Potentials of Multi-Touch Interactions for Teaching and Learning

Adewale Oluwafemi Adesina
Department of Computer Science, Loughborough University, UK
waalsadesina@gmail.com

Abstract

There has been a lot of buzz around multi-touch devices since Apple released tee .Phone in 2007 and Microsoft unveiled their surface computer the same year. However, many of the applications developed were primarily for games, not many applications have focused on teaching and learning of key educational concepts. The multi-touch environment can be used to accommodate learners who prefer to learn by doing, and enrich the experiences of visual learners, leading to meaningful learning for everyone. B&), alternatives are being sought for the traditional point and click systems used for inputs (Bhuiyan and Picking, 2009) because they can be slow and cumbersome to use especially among the elderly (Kendon, 1997). Multi- touch devices are possible replacements. These developments have led to the evolution of different gestures for accomplishing certain tasks on the devices. The need therefore arises for serious applications to be developed using context- specific gestures so that intuitiveness of solutions and user interface issues can be investigated and standardised. This paper provides an overview of multi-touch hardware, products and market as well as their uses in education for teaching and learning purposes; it presents a synopsis of the emergence and historical development of multi-touch devices and products li- have become available. It also discusses findings from a group of computer science students that used an iPad to carry out diagramming tasks using an Entity-Relationship diagram modelling tool prototype. Test results Mowed diagramming tasks to be possible and students' recognition of the potentials of such applications in meeting their educational needs.

Keywords: Multi-touch, ICTs, open and distance learning, iPad, gestures, interactivity

Introduction

The world of Information Technology is a constantly changing, challenging and innovative one. Recent advancements in multi-touch technologies have opened doorways to the building of new teaching and learning methods. Research across cultures has shown that gestures are universal and are deeply integrated with other intellectual abilities (Kendon, 1997), also anthropological and psychological studies have shown that gestures are a central feature of communication and cognition (Wolff-Michael, 2001). Some pedagogical studies have also revealed that kinesthetic learning (Dunn, 2009) i.e. learning by using the body, hands and sense of touch is a powerful and ubiquitous learning style. Yet there are very few applications that utilise gestures on multi-touch devices for learning and instruction. The advent of mobile and multi-touch devices as consumer products brings about new opportunities for investigating new learning methods.

This work presents the historical development of touch interactions and utilisation of a multi-touch diagram tool for drawing Entity Relationship (ER) diagrams used for database modelling in computer science on the iPad in carrying out diagramming tasks. It investigates the intuitiveness of the contextualised gestures used to accomplish design tasks and seeks to ascertain whether or not multi-touch technology can enhance students' abilities to better comprehend and retain the knowledge of key ER modelling concepts taught in computer science classes. It then explores the opportunities and challenges of this mode of interaction.

Aim:

To develop a multi-touch drag interface for Entity Relationship modelling on iPad and evaluate its suitability for teaching and learning.

Objectives:

- to identify and evaluate existing multi-touch devices used for instructional purposes, outlining opportunities and challenges for this mode of interaction
- to identify the different types of multi-touch gestures that can be utilised in modem educational tools
- to investigate the suitability of the merge and split type gestures in diagramming tasks

- to investigate whether or not multi-touch technology using the iPad, enhances students' abilities to better comprehend and retain the knowledge of ER diagram modeling.

Literature Review

Multi-Touch Interaction Styles and Elements

In recent times, there has been a shift from desktop computers to multi-touch and mobile devices such as iPad, smart phones, tablets and hand-held devices (Potts and Moore, 2011). These devices can be used to complement class activities and provide opportunities for students to learn anytime, anywhere. The multi-touch surface enables humans, with their bare hands, to actually manipulate objects on the screen; the closest interaction between a human and machine. This discovery has spurred the development of applications for a variety of purposes. Research has shown that mobile devices can become a platform for extended learning and comprehension, which can facilitate effective teaching and learning (Stone and Livingstone, 2004). The technological advances have made the devices now capable of email, internet, GPS location and a host of other services thereby opening a floodgate for different applications. The platforms available for use include the Google Android, Palm OS, Apple iOS and Windows Mobile.

