A SmartInk: Mediator Solution of Technology Learning Dilemma for Digital Note Application

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Abstract— This paper proposed a novel solution for technology learning dilemma found on current note taking application. SmartInk system prototypes implemented with specific mediation tools to improve technology research progress for transferring note taking into digital age. Technology learning dilemma was addressed here as one of critical issues exists in most developed tools of note taking application. Initial results of conducted experiments for evaluation SmartInk prototype proof the strong ability of systems in solving current problem in terms of system efficiency, effectively, and usability. Our conclusion drawing here that mediation tools can be developed by using the powerful of technology to bridge the gap between traditional tasks of note taking and digital environments without losing learning consistency.

Index Terms— Digital Note, Educational Technology, e-Learning, Intelligent E-Learning Systems, Learning Development, Note Mediator, SmartInk, Simulations in Education, Technology Learning Dilemma.

1 Introduction

Note-taking is an important activity for supporting learning behaviours made by most people to record events and capture information for enhancing their memorization. Note taking is a shorthand process which allow large amount of information to be summarize and written on paper quickly. It is a complex human behaviour related to personal information management with a variety of underlying mental processes, and cognitive interactions [1]. Note taking research had begun early on 1920s, when Crawford performed experimental study to examine the impacts of taking notes during lecture on student's performance [2]. Education and learning theories research reported that note taking process has two essential functions for supporting learner activities, encoding and external storage. Encoding is a function of note taking that improves learning by affecting learner cognitive process and working memory. While, External storage is the produced notes which used to record information for reviewing purposes [3],[4],[5][6]. Moreover, research found that taking notes improves the ability of learn, integrate, and capture knowledge [7],[8],[9]. Furthermore, research reported that note taking improve students learning achievement and their academic performance because it is effect their recalling of external memory [10][11]. In addition, research reported that about 99% of students are writing notes, and 96% of them consider note taking as essential activity of their academic tasks [12][13].

Recently, technology was involved to change learning environment by replacing the traditional learning tools with digital devices such as projector, lecture slides, etc. Technology had achieved well in serving learning and education area, however a slow progress of technology was made for transferring note taking into digital age. Unfortunately, note taking as education tool is still struggling to be existed traditionally, even we are in the middle of digital revolution [14],[15]. 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. Moreover, digital note is providing us with several advantages such as auditability, legibility, portability, searchability, and extra functionality such as ability for indexing, linking, and information extraction.

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2 Related Works Review

2.1 Current Note Taking Tools

Several note taking applications have been developed to support note taking process in digital environments with various criteria such as active learning, active reading, information assimilations, and collaboration tools, where we classified them based on user group targets and system functionality components. For example, active learning tools were designed to support user activities of taking notes during classroom such as StuPad, NoteTaker, Classroom Presenter, E-Notes, and DyKnow [16],[17],[18],[19],[20]. While other system is concerned to support users for taking notes during reading information resources where annotation, highlighting, and adding comments functions were got high consideration for elaborating resource materials such as DigitalDesk, XLibris, PapierCraft, Paper-Top –Interface, and InkSeine [21],[22],[23],[24],[25]. Furthermore, some developed tools were focused more about the learning gain of collaboration, and sharing notes between users such as Tivoli, Livenotes, CoScribe, and NotePals [26],[27],[28],[29]. Additionally, several tools were developed to facilities note taking in handheld, and Tablet PC devices for performing specific tasks such as creating map concepts, enabling offline learning, annotation, sharing course structure, and semantic indexing [30],[31],[32],[33].

Many research groups were participated to move note taking towards electronic formats, and advised the suitability of us-

ing hand-held devices, Taplet PCs, and personal computers for note taking activities [16],[29],[34]. Hence, current note taking tools were widely diverse in their user targets, function components, interface layout, and their ways in achieving note taking tasks.
Based on our review of current tools, We found that current note taking tools not only fails in supporting the activities of taking notes, however they are surviving from several issues such as usability, mentality, and knowledge serving. Furthermore, developed tools were impacted learning features negatively, and included some learning deficiency. In this study, we investigated most of developed note taking tools to discover the issues and problems in behind the failure of current technology in supporting note taker tasks. Investigated study was performed to examine current note taking tools with its effects on current user practice, and its effects on learning functions. Although, there has been an increasing of note taking application over last decade, however current tools were miscarried, and failed to signify the traditional advantages and tasks of note taking.

