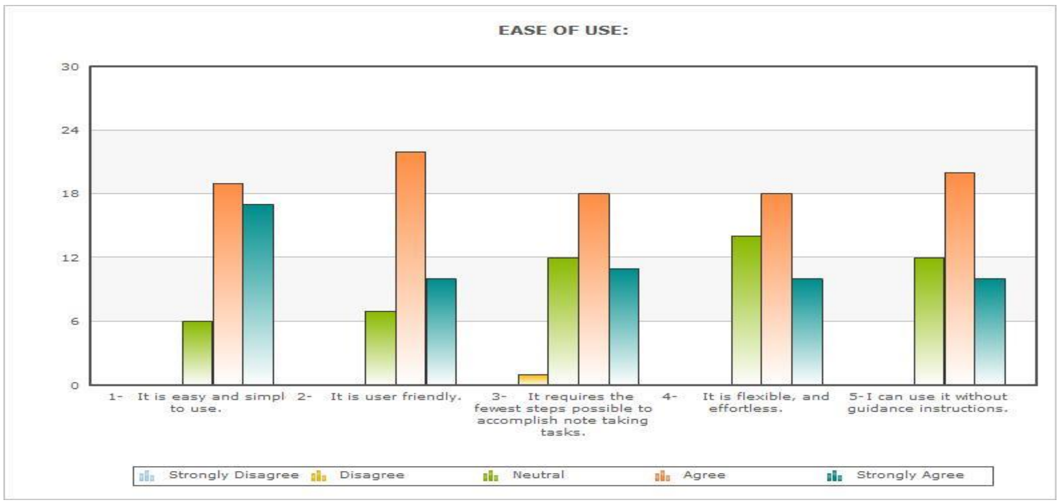


Figure 7.2 Student Response Chart for the Ease of Use of SmartInk.

Table 7.2 presents a summary of the moderate and significant rating responses of students. Results show that approximately 98% of the students who responded found the SmartInk prototype easy to use for note-taking tasks.

Table 7.2 Student Responses for Ease of Use of SmartInk.

Item Rated	**Moderate and Significant Response**	
	No. of Answer	**%**
It is easy and simple to use.	39	100%
It is user friendly.	39	100%
It requires the fewest steps possible to accomplish note taking tasks.	36	92%
It is flexible, and effortless.	39	100%
I can use it without guidance instructions.	39	100%

Interestingly, the results show that approximately 98% of the students who responded found SmartInk prototype was easy to use.

III. Ease of Learning

Ease of learning was tested by asking students three questions to address their ability to use the SmartInk prototype without being provided with instructional guidelines. Figure 7.3 presents the feedbacks of students about the ease of learning the SmartInk prototype.

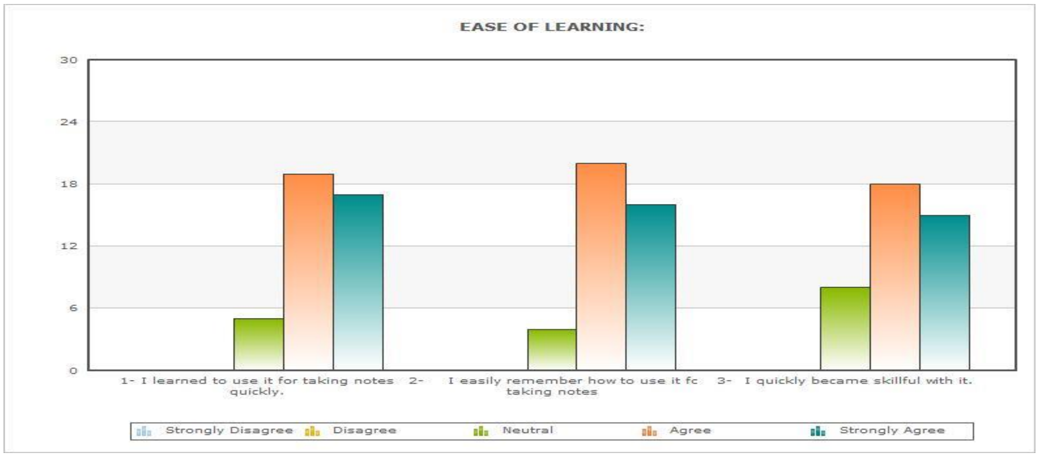


Figure 7.3 Student Response Chart for the Ease of Learning of SmartInk.

Table 7.3 Student Responses for Ease of Learning of SmartInk.

Item Rated	**Moderate and Significant Response**	
	No. of Answer	**%**
I learned to use it for taking notes quickly	39	100%
I easily remember how to use it for taking notes	39	100%
I quickly became skilful with it.	39	100%

Excitingly, results reveal that the students found the SmartInk prototype easy to use without additional help or guidelines.

IV. Functional Frequency Usage and Effectiveness

Eight questions were used to evaluate the functional operations of SmartInk and the student satisfaction on the suitability of using SmartInk in digital note taking. The students were asked to rate their experience in using the SmartInk prototype by following a rating that ranges from "very" to "not at all." The frequent functional usage was delivered from the server log entries, which will be discussed later in the observation evaluation section. Figure 7.4 shows students responses for the suitability and effectiveness of functional usage of the SmartInk prototype.