Evolution of Touch Interactions

The historical antecedents of today's touch interactions can be traced to 1953 when the first touch -sensitive technology was invented by the Canadian Physicist, Hungh Le Caine. The development of touch screens started in the 1960s. In 1963, Ivan Sutherland invented the sketchpad where objects were manipulated directly on the computer screen using a light pen. Early works done at IBM, University of Illinois and Ottawa culminated in the building of the touch screen terminal called PLATO IV in Canada in 1972 (Lee, Buxton and Smith, 1985). All these helped to define how we today interact with computers graphically. In 1985, the research group at the University of Toronto developed the multi-touch tablets. These touch tablets were capable of sensing an arbitrary number of simultaneous touch inputs that reported both the location and degree of touch. Several innovative products were subsequently developed and released over the following years, one of which was the release of the first smart phone in 1992 by IBM and Bell South. The introduction of the Apple's iPhone and the Microsoft surface computing brought about the popularity of touch- based interfaces. This development has enabled multi-touch technology transit from research, development and demos to mainstream commercial applications. The successful business model adopted by Apple through the introduction of the App Store for distribution of Apps significantly has helped to boost the popularity of the devices.

The innovations and breakthroughs allow us today to interact with our devices using the so called Natural Human Gestures; touches, swipes and taps. The wide ranges of multi-touch devices available today include table tops, tablet PC's, iPads, Whiteboards, Mobile phones and TVs.

Touch Gestures (Patterns) in Devices

Gesture is the umbrella term used to encapsulate any single interaction between the touch screen and user, beginning from the point that the screen is touched (by one or more fingers) and the time the last finger leaves the surface of the screen. For instance the Multi-Touch interface of iOS devices allows a user to interact with a device using one or more fingers on a smooth, consistent physical screen. The iOS processes a related series of touches by grouping then into multi-touch sequences with the following possible key events:

i. One finger touch on device
ii. A second finger optionally touches the device
iii. One or both fingers move across the screen
iv. One or both fingers lift off the device
v. A series of quick taps, such a double-tap

When a user interacts with the touch screen the hardware detects the physical contact and notifies the operating system. The operating system subsequently creates an event associated with the interaction and passes it to the application's event queue where it is subsequently picked by the event loop and passed to the current first responder object; the first responder being the object with which the user was interacting when the event was triggered (e.g. a button or view object). If programmed to do so the first responder calls a method when it receives the touch event and an action is performed (Boudreaux, 2009).

Touch Gestures types

There are several gestures being implemented in multi-touch devices today. Table 1 outlines the commonly used ones.

Table 1: Common Gestures

Common gesture	Description	Illustration
Tap	Used to do something/action/event	
Tap a nd hold (long press)	Selecting text or choosing items to copy	
Double tap	A common response is a portion of the screen enlarging or contracting e.g. a picture - Generally depends on the event	
Rotate	Rotating fingers m oving in opposite directions	
Flick	Quickly moving the finger across the screen e.g. flicking to move through pictures in the photo gallery or quickly scroll through a page	
Drag/pan	A more deliberate motion where a us er taps and drag s a finger across the screen. Drag can also be used to re-arrange items	
Pinch and stretch	Are two finger gestures (usually thumb and index finger) stretch to zoom in and pinch to zoom out and make something smaller	
Tap and hold an object with two fingers	The item closes, speciali sed for the photos' application.	

Opportunities and Challenges of Gesture -Based Interfaces

In 2011, Gartner (Top Information Technology Predictions) , a respected technology analysis and research company, predicted that sales growth for personal computers would fall from 15.9% growth down to lower than 10.5%. Sales of mobile devices are predicted to increase in coming years. Furthermore, at the 2011 Apples' developers' conference, the company reported that 200 million iOS devices had been sold. Twenty five million iPads were sold in the first 14 months (WENTK, 2010) and over 425,000 applications are available on the App Store with 90,000 iPad- specific apps. These show that multi-touch devices are increasingly becoming popular with users.