2.2 Research Problem

Based on our review of current tools, We found that current note taking tools not only fails in supporting the activities of taking notes, however they are surviving from several issues such as usability, mentality, and knowledge serving. Furthermore, developed tools were impacted learning negatively, and included some learning deficiency**.** In this study, we investigated most of developed note taking tools to discover the issues and problems in behind the failure of current technology in supporting note taker tasks. Investigated study was performed to examine current note taking tools with its effects on current user practice, and its effects on learning functions. Although, there has been an increasing of note taking application over last decade, however current tools were miscarried, and failed to signify the traditional advantages and tasks of note taking. Since, focusing was given mainly in this study to address the technology impacts on learning practice of note taker, we investigated current note taking tools based on learning theories of note taker constrains and limitation. Our finding was drawn here that most of existing tools of note taking are suffering from various issues of learning insufficiency which summarized here under a term of technology learning dilemma. Actually, we found that this problem exists in preceding tools of note taking because of three main issues as described below.

Linearity issues vs. Free Form: most if not all of developed tools were used a text editors for creating and editing note documents which leads to break freedom roles of note taker activities. Using keyboard for writing note in linear way was recommended by specific studies because of faster typing speed, and gain advantages of electronic notes [17],[35]. However, the free form tools are recommended by other research for supporting users to write their notes in flexible matters, and efficient way [24],[36]. This issue made developers to confuse about the appropriate tool which is most convenience for taking notes either linear or free form tool.

Confliction of traditional and digital advantages: As discussed above, linearity and free form options were lead a conflictions issue to be occurred between the gain advantages of traditional and digital note taking. This confliction occurs because the linear system is gain advantages of digital notes but linearity is impacted users current practice, and increased system inefficiency in terms of disturb users, reduce their attention, and increase their cognitive load. Vice versa, users are habitually taking notes in a free form way which provided users with learning features by reducing user time and cognitive load, and also supported user graphical familiarity features where free form tools is caused to loss the advantages of representing note digitally. In contrast, this confliction in selecting the main tool for creating notes leads to delay the process of transferring notes into digital forms, and cause most developed application to fail in representing the note taking activities digitally.

Learning deficiency: Accordingly, current technology is contained some major learning deficiency which impact negatively learning process. For example, a copy-past function had been reported its impact learning negatively because it allows note taker to copy the text without even reading it. Our finding is agreed with similar research that using copy-past function on note taking application decreased the learner ability for memories knowledge well [14],[32]. Another example of learning deficiency is occurred in sharing feature, where studies reported that including such function in note taking system can be affected note takers to change their note taking behaviours, styles, and sometime lead other students to depend on active user notes instead of writing their own notes. Moreover, education research showed that sharing function is affecting the encoding function of note taking process which impacted learning outcomes [37],[38].
Specifically, we found that technology learning dilemma is exist in developed note taking tools because of many issues including the design decision mostly mad by system developers whom doesn't related to education area, the design tools developed without special consideration about learning roles and theories, and most developed tools had not evaluated well.

3 Design Decision

The main objective of this work is to offer a limited solution for technology learning dilemma of note taking application, and to contribute with others research for allowing note taking process to take place in digital age. Thus, for accomplishing these goals we identified a set of key objectives for mediating note taking application as listed below:

1- Solving the technology learning dilemma by designing specific tools to acquire maximum gain for both advantages of traditional and digital notes.
2- Introducing the powerful of technology to mimic the context of traditional notes, and to improve user gain learning functionality.
3- Making the process of taking note with technology more realistic for simplify the transferring process of note taking tasks into digital age.

3.1 SmartInk Mediator

Consequently, a prototype SmartInk is designed to be integrated with several tasks, where technology was employed

here to mediate note taking tasks that had conflictions or learning dilemma issues. In this research we avoided to design any tools that caused learning deficiency such as copy past, auto-summarization, and sharing functions because they required extensive studies for getting the right design decision.
Mediator note is used for providing changeover between traditional and electronic notes for utilizing the best advantages rather than trying to emulate each traditional task within digital note applications. Furthermore, SmartInk mediation tools was designed to provide user with the ability to create notes using handwriting with pen-based technology, where a background processes run to convert inked notes into digital form. Hence, using this technique is allowed both linearity and free form benefits to be gain. SmartInk was designed to allow users for entering their notes using free forms while transferring processes run in silent mode to generate electric copy of user notes. The SmartInk system is designed to generate the electric version of user notes automatically as illustrated in figure.