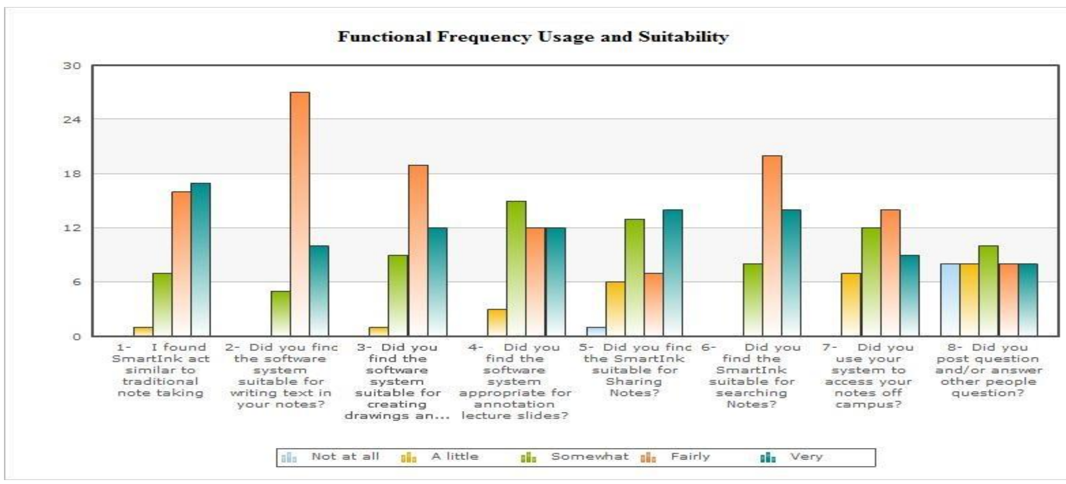


Figure 7.4 Student Functional Usage and Effectiveness of SmartInk.

As shown in Figure 7.4, the students rated their frequency usage of SmartInk functions. The rating can be used to discover the preferred tools of students and to address the difficulties in using specific tools of the SmartInk prototype. Students were also asked if they found the specific SmartInk features suitable using the following responses: *not at all, a little*, *somewhat*, *fairly*, or *very*. Questionnaires for this section focused on evaluating the suitability of most commonly used features, as listed in Table 7.4. The given values show the percentage of students who indicated their rate of use of these features using *somewhat*, *fairly,* or *very*, where these terms means students are used these functions frequently.

Table 7.4 Student Responses for Usage Features of SmartInk.

Item Rated	Moderate and Significant Response	
	No. of Answers	**%**
I found SmartInk act similar to traditional note taking	36	92%
Did you find the SmartInk suitable for writing notes?	39	100%
Did you find the SmartInk suitable for creating drawings and diagrams	36	92%
Did you find the SmartInk appropriate for annotation lecture slides	32	82%
Did you find the SmartInk suitable for Sharing Notes?	29	74%
Did you find the SmartInk suitable for searching Notes?	35	89%
Did you use your system to access your notes off campus?	31	79%
Did you post question and/or answer other people question?	19	48%

Results show that SmartInk is "somewhat" suitable for achieving specific tasks, such as handwriting, annotating, sharing, searching, and drawing diagrams; other tasks, such as posting and answering questions, are not used widely. In the discussion part, we will describe in more detail the issues of usability, effectiveness, and functional usage of the SmartInk prototype on based of these results.

7.1.4. Observation Evaluation

User activity is used to observe their reaction with using SmartInk prototype. Observation students during using SmartInk in classroom are used to evaluate the flexibility of SmartInk prototype.

7.1.4.1 Observation

Observation volunteers were conducted with the permission of the instructor during the first half-hour of the lecture at the beginning of each week. Observation was performed to record student's behaviour in using the prototype, their motivation for using the prototype, and their interaction with the SmartInk prototype itself during classroom discussions. This method was also carried out to observe difficulties encountered by users throughout their use of the SmartInk system.

Observation conducted for seven lectures after the SmartInk is introduced to the volunteers. We found that students had a positive reaction during the introduction of the SmartInk prototype, during which the concepts of moving notes into digital environments were also discussed. Observation indicated that most students can use SmartInk in a confident and flexible manner, as they were able to write notes, draw diagrams, and find related contents on their notes. Specifically, they experienced the ability to enter notes anywhere in the interface layout as well as moving and deleting note elements without the need to switch between edit and select modes. Moreover, students with computer backgrounds demonstrated a great ability in using SmartInk for note taking. Another interesting observation is that the note contents of students who used SmartInk and those of others who used the traditional way were approximately similar. The format of the digital notes was also similar to that of notes written on paper. The main difference observed in the notes written using SmartInk were larger in text size compared with those of typical notes written on paper because of the thicker SmartInk Pen Stylus and the different feel in writing on tablet PC devices.

We also observed that the physical space for volunteers should be designed such that a specific space for note taking is included in the digital device and users are given more freedom to use tablet PCs for note taking. Observations on the physical Tablet device and the pen-enabled technology also revealed that the type of pen device and the smooth surface of the tablet PC have effects on user behaviours, as user were found to have better control when using the SmartInk prototype.

The most interesting observation is that participants used the SmartInk without asking additional questions about using the system's specific functions. This finding is attributed to two reasons: the similarity of the prototype with traditional methods and the good experiences of volunteers in using computer devices.

7.1.4.2 Server Log Entries

The SmartInk prototype was designed to record user activities inside and outside the classroom using server log events. The server log can provide us with accurate and useful information about note contents, user activities, and reliability of prototype functions. The server log contains the summary of the created notes, imported slides, login user details, user and system events, number of system access on capture and review mode, and frequency of executed user tasks, such as highlighting, annotating, searching, and sharing. In addition, server entries were used to validate the efficiency of the SmartInk functions in achieving user tasks and to measure the frequency of usage of each function. Observation server log entries were used to assess the accuracy and completeness of the achieved tasks, especially the transfer of handwritten notes into digital text notes. The evaluation of the functionality and performance of SmartInk was conducted by observing the server log entries of note contents and user activities stored in the data repository. The server logs provide us with a very accurate and detailed summary about user activities and frequently used functions, such as creating, highlighting, erasing, tagging, and searching activities (see Appendix E).

Reviewing the content of server logs revealed 3,551 different event types of user activities which were created during the experiment period. These events simply described the user activities for the SmartInk prototype functions, as shown in Figure 7.5.