Opportunities

The real power of touch- based devices lies in multi-touch capabilities. Being able to touch points simultaneously brings about a new dimension of interacting with software and data, and allows for multi-user interactions. Touch provides a natural, real-world feel to interaction. Another advantage of multi-touch devices is that they enable efficient use of space, this is because the type of button needed can be generated on the fly depending on the circumstances, when required keyboards can be displayed and removed providing a great breath of flexibility. Multi point interaction allows more parallel interaction on large screens, users can collaborate on tasks the parallelism in multi-finger interaction can reduce time spent to carry out tasks (Apple).

For educational purposes, perhaps the most significant benefit of the multitouch environment is that they provide a feeling of activity which engages the learner on the learning activity [5] which is perceived to be lacking in traditional point and click systems. Many universities and educational institutions have started harnessing the power of these devices for teaching and learning. The iPad being a highly mobile device can be used for mobile learning i.e. learning that happens when a learner takes advantage of learning opportunities offered by mobile technologies. Some early adopters have reported using the iPad for quick skill drills, saving on printing, teaching music and keeping more organised (Medeiros, 2010)

Challenges

Despite the numerous benefits, multi -touch devices are not without challenges that need to be addressed. These are listed as follows:

i. touch- based devices have lower precision compared to point and click devices like the mouse
ii. every time users touch the screen, they may be sacrificing some kind of display because their hand can cover portions of the screen during an interaction thereby obscuring view
iii. most gestural interfaces do not have the ability to bring up alternative menu for objects as the right click action of a mouse does. Similarly drop-down menus do not work well and cut and paste is not very smooth. It is also hard to undo a gesture
iv. Don Norman (Norman) in his work analysed that, gestural interfaces could be a step backwards in usability- please give examples of these issues backwards. Apple, Google, and Microsoft have developed their user interface guidelines and often do not have consistent implementations of gestures. In Apple Mail for instance, to delete an unread item, users swipe right across the unopened mail and a dialog appears, allowing you to delete the item. This is not the case with the Android and Microsoft applications
v. Norman (Norman) also identified several problems with these interfaces that must not be overlooked; one of the problems identified is the lack of a set standardised interface due to the large number of third-party developers and the infancy of the technology
vi. the lack of adequate feedback also makes it difficult for users to understand why certain inputs are not recognised as intended, novice users might also have trouble understanding what to do if no indication of the result of a gesture is shown.
vii. often people with poor motor skills are not adequately catered for
viii. another drawback is that some actions can be troublesome to perform using a single hand, when wearing gloves or when having really cold hands
ix. users have to know gestures in advance before using the devices effectively
x. there is a steep learning curve especially for complex systems using

advanced gestures. **Entity Relation (E-R) Diagramming Application for the iPad**

An Entity-Relationship model helps to develop an understanding of the nature of data and its organisation into logical, systematic and structured form (Dawson, 2009). Peter Chen in his 1976 paper (Chen, 1976) proposed a data model which has become widely accepted, due to the fact that ER diagrams provide a visual conceptual schema of a system, it is widely taught in Information Technology and Computer Science classes. Research is needed to see if touch screen editing can enhance the development of ER modelling diagrams.

Diagram Modelling Tools

Several diagramming tools exist today with a wide variety of features. The Computer Science Department at Loughborough University worked to develop editors with unique features. The diagrams are drawn from a scenario, a method used for scenario text writing developed for controlling reasoning diversity can be found from the works of Batmaz and Hinde (Batmaz, 2007).The two main editor types developed are the web base solution and the PQ labs solution. These have been used successfully for data modelling tasks. The web- based version dubbed “Co-Draw” (Stone, 2007) was developed with PHP, MySQL and JavaScript while the PQ labs solution was developed with C# on .NET. Stone and Batmaz (Stone, Batmaz ; Rickards, 2010) have extended the capabilities of the editors to provide semiautomated diagram assessment functionalities. There is no native diagram modelling tool for the iPad; therefore, a third is required for further investigations. This need has led to the development of a third editor specifically for the iPad. The development was done using the Objective C programming language commonly used to build native applications for Apple's iOS devices.

Research Methodology

Research Design

The work is an action research and a survey. It involves developing an ER diagram prototype application for the iPad using Objective C programming language. The resulting prototype is then tested by a group of students who are required to produce diagrams.