3.2 SmartInk Design

SmartInk system functions is delivered from user activities during note taking where we tried to implement these function to be similar as much possible with traditional activities. Table 1 is shown the list of developed functions of SmartInk system.

Table 1: SmartInk Functions

Functional requirements	Specification Context Description
Write notes	Using handwriting for writing notes
Handwrite drawing	Drawing diagrams and shapes
Annotation notes	Using handwriting to annotate material
Select note elements	Select specific note elements.
Erase note elements	Delete word, sentences, and diagrams.
Move note elements	Change the location of note elements
Highlight note element	Highlight specific note elements
Search notes	Search about specific note elements.
Index, Tag, and linking notes	Ability to index, tag, or linking notes with other resources.
Query	Initiate query operation
Import lecture slide	Include lecture materials for annotating and write notes.
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.

Server-client and data repository models were used for implementation SmartInk system architecture as shown in Figure 1. The client server model is used here to specify the higher level of SmartInk abstraction for addressing the interaction process between user interface clients with data repository in sever side. We identified the client side here as note taker devices, where server side represent the data service machine which contains the learning material, user notes, and lecture slides. Furthermore, client-server model of SmartInk was designed to support parallel interaction with data repository for multiple users simultaneously.

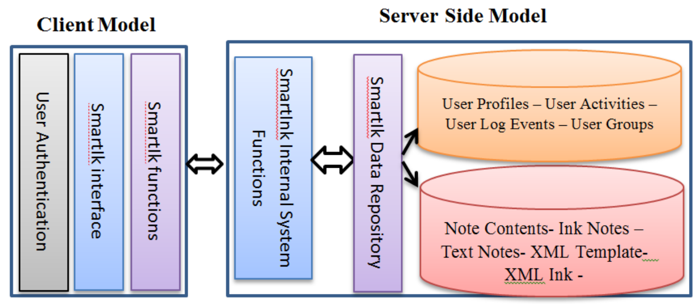

Figure 1. SmartInk Architectures models.

Although, Data repository model is used to store a large amount of data such as user information scheme, user notes, lecturer material, and electronic resource material in a central repository of SmartInk server side for allowing users to access, control, and maintains their own data schema. In addition, data repository model included database structure, and metadata objects where database structure store user information, user authentication roles, and user activity events, and the metadata represent the properties and attributes of notes, form layout, and user note documents in XLM formats.

3.3 SmartInk Implementation

SmartInk prototype was implemented to work on Tablet PC devices with pen-based technology to achieve our key objectives. Moreover, SmartInk prototype coded by using Microsoft C#.Net and Microsoft SQL server 2008. We selected C#. Net because it's a platform independent language which can be integrated within various operating system, and Tablet devices. Also, Microsoft SQL server selected here because it is suitability of implementing SmartInk models for creation data repository schemes, manages user storages, and storing the various types of note files.
Furthermore, several classes developed to implement SmartInk functions and interaction process with note taker users including **NoteDocument, NotePage**, **NoteElement**, **NoteTransformer**, **NoteViewer, NoteUser**, **XMLNote**, and **NoteAgent**.
The **NoteDocument** class is the superclass of SmartInk system which responsible for adding, removing, and organizing note topics, subjects, pages.
The **NotePage** class is a child of **NoteDocumen**t class which used to define the stored information in each page. **NotePage** is designed to be responsible for adding and removing note elements, keep information about page properties such as dimension, margins, and default page view.
The **NoteElement** class is a child of **NotePage** which used to identify the note elements in each pages, it is used for storing note element such as handwrite text and diagrammatic with element properties such as type, location, and dimension of each element.
The **NoteTransformer** class is a subclass of **NotePage** which responsible to track the user ink and to categorize user stroke components into shape, lines, paragraph, and chunks. Also, it is responsible to store ink note in data repository, where the ink note is converted into associated text note, and the dia-

ject which used as input for recognition module.