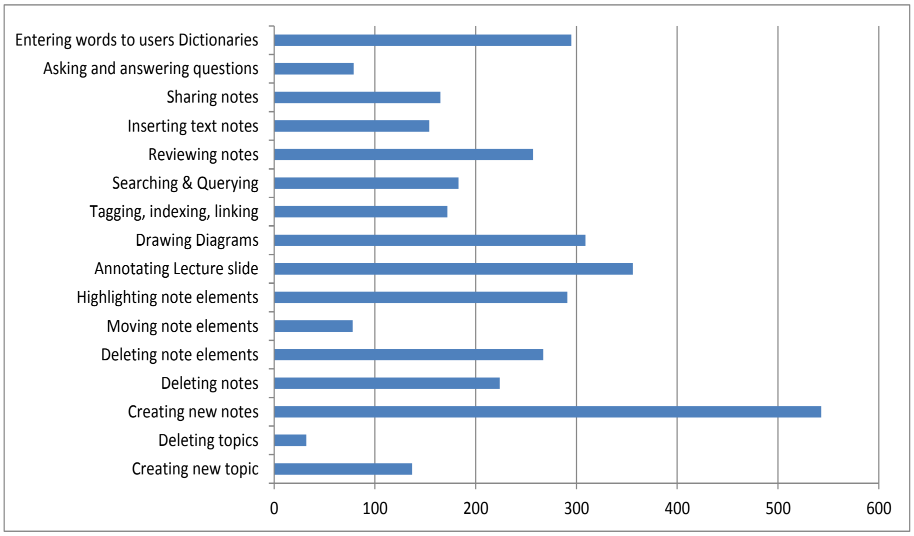


Figure 7.5 Summaries of Server Log Entries for Frequently Usage.

The SmartInk functions were used by users with several variations, as shown in Figure 7.5. Some functions are used heavily, e.g., creating notes, highlighting note elements, deleting notes, annotating slides, drawing diagrams, reviewing notes, and searching features. Some functions are used regularly, eg., sharing, tagging, indexing, linking, erasing elements, and entering words in user dictionaries. A number of functions are used rarely, eg., asking and answering questions, moving note elements, and deleting topics.

7.1.4.3 Efficiency Results of SmartInk Mediator

For evaluation the efficiency of SmartInk mediator, we randomly selected 35 ink user notes for comparison with generated notes saved in the data repository to measure the accuracy of the SmartInk mediator conversion process. The contents of both versions of the selected notes were compared to verify the degree of similarity between the ink note contents and the electronic note files. The total number of words counted in the selected ink notes were 623. These words were used to verify the correctness of the conversion by the SmartInk mediator. Table 7.5 presents the SmartInk mediator results based on the comparison of the contents of ink notes and their digital counterparts. The results were used to obtain the accuracy of the SmartInk mediator conversion process. We assumed the identified words in the user dictionaries as correct because those were specific words that the users used as abbreviations, synonyms, or other shorthand words. The total accuracy of the SmartInk mediator was calculated as the total number of correctly converted words and the identified words in the user dictionary.

Table 7.5 SmartInk Mediator Conversion Results.

Conversion Results	No.	Percentage
Total words of ink notes	623	100%
Total words converted correctly into electric notes	327	53%
Total of identified words in user dictionaries	83	13%
Total unidentified words	97	15%
Total errors of transferring process	116	19%

We found that the accuracy of the mediator conversion process was approximately 66%, the error conversion was 19%, the identified words in dictionary were 13%, and the unidentified words were 15%. Accuracy of the mediator is the total of converted words and the identified word in the dictionary, while the error in conversion process was 24% which represented the total of unidentified words and the error of converted process. These errors mostly occurred because of several issues, such as users writing notes in different axes, user handwriting font, differences in spaces between letters or words, and the high demand of using abbreviations, shorthand techniques, symbols, and special characters.

7.2 Discussions

The data gathered from the survey questionnaires, observations, and examination of note contents lead to a clear insight about the usability, and effectiveness of SmartInk, and efficiency of the mediator approach. This data also provide us with an indication about our proposed framework for SmartInk designed. The survey and observation results clearly illustrate that SmartInk has been well received by students with respect to its impact on in-class interaction and after-class note review. The usability and effectiveness of SmartInk showed significant results in reducing the inefficiency issues. Users use SmartInk in flexible way similar to the traditional approaches. Thus, SmartInk is usable and effective for digital note taking. In the following sections, we used the student feedbacks to measure the usability features and effectiveness of SmartInk prototype in term of scale.

7.2.1 SmartInk Usability

The survey questionnaires were designed to evaluate the SmartInk usability by analysing three key human factors and attributes from user feedbacks: usefulness, ease of use, and learnability.

The usefulness factor is divided into two attributes: consistency and compatibility. The usability factors were driven from selected questions of the proposed survey. The consistency factor measured the similarity of SmartInk with traditional environments of note taking, such as in terms of interface layout appearance and various interactive features. Compatibility is about how SmartInk features fit with user productivity, and whether SmartInk meets the needs of users for digital note taking.

Ease of use is about the simplicity and flexibility of the SmartInk prototype during note-taking activities. Flexibility is indicated by the adaptability of the SmartInk features in achieving user tasks with minimal action.

The ease-of-learning factor is associated with ease in learning the various features of the SmartInk prototype in terms of time. In the analysis survey data we set here the success of these attributes to be greater than 80% for achieving acceptable usability. The usability is achieved if the mean score of user feedbacks was 75% or above such as SUS, USE approaches (Brooke, 1996). Thus, accepting or rejection of each SmartInk feature is depending on the usability score value, where the features will be accepted if the usability score is 75% or above, and will be rejected if he usability score < 75%.

The consistency, compatibility, and flexibility attributes were driven from selected questionnaire data. Learnability attribute is evaluated by the time required to learn the SmartInk prototype. For this measure, we found that students need an average of one day only to learn the features of and become fully acquainted with SmartInk. A one-tailed t-test was used to analyse the results of the survey data. One tail test is used here to measure the statistical significance of SmartInk usability. A one-tailed test measures the significance of usability features using the mean score value. A significant level of mean score was set to be 75% or above when p-value less than 0.05. Thus, each feature of SmartInk prototype with a mean score 75% or above are considered significant. The mean score value was set to be 75% based on the USE approaches, where this approach showed that usability is achieved if the mean score equal or greater than 75%.