Table 2: Equipment and Resource List

S No. Equipment/Resource	Comments
iPad/iPhone	For testing on the iPad and performing diagram editing task
Apple - Mac OS X Snow Leopard	Primary development operating system
Development Tools: X code, Interface builder & Instruments	Required for Provisioning devices Testing codes Submitting applications to the Apps store
- Apple Developers Registration	Essential for integrating test environment with actual device

The diagramming application should assist students carry out the following data modelling tasks:

i. load a scenario text in multiple sections allowing the user to move back and forth as desired
ii. create entities by using the drag gesture to drag a noun phrase from the scenario to the diagram portion of the editor
iii. create attributes by dragging a noun phrase from the scenario and dropping it on the entity
iv. create and label relationships between two entities appropriately
v. specification of cardinalities between two entities
vi. users should be able to arrange the position of the objects on the screen to desired positions
vii. users should be able to merge entities and name the newly merged entity appropriately using an onscreen keyboard
viii. users should be able to split entities and name such using the onscreen keyboard
ix. there should be provision for users to specify the primary key for the each entity

x. users should be able to delete an entity, attribute or relationship when desired.

Participants

The population used for the study was all students pursuing Computer Science and Information Technology degrees at Loughborough University, UK. The students were all taking course modules on database design and analysis. The number was thirty five (N), participants were eleven volunteers (n) chosen at random from the class. Each participant was given an iPad with the application installed on them and was asked to create diagrams from two different case scenarios. On completion of the diagramming tasks, the participants were asked to complete the test instruments.

Instrument and Data Sources

Questionnaire, designed by the researcher, was used to collect data. The instrument consisted of three sections. The first section called Part A asked questions on the usability of the application. The second set of questions Part B further asked questions on the suitability of the merge and split gestures introduced for diagramming operations. Part C questions investigated participants' perception of the educational advantage or otherwise of the tool. The items were structured on a five-point Likert scale comprising the following options: *strongly agree, agree, neutral, disagree* and *strongly disagree.* Respondents were asked to indicate how strongly they agree or disagree to the test elements.

Validity of the Instrument

According to Kerlinger (1986), validity is the extent to which response or answer given is the true measure of what the researcher expects it to mean. Two professors from the Department of Computer Science at Loughborough University, UK established the validity of the instruments. The panel assessed the content of each item and of the test as a whole for content validity and appropriateness of the items. Additionally, the study was based on a broad review of research and related works.

Data Collection Procedure

After the development, provisioning and testing of the application on the iPad, the participants were presented with a scenario case study and asked to construct ER diagrams by dragging words (noun phrases) from the scenario to the diagram pane of the screen. They were then asked to create relationships between the attributes dragged to the pane. The users were also to carry out the diagram editing tasks of merging entities, splitting entities, moving and deleting diagram components. At the completion of the exercise each participant completed the test instrument administered.

Results and Discussion

The ER editor enables users to create diagrams on the device using drag and drop finger gestures. A screen shot of the developed application is shown in Figure 1. The tool allows for the creation of entities, attributes and Relationships. It also allows for using merge and split gestures for diagram editing tasks.

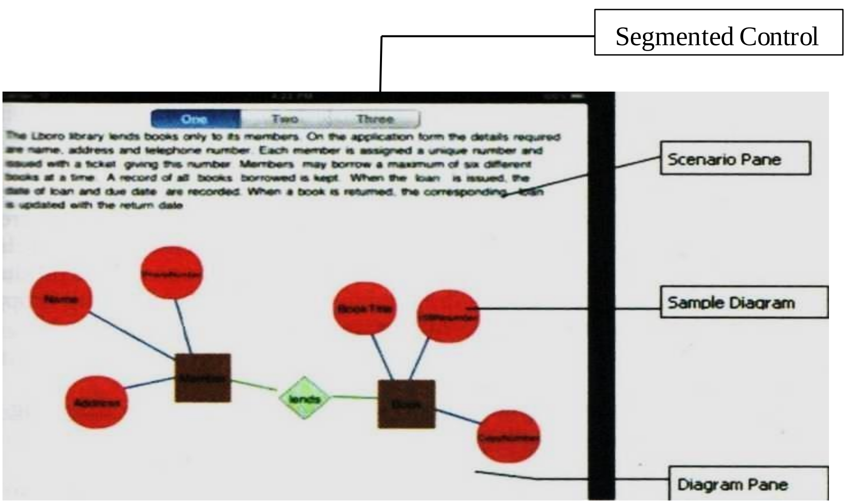

Fig. 1: ER Diagram Modelling Prototype on the iPad

Entity Creation: Simple drag and drop gestures are used to create entities. A user selects and drags a copy of the noun phrase from the scenario pane to the diagram pane. The process of dropping the noun phrase creates an entity based on the noun phrase.