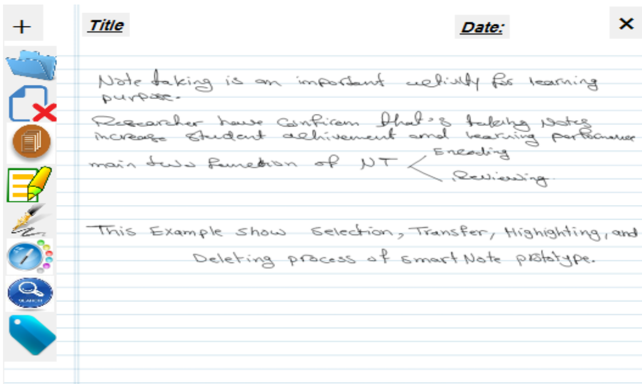

Figure 4. SmartInk note sample.

Converting ink notes into text: SmartInk prototype implemented to allow the ink note to be converted into text file and XML file automatically. Divider object is used in SmartInk system to analyse the ink elements, classify them into a group of data strokes, and save the results of layout in DivisionResults objects. The Divider object is used mainly to improve the recognition process of note elements via categorizing ink elements into related components for separating the text and drawing objects.

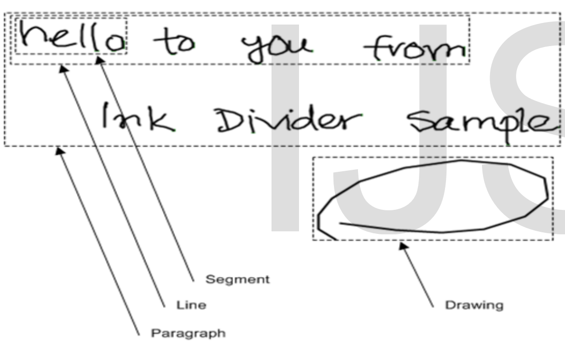

Figure 5. Divider Object Process Representation.

Next, the Ink strokes of text objects are sent to the recognition engine module, where recognition module is design here with limitation to recognize English language only. RecognizerContext object is run asynchronously to recognize a given collection of data strokes with two dictionary types Microsoft embedded dictionary and user dictionaries. In case of recognized text is not identified in both dictionaries, the unidentified word is stored in text files normally, and user notification is set to remind user for identifying it properly. The user dictionary is a file in data repository which identified mainly user abbreviation, shorthand word, and special user glossary words. Using this approaches allowed SmartInk to guess the best matches word with alternative possibilities about words, with capabilities to break the alternate segments into separate words and perform autocomplete, and autocorrecting for ink notes automatically. Finally, the results from recognition algorithm are stored in text file where each chunk is stored as text file, where XML file is generated to specify word properties such as coordinates, highlighted, indexed, and other XML attributes. In addition, ink note, text note, and XML note files associated together with index value for storing, and manipulating process, where each associated text file consider as an electric copy of original ink note file as shown in Figure 6.

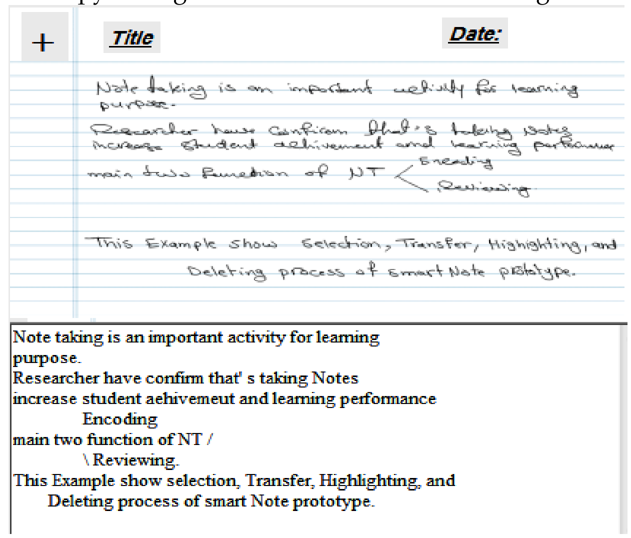

Figure 6. Demo for Ink note with generated text note.

Saving ink notes in data repository: SmartInk is designed to save ink notes in a database to facilitate digital tasks document such as editing, searching, and querying. In SmartInk server side the database is designed to store both versions of ink and electric notes in two individual tables, they are ink_note and txt_note tables. The ink notes table contains a unique identifier, the image data in fortified GIF persistence format, and length of data array. While the associated text note table contains unique integer index, the ink identifier, ink words in text, and chunk attributes such as the left, top, right, and bottom values of bounding box. A Useful metadata of ink notes is stored in database tables such as bounding box values, length of ink strokes, and other ink attributes such highlighted, bolded, indexed, tagged and underlined.