Survey questionnaires were designed with five responses ranging from strongly agree to strongly disagree. The participant response has been converted into a scale. Scale is simply one based on forced choice questions, where a statement is made and the respondent then indicates the degree of agreement or disagreement with the statement on a 5 point scale. Then we use the numerical value feedbacks to interpret the results for measuring the usability. Below, we listed the process of calculating the mean score for usability feature.

- Each usability features are represented in survey with one or more questions, thus we extracted user feedbacks for each usability feature, e.g. consistency is represented in questions number (1,3, &7) of the survey.
- Each item’s score contribution will range from 1 to 5.
- Item’s score is calculated to obtain the mean score, standard deviation, and mean percentage for each usability feature.

Table 7.6 summarizes the attribute scores of the usability factors in percentage.

Table 7.6 Usability Analysis Results

Usability Features	**Mean Score N = 39**	**Standard Deviation**	**Mean Score %**
Usefulness	4.340476	0.061035	86.8%
Consistency	4.120341	0.757066	82.4%
Compatibility	3.909091	0.15382	78.4%
Easy to use	4.114634	0.141639	82.2%
Flexibility	3.991091	0.772136	80.2%
Easy to learn	4.227273	0.710834	84.6%

As shown in Table 7.6, the "usefulness," "consistency," "easy to use," and "easy to learn" attributes have more significant ratings (mean score percentage were > 80) at p = 0.05. Compatibility has a slightly less significant rating (mean score = 78.4), and flexibility has a critically significant rating (mean score = 80.2%) at p = 0.05. From our analysis, we found that the lack of familiarity with tablet environments was the main reason for the slight difference in the compatibility score.

By contrast, we determined that the usability factors achieved a high score rating, wherein the overall impression made by the SmartInk prototype was positive. Thus, the SmartInk prototype does not significantly change the behaviour, style, and environments of note takers. The score for the usability attributes was in line with our observation that students used the system without additional help or specific guidance. One of the more interesting findings is that the SmartInk prototype interface did not present any differences with regard to learning outcomes and time to achieve the tasks.

7.2.2 SmartInk Effectiveness

The term "effectiveness" used in this section is based on the SmartInk functionality and is used to identify the effectiveness of SmartInk functions in achieving note-taking tasks as well as the level of student satisfaction on each feature of SmartInk.

Based on the proposed framework evaluation criteria, we designed the survey to collect student feedback on each SmartInk feature. Based on this evaluation, we can correctly decide which feature should be accepted, modified, or rejected for the release of the next SmartInk version. We set here each SmartInk function that has a rating score of over 75% is accepted, the function with a rating score between 60% and 75% should be improved, and the function that has a rating score of less than 60% is rejected based on SUS, and USE approaches (Brooke, 1996). Selected features for evaluation were handwriting, drawing diagrams, annotating, sharing, searching, accessing, as well as asking and answering questions. Our decision was based on user satisfaction feedbacks. One-tailed t-test is used to analyse the data on frequency usage and suitability. The results shown in Table 7.6 reveal that the handwriting, drawing, and searching features of SmartInk have a more significant rating (mean score > 80). Annotating has a critically significant rating (mean score = 75.2), which is approximately near our optimal suggestion. Sharing and accessing features have slightly less significant rating (mean score < 75). The asking and answering question features have non-significant rating (mean score < 60). All tests are performed at p = 0.05.

Table 7.7 Functional Effectiveness Analysis Results

SmartInk Features	**Mean Score** N = 39	**Standard Deviation**	**Mean Score** %
Handwriting	4.133333	0.587754	82.6%
Drawing Diagrams	4.023256	0.771158	80.4%
Annotating	3.755556	0.933117	75.2%
Sharing	3.651163	1.1523	73%
Searching	4.181818	0.724095	83.6%
Accessing note	3.577778	1.01105	71.6%
Asking & answer Questions	2.977778	1.422049	59.6%

The SmartInk prototype has been proven its effectiveness in satisfying users in terms of the handwriting, drawing, annotating, and searching features. Sharing and accessing note features should be improved to be more effective in satisfying user requirements. However, asking and answering features should be excluded in the design of any version of SmartInk because students were very unsatisfied with those features. The inclusion of these features may cause a disturbance during the learning process. Other issues need to be addressed in the future studies.

The effectiveness of SmartInk functions is cumulative with our observation study of server logs, which revealed that students utilized most of the features with significant ratings frequently; those with slightly significant ratings were used ordinarily, and those with non-significant ratings were used rarely (Figure 7.5).

An interesting finding is that the search feature was rated significantly with high user satisfaction, confirming our observation regarding the frequent usage of this feature. Despite the several limitations of this feature brought about by the inaccuracy of the conversion process of ink notes into digital notes, input language, system dictionaries, and user font stylus, it remains one of the important advantages for moving notes into digital form. Nonetheless, more studies must be conducted to make the necessary improvements.

7.2.3 Implications of SmartInk in Learning

The goal of this study is to design a note-taking application that will support university students. In this section, we discuss several implications of the SmartInk prototype in the learning process.

I. Handwriting feature

The handwriting features included in the SmartInk prototype support students in obtaining the pedagogical benefits of conventional note taking. The readability advantage of digital notes is given less priority if compared with the advantages of familiarity and free form of traditional tools. In this case, the note is considered as personal information created by users for their own purposes and for their own reading. The experimental evaluation of this feature showed a highly significant result, proving the functionality of this feature in satisfying user requirements. Furthermore, we determined from observing note contents that the resolution of the handwriting did not differ significantly in notes written using pen-enabled technology of tablet PCs. We found that the handwriting feature is a critical tool for supporting free form tasks, consequently maximizing the pedagogical practice of students. We also determined that enabling handwriting tools not only reduces user distraction but supports users in writing their notes efficiently. Therefore, our findings indicate that a tablet PC device is the most adequate device for a handwritten input of notes in courses that should be supported by any learning application.