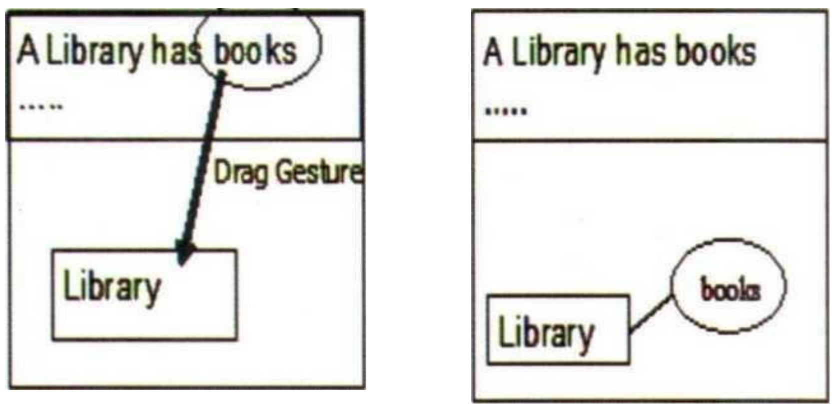

Fig. 3: Dragging a noun phrase from the scenario pane to an entity creates an attribute

Creation of Relationships: The creation of relationships involves two attributes on the screen and requires two fingers on two points on the screen. Participants are required to find a sentence from the scenario which relates the two entities and then simultaneously touch two points on it. This produces relationship diamonds which is dragged to the diagram canvas and dropped on the entities to create a relationship between them.

Component Deletion: A components is simply deleted by dragging the component away from the diagram pane back to the scenario pane.

Merging of Entities: To merge entities, the respondents are required to tap and hold (anchor) the two entities and then drag the entities toward each other until the edges meet. This action merges the two entities into a single entity 2nd presents the users with an onscreen keyboard to give the merged entity a new name.

Splitting of Entities: To split entities, participants are required to tap and hold one of the entities and drag the attached attribute away from the entity element. This creates a new entity with an attribute component attached to it. The new entity can be labelled with an on screen keyboard.

Usability test seeks to ascertain the learnability- and ease of use of the application determining how the application works for non- experts, how users have learned the design and how quickly they can perform tasks. According to Nielsen and Shneidermann (Nielson, 1994), the concept of - usability can be divided into five core parts learnability, memorability, error level, efficiency and satisfaction. The test questions targeted these core parts: An essential element of the test was to investigate the feasibility of normal users with no experience with the iPad application carrying out the diagramming tasks using the multi -touch features and also to find out the merits or otherwise of the tool on the database modelling course being studied.

The first part of the survey investigated the usability of the editor to carry out basic diagram creation and editing; the second part investigated the suitability of merge and split gestures implemented while the third examined :he overall educational value of the tool.

Part A

This part investigated the usability of the iPad editor to carry out diagram editing tasks.

Figure 4 presents the results from investigations on learner's ability to carry out diagramming functions using the multi-touch gestures.