Selecting Note element: Selection process is considered as the pre tasks for achieving specific tasks of note taking such as deleting, transferring, highlighting, tagging, and linking functions. SmartInk prototype is allowed the selection of ink elements via pen tips, where InkOverlay object used to trace the selected area and return the strokes collection of user selection. The select process is designed to detect pen tips movements by determine the beginning and ending of stroke locations. A bounded box appears on selected area with three options for user desired operation such as deleting, moving, and highlighting tasks as shown in Figure 7.

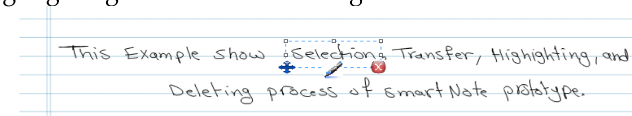

Figure 7. Example for Selection process in SmartInk.

Erasing, Highlighting, and Transferring note elements: The note element can be selected, sized, and handled appearance of four corners of bounding box to perform the note taking activities on note elements. After selecting elements, users can just simply strokes the pen tip on desired options for performing their tasks as represented in Figure 8.

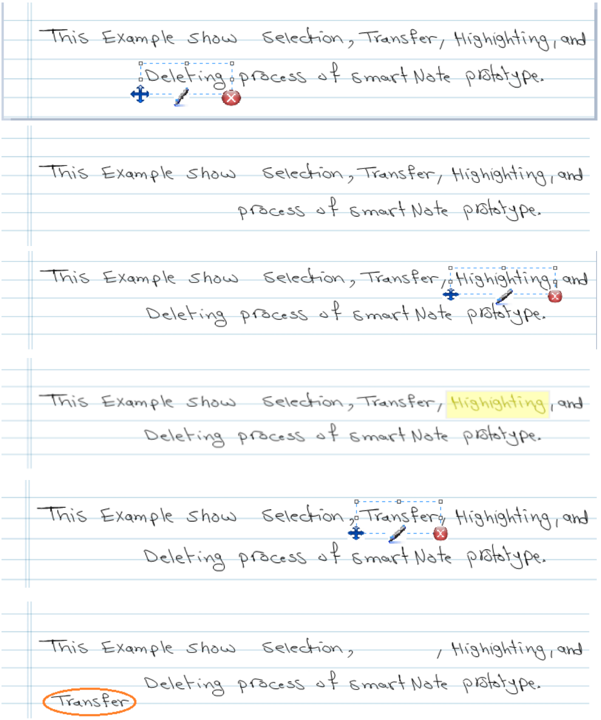

Figure 8. Examples for Erasing, Highlighting, and Moving note.

Searching, and querying: Searching and querying about ink notes are considered as one of fundamental purpose of digital notes which supports users for accessing specific information through one or more documents quickly. SmartInk prototype was designed to store ink notes in a database table as discussed previously. SmartInk prototype is designed to support users for searching about specific topics, paragraph, and words either by note contents or creation dates. Searching process is allowed users to initiate search or a batch search for purpose of creating query index of ink notes. In addition, searching procedure is executed to retrieve the index, ink identifier, and matched words from text_note table. Then the index, and ink identifier is used to retrieve the related ink document files where the stored attributes of chunks is used to identify the position of retrieved words. These functions is implemented with internal procedure in database to retrieve data fast, and display the results of found words in ink note files as shown in Figure 9.

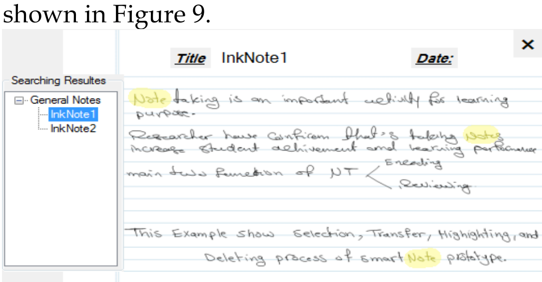

Figure 9. Example for Searching Process in SmartInk.