II. Annotating Feature

Evaluation results showed that students demonstrated a heavy demand for annotating lecture slides during classroom discussions. The special design of the annotated feature in the SmartInk prototype establishes a close association between the students and the course by directly referring to the adequate position within the lecture materials. The extra space provided through a blank region in the screen offers pedagogical benefits for students by allowing them to create their own notes, thereby increasing the effectiveness of the learning process. Observation experiments showed that students included both annotation and handwriting in their note contents. Frequent use of this tool during the use of the SmartInk prototype proves the feature's usability in satisfying user requirements for annotation tasks.

III. Selecting, erasing, moving, and highlighting

Observation showed that students used the selection feature as an easy way to perform the three main options of erasing, moving, and highlighting. More flexibility was observed during the selection process, which supports the users in performing specific tasks efficiently and similar to the conventional way. However, we found that the feature for moving note elements was only used widely for moving diagrams, with an even lesser usage for moving note chunks. The feature should thus be disregarded in the release of the new SmartInk version. The erasing operation reduces the sloppiness of the created notes, which can improve learning performance by having a clean notes. The frequency of usage of the highlighting feature showed the significance of including that feature in the SmartInk prototype, as this feature can improve the ability of users to memorize highlighted items.

IV. Collaborative features

We designed two features in the SmartInk prototype for collaborative purposes: the ability to share notes and the ability to ask and answer questions. With regard to the evaluation experiments, we noticed that students demonstrated an interesting perspective toward sharing their notes. However, no significance was observed in the use of the asking and answering feature, as the interface may not be appropriate in their learning tasks. Therefore, we need an extensive experiment evaluation for this tool to address its inefficiency issues. The sharing feature in SmartInk had less significant rating, as explained previously. It therefore requires fine tuning in the future design of the SmartInk application.

V. Digital advantages features

We integrated SmartInk with several tools, such as indexing, tagging, linking, and searching, as part of the recommendation to transfer traditional note taking into electronic form to gain the advantages of digital documents. Therefore, indexing and linking tools indicated significant results during the evaluation of their frequency usage. However, we found that the SmartInk prototype needs improvement in representing outside materials in a special form.

We also found that the search feature was used frequently by users despite its obvious limitations. Thus, the search feature can be designed such that it is free from limitations by improving the mediator algorithms used in creating and retrieving user note contents. The mediation algorithms used in the SmartInk prototype are proven suitable and efficient in adopting digital advantages for the SmartInk prototype.

Overall, adaptability of the SmartInk prototype for taking digital notes over the existence tools was because we employed some specific techniques on system developments, some of these approaches are listed below:

- Appropriate analyzing of current issues of note taking tools used to identify clearly the critical challenges in developing successful note taking application
- The theoretical framework expands the role and responsibilities of developments note taking tools based learning objectives. The framework is used to facilitate the development process through the guidance steps from initial stage of selecting tools until the final stages of integration tools in realistic system.
- The guidelines used for successful adoption of digital note taking are set here in the proposed framework.

The new developed technique of intelligent mediator of note taking tasks was used to improve overall note taking process significantly, where mediation tools showed great adaptability for keeping note taking tasks consistence in technology device.

7.3 Chapter Summary

In this chapter we analyzed the experiment results to evaluate the usability features, and effectiveness of the SmartInk prototype by using the data of student feedbacks and server logs. The efficiency of SmartInk mediator approach was also evaluated by using student note contents. Then, we discussed the usability, effectiveness of SmartInk prototype and the efficiency of mediator approach. Results showed that SmartInk is usable and effective for digital note taking, while the mediator approach is acceptable in converting ink notes into digital notes. Finally, we described some implication of SmartInk prototype with learning aspects.

8.0 CONCLUSIONS AND FURTHER WORK

The claim of this thesis is to address the reasons for the resistance to the use of digital notes, identify the role and responsibility for developing note taking tools, and build a prototype for usable and useful note taking applications. This study focuses mainly to push forwards the current efforts of transferring note taking activity into digital form, and to contribute with other people works in affording digital note taking application. Accordingly, we developed a solution involving two components: 1) a framework for note taking application to address the complexity, inefficiency, and integrability issues; It provides the necessary guidelines for the developments processes of note taking tools;2) an intelligent mediator for adapting note taking tasks into digital environments without interfering users current practice, and inline with learning and cognitive theories. Additionally, the mediator is designed to solve the critical problem of technology learning dilemma described previously.

8.1 Findings

We have argued that successful design, development, and deployment of student-oriented technologies are feasible but not an easy task because of many reasons including:

- Students have a wide variety of skills and capabilities all of which must be engaged.
- Students are constantly multi-tasking and overloaded with many activities.
- Students are quite adapt at optimizing their situation, finding maximum benefit with minimal effort.

In addition, we found that there are several issues in sticking with pen and with paper, rather than using digital tools for note taking, such as complexity, inefficiency, integrability, and technology learning dilemma issues.

- Complexity is related to the difficulties in carrying out the various tasks of traditional note taking.
- Inefficiency is related to the time of achieving tasks and user cognition terms, where inappropriate design leads to unnecessary actions and cognitive over loads.
- Integrability is due to the wide diversity of current technology in both hardware and software requirements for development note taking tools, and the difficulties to integrate the current tools within typical note taking application.
- Technology learning dilemma describes the effects of technology in development of education tools, where we found that improper usage of technology can lead to negative impact on learner negatively leading to learning deficiency. It is an important factor when addressing the confliction between the gain of traditional and digital advantages of note taking.

We have also shown that with SmartInk the objectives of the thesis are achievable in developing usable and useful note taking application. It provides users with the necessary functionality of technology based tools without losing the flexibility, speed, and advantages of traditional approaches. In addition, the proposed system provides students with the appropriate tools that facilitate note taking process inside and outside classroom.