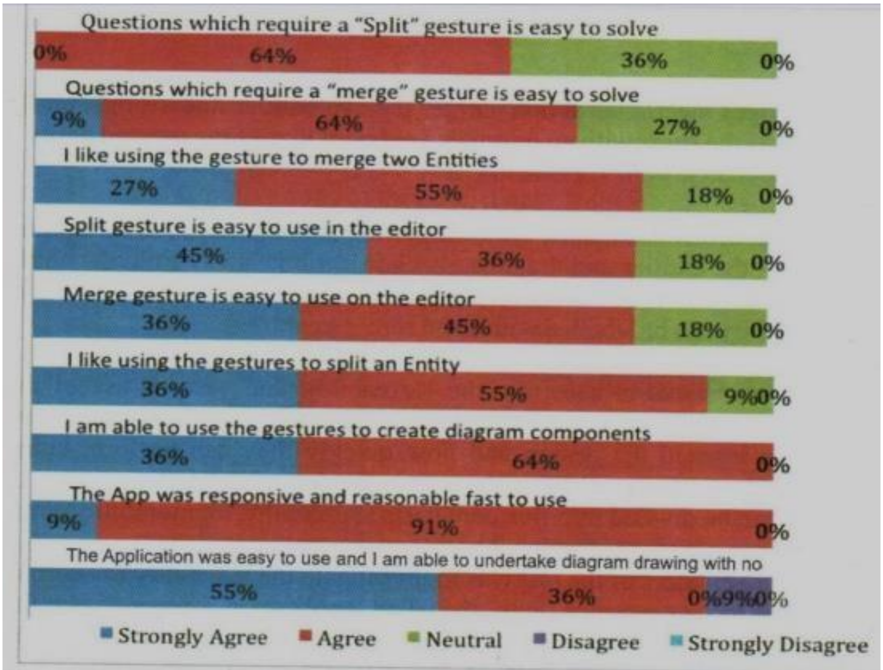

Fig. 4: Ratings on Using Multi-Touch Gestures for Modelling Tasks

The survey results show that users are able to carry out diagramming tasks with the gestures. All the respondents strongly agree (100%) to the statements that they are able to easily create entities and attributes. This confirms that the gestures are usable on the iPad as was with larger multi-touch devices. Responses to statements on using merge and split gestures had 45% and 36% respectively strongly agreeing that they can perform the tasks. Deletion of components received high rankings indicating that the users were very comfortable with the gesture for the tasks. Creation of relationships and changing of cardinalities had the lower percentage ratings this is probably because performing the tasks take more than one step and it took the participants longer time to learn and use the gestures . The two gestures can be improved on.

PartB

This section further investigates the suitability of the merge and split gestures for diagramming operations the survey questions and results are presented in figure 5

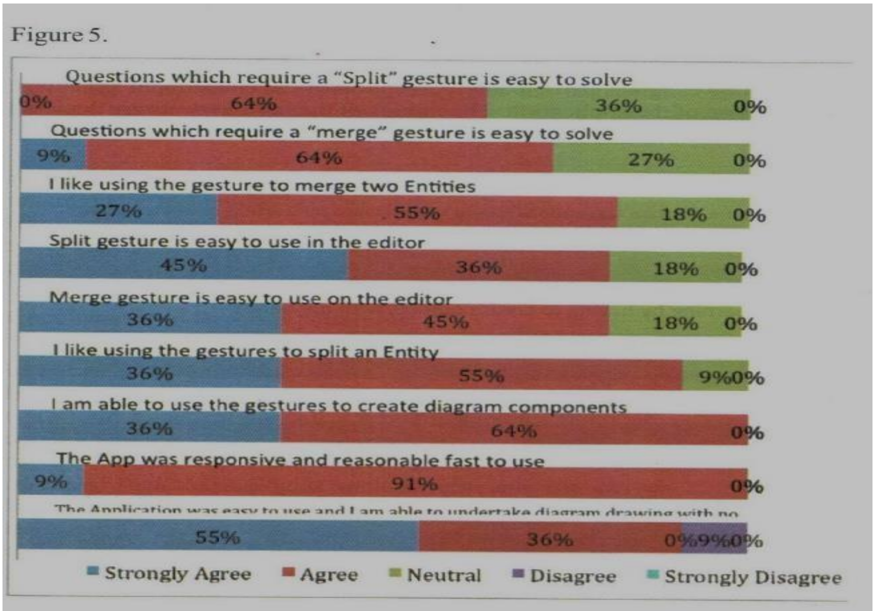

Fig. 5: Ratings on the Suitability of Merge and Split Gestures

According to the survey results, 36% of respondents "strongly agree" and „4% "agree" to the statement that they are able to use the gestures for diagram editing. However, there are no significant differences between ratings for the merge and split gestures. Generally, the respondents found the gestures more challenging to use compared to the creation of simpler diagram components like entities and attributes. This may be because case scenarios that require participants to use the gestures are perceived to be more difficult and challenging.