3.6 SmartInk Evaluation

Two combination evaluation approaches of survey questionnaires, and observation experiments were conducted for getting user feedbacks about system usability, and for validating efficiency of SmartInk functions. Students from different majors with less diverse are volunteered to use SmartInk system during their classroom for taking notes for seven weeks. Total of 35 students were volunteered for purpose of evaluation SmartInk system, where volunteers were 23 male and 12 female, from Twintech University at Yemen [39]. The hardware devices used for evaluating SmartInk system inside classroom were various Tablet PC devices; we used two Acer Iconia Tablet Pc, two Compaq TC1100 Tablet Pc, and one iPad Tablet. a total of five Tablet devices used for evaluation SmartInk prototype, where the SmartInk system was customized by using MonoDevelop software ver. 3.0.6 to work on apple OS [40]. Normal PC with powerful performance is used as a server machine and connected with device via intranet network. Five students are selected to use SmartInk system with the provided Tablet devices for taking their notes during classroom for one week only. At the beginning of each week, short introduction for ten minutes was given to the volunteers about using SmartInk in Tablet device for taking notes where volunteers had informed to take their notes by using English language only. Moreover, web based questionnaires is used to evaluate SmartInk usability based on System Usability Scale approaches [41]. In addition, server log files which contents the volunteer's notes and their activities are used to observe the efficiency of SmartInk functions.

4 Discussion

Evaluation experiments conducted here were designed to evaluate SmartInk system within two dimension, system usability and efficiency.

System Usability: Student feedbacks about SmartInk system were collected at the end of experiment period. SUS approached was used to calculate the usability scale of SmartInk system which considered as a simple and common approaches for giving usability scale as numerous value varied between 0 - 100. Analysing data of student feedbacks, and calculated the usability score based on SUS approaches was showed an excellent scored resulted approximately 93.2%. This higher rate is giving to the system due the specific design which constrained to be similar with traditional tools in appearance and functionalities. Students were very satisfied about using SmartInk to take their notes in Taplet PC devices.

System Efficiency: Accordingly, evaluation SmartInk system functionality and performance is conducted by observing students note contents and log events of user activities which stored in data repository. The server logs provide us with a very accurate and detailed summary about user activities and their usage including inked notes, electric notes, associated image diagrams, and user activities logs about usage functions such as create notes, highlight, erasing, tagging, and searching. We compared the user note contents with generated system note to evaluate SmartInk mediator efficiency. 25 ink note samples from different users with their electric text notes were selected randomly. We compared the ink contents with generated notes and found that around 76% of ink notes samples had transferred correctly, while around 11% of ink note had been identified in user dictionaries, and the remaining of 13% of ink note contents converted with some errors. These errors were mostly occurred because user writing notes in different axis, user font is not clear even to us, and due the space distance leaving between letters or words.

In addition, server loges was contented 454 entries of user activities created during experiment period, 193 entries was about creating, and deleting new notes, while the other enters were divided between other user tasks as shown in Table 2 below.

Table 2. Summery for Server Log entries and Usage.

System loge entries	No. of Entries	% user Usage
Creating notes	127	27.9%
Deleting notes	66	14.5
Deleting note elements	43	9.4
Moving note elements	26	5.7
Highlighting note elements	86	18.9
Searching & Querying tasks	57	12.6
Tagging, indexing, linking	49	10.8

We used the observation methods to verify that students had used all available SmartInk functions, and to know which functions were used frequencies, and which is rarely used. Table 2 showed that users had used some SmartInk system heavily including creating notes, highlighting note elements, deleting notes, and searching functionality. However some SmartInk functions were used regularly such as Tagging, Indexing, Linking, Erasing element, and moving element features. On other hand, we noticed that each user had used all system functions; however we need to perform other experiments to evaluate the intended of users with system functionality.

5 Conclusion

In this study, we found that mediation tools can offers a new vision for developing appropriate tools to mimic the actions of performing traditional note taking tasks. Furthermore, evaluation SmartInk was showed that using this technique makes user able to perform activities in more efficient time, and reduce action overhead. In addition, mediation tools developed in SmartInk system were approved its functionality, efficiency, and usability for solving technology learning dilemma which considered as one of essential problems that prevent note taking to be exists in digital era. In addition, current powerful of technology tools should be employed well to mediate the complicated tasks of learning which resisting to be existed in digital media. Even there are some constrains and limitation in this study such as handwriting accuracy, input language, unexpected user behaviour for drawing diagrams. However, our technique is still promising to provide note taker with the appropriate solution of several issues in previous note taking systems. The future of note taking is drawn based on learning advantages, and demand mainly to mediate the note taking activity, style, and behaviour into digital environments.

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