Hence, our experimental findings are listed below:

- Designing successful note taking application is feasible using framework with mediation approaches proposed here. Thus, the framework is responsible to solve the complexity, integrity, and inefficiency issues of digital note, while the mediator responsible for solving learning dilemma and adapting the difficult tasks of note taking.

- Mediation tools can offer a new vision for developing appropriate tools to adopt the actions of traditional note. These technologies are tools and artifacts that must be constructed in the learning context. We must endeavor to devise technologies that mediate our own cognition and learning.
- SmartInk prototype can settle the confliction issues occurred between linearity and free form features while students can use it to achieve both; the benefits of digital and traditional note taking approaches.
- The pedagogical benefits of SmartInk enable students to do their tasks without losing the normal activities performed during lecture where students can maximize the new utility afforded by note taking with electronic devices.

In this thesis, we presented an integrated student learning environment of pen-based technology for taking note in Tablet devices. Comparing the findings from these user studies indicates that students are prepared to embrace technologies that they perceive minimal changes to their existing practices. Overall, our finding in this study shows that note taking with pen enable technology as a hardware platform, framework guidelines for development process, and the mediator for adapting note taking activities can be successfully implemented.

8.2 Contribution

Traditional note taking was explored extensively to identify pedagogical practice, education theory, and cognitive effects of note taking, which illustrates the importance of note taking from a psychological perspective. We also examined the existing system to identify main challenges and current problems that make the transition of note taking into the digital environments difficult as discussed briefly in chapter 4. Extracted problems of the current system provided us with clues to the critical question of why people still use pen and paper to take notes. Then, we established a design solution based on pedagogical opportunities of student note-taking practice in a traditional class as discussed in section 4.3.

From this research work, the main contributions of this thesis are listed as follows:

1) Constructing a framework for the design space of a digital note application with five layers and a set of guidelines for developing successful technology adoption of digital note applications and for evaluating digital note-taking tools. We set the standardization of digital notes in roles, constraints, responsibilities of framework, to identify the framework guidelines design, and identify the evaluation criteria for note taking applications. The proposed framework identified the process of reducing complexity, adapting realistic tasks to reduce user cognition, and facilitate the modular engineering to solve integritability issues.
2) Introducing mediation tools as novel solutions for the existing problem of technology learning dilemmas, and for technology adoption to adjust the transferring of traditional note-taking tasks into digital tools. The mediation techniques are optimal solution to develop technology tools of realistic activities especially for education technology tools.
3) Designing typical note taking application four types of tools are identified for implementation within the system include: capturing, reviewing, manipulating, and collaborating tools. Additionally, system function requirements to take notes inside classroom are varying widely with those functions required for taking notes outside classroom.

4) Finally, both the framework and the mediation tool are considered as the first steps in the right path toward shaping the next-generation technology support for educational content on digital notes. This solution can be used to convert traditional notes into digital notes easily and without negative effects on user behaviour and current practice, as well as to simulate user activities in treating digital notes with an attitude similar to that for traditional notes toward the goal of replacing the latter. SmartInk prototype is a result of applying the theoretical (framework) and technical (mediation) solution for current issues, which proof its usability and effectiveness for taking note in digital form.

8.3 Limitation

The current SmartInk suffers from several issues that require refining and improving with respect to the system functionality and performance. Some of these limitations are listed below.

- The SmartInk prototype was designed to recognize handwriting input of English language only. However we noticed that students tend to combine several languages when taking notes, especially if the course is taught in a language other than their native language.
- SmartInk prototype is the initial version for a typical note-taking application which build by using the evolutionary architecture model (refer to section 6.1). SmartInk is currently the first release version which includes a limited functionality for note-taking activities.

- Mediator has some limitation includes accuracy in converting handwriting notes into XML format, performance of searching and query algorithms, and the slide of lectures for annotation should be imported from learning systems

There are some limitations in this study such as handwriting accuracy, input language, and unexpected user behaviour for drawing diagrams. However, our technique is still promising to provide note taker with the appropriate solution of development typical note taking application. In addition, one of this study limitation is the framework evaluation to test the reliability and validity of proposed framework in designing successful note taking application. The evaluation of framework should be performed by conducting an experiment study to ask experts about suitability and validity of proposed framework.

8.4 Further Work

The limitations described above require some further work to be done to overcome them as listed below:

- Recognition techniques should correspond to the complex situation of combining different languages during input notes and offer support for several languages.
- SmartInk requires additional functional increments to represent overall note-taking activities.
- Experimental evaluation requires studying the implication of SmartInk in learning outcome and achievements. Additional evaluation for SmartInk is performed to test the student performance using the different evaluation criteria of proposed framework. Further research is suggested to make a comparison study between two note taker groups using the SmartInk for digital note taking and the traditional note taking.

- Improving the mediator algorithms in terms of accuracy of converting handwriting notes, improving the XML representation for user notes, improve the overall performance of mediator background process, enhancing the procedure of searching and querying functions, and integrated the annotation functions of SmartInk to import the slide lectures from organization learning system.

8.5 Conclusion

Experimental evaluations were performed on SmartInk prototype to test its suitability in solving the issues of usability, efficiency, and effectiveness of the existing note taking tools. The data was analysed qualitatively (observation and server log) and quantitatively (survey questionnaires) to obtain the appropriateness of these solutions to transform paper based notes into digital notes. Evaluation of SmartInk showed that adaptation of our proposed solution in developing note taking application is successful. The significant results of SmartInk prototype evaluation indicate the suitability of frameworks in building the scaffold criteria of technology based learning tools.