Part C

This part investigates participants' perception of the educational advantage or otherwise of the application. The ratings of the test elements are depicted in Figure 6.

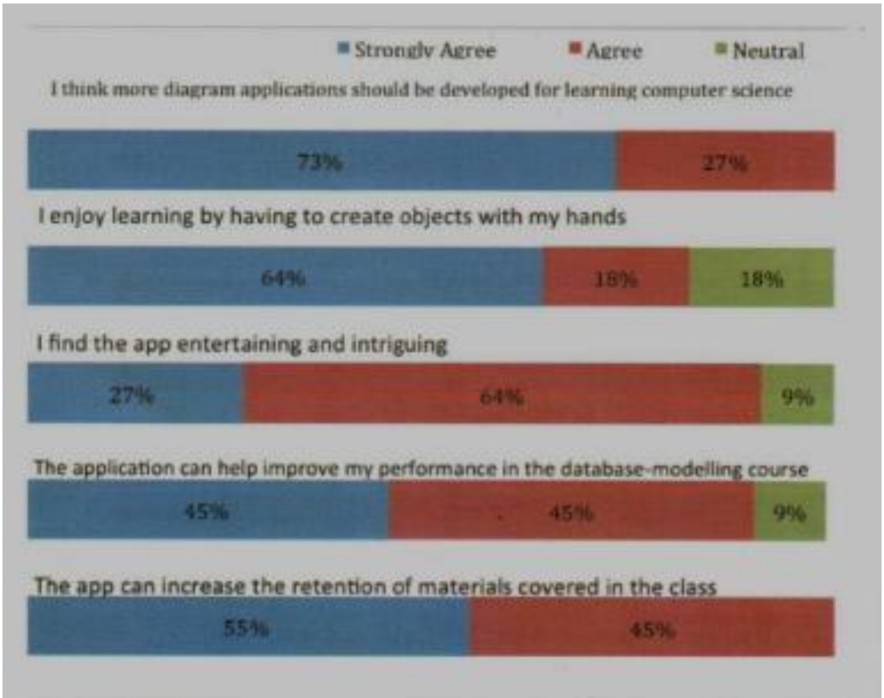

Fig. 6: Ratings for Questions Investigating the Educational Value of the Application

The first question assessed participants' agreement to the fact that the tool car help them understand and retain concepts taught in the class. Here 55% of respondents "Strongly Agree" and 45% "agree." These show that they believe that it has some high cognitive value. However, they were not as certain that it can help improve performance or grades.

On the question determining if the users thought the tool was entertaining and intriguing, only 27% strongly agreed with the statement. This may be because users anticipated more interesting features like animations and sound effects as they have come to expect from interacting with games

However, the respondents foresaw' an interesting range of possibilities regarding the technology because of the high positive ratings to questions on learning to create objects with hands and the development of more diagram type applications. This suggests that the participants were favourably disposed to using gesture- controlled diagram applications in their studies.

Conclusion and Recommendations

Innovations in hardware, software, interactive design, and pedagogical studies are expanding our understanding of design considerations for educational applications in a modem society. Multi-touch devices are coming of age and can be exploited for instruction as the applications can engage learners when they carry out learning activities. The benefits of adopting such technologies include efficient use of space; multi-user interaction quick skill drills and excellent pedagogical value for kinesthetic learners (Potts and Moore, 2011). Current challenges include low precision compared to point and click devices, lack of universal standards for gestures implemented by different vendors, and lack of adequate feedback to users when interacting with the devices with gestures.

A group of Computer Science students were able to successfully carry out ER diagramming on a prototype iPad application using contextualised gestures. Users were able to use drag and drop gestures, perform merge and split operations to create diagram components. The users recognised the applications potentials in helping them to understand concepts taught in database modelling courses.

Further works should be carried out on standardising gestures implemented on multi-touch devices leveraging on well tested usability and pedagogical studies. The gestures used to carry out merge and split operations can be further improved. Also, adequate feedback during design and implementation should be incorporated to increase performance and decrease the learning curve for new learners.

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