The proposed guidelines keep the developers in the proper path for transferring paper based note into technology based notes. SmartInk prototype showed significant results on using mediation techniques to simplify note taking activities to be performed in more efficient time with reducing action overhead. Experimental results of integrated mediation tools in SmartInk support the mediator functionality, efficiency, and suitability for solving technology learning dilemma. In addition, SmartInk prototype evaluation results indicate that taking notes using digital device significantly improve user ability to create notes in efficient and effective ways. SmartInk is able to solve current limitation of note taking tools by reducing complexity, improving inefficiency by minimum action and reduce cognitive load, and resolving learning dilemma issues. This study illustrated the feasibility of transferring the traditional note taking tasks to be accomplished in digital devices. Technology holds the promise for improving the inherent benefits of notes by making them longer lasting, easier to manage, easier to review, and easier to share.

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APPENDIX A

Table A.1 SmartInk Implemented Functions

Functional requirements	Specification Context Description
1- Access System	Each user has account and data space.
- User authentication	User name and password required for login
- Update Information	Modify user profile
- Response System notification	Read, response, for system notification such as error, warning messages
- Change interface components	Add, remove specific interface components
- Change note styles	Change page view style
2- Entering Notes	
- Write hand notes	Allow Handwriting notes
- Handwrite drawing	Allow drawing using hands
- Type text notes	Allow insert text notes using keyboard
- Use system built in diagram	Insert built in system diagram
- Draw diagrams by mouse	Allow to draw diagram by mouse
3 – Accessing, Manipulate Notes	
- Add annotation, comments	Allowing to add notes, comments, and annotations
- Delete note elements	Allow to delete word, sentences, and diagram
- Select note elements	Allow to select specific note elements for later use.
- Move note elements	Change the location of word, sentences, and diagrams
- Highlight note element	Highlight specific note elements
- Search notes	Search about specific note elements by contents or creation date.
- Index, and linking notes	Ability to index or linking notes with other resources.
- Query information	Ability to query about specific information
- Import lecture slide	Ability to include lecture materials for annotating and write notes
4 – Organize Notes	
- Create subject	Allow to create subject folder to categorize note pages.
- Remove subject	Ability to remove subjects with its note pages
- Name page & subject	Ability to assign specific names for each subject and page notes
- Save note page	Ability to save notes
- Delete note page	Ability to delete notes
- Process multiple page	Ability to brows and open multi note pages
- Separate and move pages	Ability to move and organize multipage under specific subject.
- Backup Data	Ability to save all user work space for export and import purposes
5 – Collaborate Notes	
- Share notes	Ability to share note with specific people.
- Ask questions	Ability to send question to user group.
- Answer questions	Ability to answer of asked question.
- Include resource material	Ability to upload related resource information
6 – Internal system function	
- Record users activities	Recording user activities for creating, accessing, reviewing, and modifying notes
- Detect access location	Ability to detect user location from intranet or internet.
- Monitor user behaviour	Ability to track user behaviour during achieving note taking tasks
- Monitor user note style	Ability to monitor the preferred note styles that user used it mostly
- Interaction with user	Communicate with users by identifying errors, warning, and control

	message notification.
- Interact with Data Repository	Ability to communicate with data repository in creation, modifying, and deleting contains.
- Organize User Groups	Ability to classify user groups based on subjects, and class.

APPENDIX B

Table B.1 Guidance of SmartInk Functions.

Functions	Icon	Description
Annotation		This function allowed users to switch into annotation mode; an Open dialog appears to allow users for uploading the lecture slide for annotation.
Highlight		This function allows users to highlight their notes, or highlight materials in reviewing mode.
FullScreen Mode		This function allows users to make the system interface in full of the screen, and exit from full screen too.
Change Pen Colour		This function allows changing the colour of writing notes.
Change Input Mode		This functions allows users to change their input modes either keyboard or pen in reviewing mode only.
Tagging & Indexing		This function used to link specific elements of notes with other resources using tagging and indexing service.
Sharing		This function allows user to share their notes with specific users or groups.
Searching		This function allows users to perform search and query operations.
Navigation		This function allows users to navigate their notes in the same topic or subjects.
Delete Note and Topics		This function allows users to remove note documents.
New Topic		This function supports creating new subjects and topics.
User Setting		This function supports users to change specific setting in their interface such as style, interface components.
Change Pen Stroke Width		This function allows users to change the width of input pen.

APPENDIX C

SmartInk System Evaluation Survey

A- Usefulness Gained

1- SmartInk helps me to be more effective.

Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree

2- SmartInk helps me to be more productive on taking notes.

Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree

3- SmartInk is useful.

Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree

4- SmartInk gives me more control over note taking activity.

Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree

5- SmartInk makes note taking process easier to get done.

Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree

6- SmartInk saves the time when I use it.

Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree

7- SmartInk meets my needs for taking notes digitally.

Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree

8- SmartInk does note taking activities.

Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree

B- Ease of Use

1- It is easy and simple to use.

Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree

2- It is user friendly.

Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree

3- It requires the fewest steps possible to accomplish note taking tasks.

Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree

4- It is flexible, and effortless.

Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree

5- I can use it without guidance instructions.

Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree

C- Ease of Learning

1- I learned to use it for taking notes quickly.

Strongly Disagree , Disagree, Neutral, Agree, Strongly Agree

2- I easily remember how to use it for taking notes

Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree

3- I quickly became skilful with it.

Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree

D- Functional Efficiency

1- I found SmartInk act similar to traditional note taking

Very, Fairly, Somewhat, A little, Not at all

2- Did you find the SmartInk suitable for writing text in your notes?

Very, Fairly, Somewhat, A little, Not at all

3- Did you find the SmartInk suitable for creating drawings and diagrams?

Very, Fairly, Somewhat, A little, Not at all

4- Did you find the SmartInk appropriate for annotation lecture slides?

Very, Fairly, Somewhat, A little, Not at all

5- Did you find the SmartInk suitable for Sharing Notes?

Very, Fairly, Somewhat, A little, Not at all

6- Did you find the SmartInk suitable for searching Notes?

Very, Fairly, Somewhat, A little, Not at all

7- Did you use your system to access your notes off campus? Portability

Very, Fairly, Somewhat, A little, Not at all

8- Did you post question and/or answer other people question?

Very, Fairly, Somewhat, A little, Not at all

APPENDIX D

Table E.1 Survey Data Results for SmartInk

	Usefulness Survey Questions								**Ease of Use Questions**					**Ease to Learn**			**System Functional Efficiency and Usage**							
	Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q1**	**Q2**	**Q3**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**
1	4	4	5	5	4	4	3	3	4	5	5	4	4	4	5	4	4	5	5	4	4	4	3	4
2	4	4	5	4	5	4	4	4	5	5	4	4	4	5	4	5	5	4	4	4	4	4	4	3
3	3	4	4	4	4	4	5	5	5	4	4	5	5	5	5	4	5	4	3	3	3	4	4	3
4	4	4	4	4	4	5	5	4	5	4	3	3	4	4	4	4	5	4	4	5	5	4	3	3
5	4	4	3	3	4	4	3	3	5	4	3	3	3	5	5	5	3	3	4	4	5	3	3	2
6	3	3	3	4	4	4	5	5	5	4	4	3	4	5	4	4	4	4	5	5	4	4	4	5
7	5	5	4	4	4	4	4	5	4	3	3	3	4	4	4	5	3	4	3	3	4	4	3	3
8	4	4	5	4	4	4	4	3	3	3	3	4	4	4	5	4	5	4	4	4	3	3	4	2
9	4	5	4	4	5	5	5	5	3	4	4	4	3	3	5	5	3	5	5	5	5	5	4	4
10	3	4	4	3	4	4	4	4	5	4	4	3	3	4	5	5	4	4	4	5	5	4	3	3
11	3	4	4	4	4	5	4	4	5	4	4	4	4	4	5	5	5	5	3	3	4	4	4	2
12	3	4	4	5	5	5	3	3	4	4	5	5	5	4	3	3	4	4	3	3	5	4	3	4
13	4	4	3	4	4	4	5	4	4	4	4	4	4	5	5	5	4	3	3	3	4	4	4	2
14	5	4	4	4	4	5	4	4	4	3	3	4	4	4	4	4	4	4	5	5	4	3	4	2
15	5	4	5	4	5	4	4	4	5	5	5	5	5	4	4	4	4	4	3	4	3	3	4	5
16	5	5	5	5	5	5	5	5	4	4	5	4	3	3	4	5	5	4	4	4	3	5	5	3
17	4	4	4	4	4	3	4	4	4	4	4	4	4	4	4	4	4	5	4	4	5	5	5	5
18	4	4	4	4	4	5	5	5	4	5	5	5	4	5	5	5	5	5	4	4	3	5	4	3
19	4	4	5	4	4	3	4	4	3	4	5	5	4	5	4	5	3	4	3	4	3	4	3	4
20	5	5	5	4	5	5	4	4	5	5	3	4	5	4	3	4	4	4	3	4	3	5	5	5
21	3	5	4	3	5	4	3	5	4	5	5	4	5	5	4	3	5	4	4	3	3	5	4	3
22	4	4	5	4	4	4	4	3	5	5	5	5	5	5	5	5	4	4	5	5	5	4	4	4
23	4	4	5	5	5	5	4	4	4	3	4	5	4	5	5	3	5	5	5	3	3	5	4	3
24	5	4	5	4	5	4	5	4	3	3	3	4	4	4	4	4	5	5	5	5	5	5	5	5
25	4	4	4	4	4	3	4	3	5	4	4	4	4	4	4	3	5	4	5	5	5	5	5	5
26	4	4	4	4	4	4	5	5	3	4	3	4	3	3	4	3	4	5	4	3	4	5	4	1
27	3	3	3	4	4	4	4	4	5	4	4	3	4	5	5	5	4	4	4	5	5	5	5	5
28	4	4	5	3	3	3	3	2	5	4	4	4	5	3	3	4	5	4	4	4	3	4	3	2
29	5	5	5	5	4	4	4	4	3	3	2	3	3	4	5	4	5	5	5	5	5	5	5	5
30	3	3	3	2	2	3	3	2	5	5	5	5	4	5	5	5	3	4	4	4	3	4	3	1
31	4	4	5	5	4	4	5	5	4	4	4	3	3	3	4	3	4	4	5	5	5	5	5	5
32	3	3	3	4	4	4	4	3	5	5	5	4	4	5	5	5	2	3	2	2	3	4	2	1
33	4	4	4	4	4	4	4	4	3	3	4	3	3	5	5	5	5	5	5	5	5	4	4	4
34	4	4	5	3	3	3	3	4	5	5	5	5	5	3	4	4	3	3	3	3	2	3	2	2
35	4	3	3	3	4	3	3	4	5	4	4	4	4	5	5	5	4	4	4	3	2	4	3	2

36	4	4	4	3	4	3	3	4	4	4	4	3	3	4	4	4	5	4	4	3	2	4	3	1
37	4	4	3	4	3	3	3	4	4	4	4	5	4	4	4	4	4	4	4	3	3	4	2	1
38	3	3	4	4	3	4	4	3	4	3	3	3	3	4	4	3	4	4	4	3	2	3	2	1
39	4	3	3	3	3	3	4	3	4	4	3	3	4	4	4	4	4	3	3	2	1	3	2	1

APPENDIX E

Table E.1 Server Log event Entries

Server Events	**No. of Events**
Creating new topic	**137**
Deleting topics	**32**
Creating new notes	**543**
Deleting notes	**224**
Deleting note elements	**267**
Moving note elements	**78**
Highlighting note elements	**291**
Annotating Lecture slide	**356**
Drawing Diagrams	**309**
Tagging, indexing, linking	**172**
Searching & Querying	**183**
Reviewing notes	**257**
Inserting text notes	**154**
Sharing notes	**165**
Asking and answering questions	**79**
Entering words to users Dictionaries	**295**

Figure E.1 Chart of Server Log Events