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UNIVERSITY OF CALIFORNIA, SAN DIEGO

Study of Split Screen in shared-access scenarios- Optimizing value of PCs in resource-constrained classrooms in developing countries

A thesis submitted in partial satisfaction of the requirements for the degree Master of Science

in

Computer Science

by

Divya Kumar

Committee in charge:

William Griswold, Chair
Ingolf Krueger
Beth Simon
Sukumar Srinivas

2008

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Chair

University of California, San Diego

2008

DEDICATION

To my parents

EPIGRAPH

“Tell me, I’ll forget
Show me, I’ll remember
Involve me, I’ll understand “
- Chinese Proverb

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ABSTRACT OF THE THESIS

Study of Split Screen in shared-access scenarios- Optimizing value of PCs in resource-constrained classrooms in developing countries

by

Divya Kumar

Master of Science in Computer Science

University of California, San Diego, 2008

William Griswold, Chair

Cost restrictions in developing countries result in multi-user, shared-access scenarios preventing each user from having exclusive access to a computer. Increasing student enrollment raises technology demand in classrooms. Despite collaborative learning practices, skewed user-computer ratios continue to result in unequal opportunities for independent learning.

This research studies students sharing a PC using a novel Split Screen User-Interface concluding that it enables students to achieve benefits of both independent and peer-supported learning. This interface allows two co-located students to share one computer, interact with independent Windows Desktop sessions through the same display using separate input devices.

The thesis draws conclusions from a study conducted in a computer education school in Bangalore, India. Qualitative observations of two user groups are analyzed and a comparison is presented. The first group retained traditional 'Shared Screen' practice while the second group employed 'Split Screen' mode. Although the experiment did not account for significant quantitative difference in performance between the two groups (as the sample size was small), detailed observations show that students in Split Screen group had the natural tendency to become individual learners, but there were ample evidences of peer-assisted learning. This confirms the thesis that Split Screen offers students the active and independent involvement opportunity of First World classrooms while retaining peer learning behaviors of traditional classrooms in developing countries. Although there are some usability constraints that prevent universal applicability, Split Screen potentially maximizes the value of existing computers while ensuring that educators retain their flexibility to design learning structures and methods.

Chapter 1.

Introduction

Over the last decade, the Information Technology sector in developing countries has seen radical growth. Countries like India and China in particular offer increased economic opportunities for outsourcing and software industries. The relevance of computers is becoming critical in both IT and non-IT areas [1]. In a country like India with a large population, high unemployment rates and severe competition it becomes a necessity for all job-seekers to be equipped with minimum computer knowledge to qualify them for better jobs. This demand for computer education has led to the establishment of firms that provide basic computer education. Besides traditional schools, colleges there are thousands of organizations, NGOs and institutes distributed across the spectrum of developing countries providing what is termed as IT skills training and education [2]. IT skills can range from basic computer know-how to advanced programming language expertise. Graduates from these classrooms are equipped with official certification qualifying them for the job market. Besides vocational computer education, these classrooms also provide some life skills training for their students. Students who typically come from low-income groups and poor schools are trained to become better communicators and team players.

However infrastructure in most of the classrooms is crumbling [3]. With schools and colleges ill-equipped with the appropriate volume and quality of computers, it is not uncommon to find several students pooled behind one computer

and few qualified tutors to manage them. A few well managed classrooms effectively employed available resources by allotting specific time slots for students and tutors. However limited availability of tutors and social pressures on students to attend classes in groups, make computer sharing inevitable.

Sharing becomes painful when there is only one access channel [3][4]. In this case the PC is the resource and one pair of keyboard and mouse becomes the bottleneck. Since students are compelled to work together there are benefits to the scenario that the tutors would like to retain. However this system lends itself to a tricky situation- since the mental models being reinforced are not the same across students, without independent learning individual testing will not be suitable. Unfortunately course structures are designed such that students are evaluated individually in final exams even when they may never receive the opportunity to practice individually.

A closely related resource crunch can be observed in classrooms fostering Computer-Aided Learning in education [20]. In such scenarios, even up to six students can be seen behind one computer! With classrooms unable to afford more PCs or even monitors, different educators attempt to overcome these shortcomings differently. Pal et al [3][21] talk about teacher interventions- shuffling seats and redesigning on-screen content to support multiple users, to ensure all students interact. In commercial environments such as small businesses sharing is inevitable (explained in detail in Appendix B). Users resort to time-sharing even if it means loss of revenue. Nevertheless, there are benefits to sharing. Much has been written about the merits of

learning with and from peers [22] and it seems as if these resourced constrained classrooms may not all be lagging in learning opportunities. Part of this research studies the shortcomings of sharing a computer in a classroom while extracting the beneficial aspects to such sharing practices. Therefore it leads to the question whether solutions that stem from optimizing the value of an existing PC, retain benefits of sharing?

An earlier work, the MultiPoint [5] project proved the value of providing each co-sharing student with his own mouse to increase engagement with computer-aided learning software. Therefore all students sharing one PC can simultaneously participate in a learning process brining down the per-user involvement cost to the cost of the additional mouse (~ $5). Successful adoption of MultiMouse led to the invention of Split Screen.

Split Screen is a user-interface of the Single Display Groupware [6][7] paradigm. It allows input from two independent sets of mice and keyboards connected to the same PC. The interface runs two Windows Desktop sessions each occupying half the screen space. Each session has a unique input channel, therefore one keyboard and mouse pair is tied to one session. This implies that two users can work independently on the same PC and monitor just as they would in separate PCs. The only limitation is the diminished screen real estate available to each user i.e. horizontal resolution for each screen is halved. To what extent does this impair usability? Can Split Screen be employed in real-world scenarios? These questions drive much of the research on which this report is based.

This thesis studies Split Screen in a traditional IT education environment in developing countries. It posits that tight-budgeted classrooms that want to reinforce IT training along with peer learning skills will find Split Screen a cost-optimizing alternative with minimal disruption to existing pedagogical practices.

Chapter 2 explains the current prototype of Split Screen User Interface in more detail. Chapter 3 describes the experiment designed in an actual classroom where many of the above described problems are prevalent. Chapter 4 describes experiences in a traditional classroom with shared-use and analyzes the merits and demerits of the same based on observations from the study. Chapter 5 highlights the key observations in Split Screen mode with emphasis on peer-oriented behavior and usability. Chapter 6 reflects on the two experiences and presents a comparison. Chapter 7 discusses ways to further Split Screen adoption and improvements that can be made. Chapter 8 concludes the analysis of this research.

The two appendices at the end of this report summarize independent projects on Split Screen. Appendix A describes usability tests that were conducted to assess user performance on various word processing tasks in Split Screen mode. Appendix B reports findings of an ethnographic study conducted in small businesses in Bangalore that depend on a PC for day to day activities. This study was done to understand if Split Screen is a valuable proposition for businesses.

1.1. Alternative approaches to the problem

Most work in optimizing the display to support multi-user inputs falls under the Single Display Groupware (SDG) paradigm. SDG is a software model which

enables groups of users to perform actions simultaneously by allowing the application to communicate with multiple input-devices. SDG are being used in various applications in the educational, entertainment and research communities. There are specific works that study collaboration, gender and privacy ware [5][8][10][12][13]. Most innovative SDG techniques were developed with co-present collaboration as the goal or consequence of sharing display. Cost constraints were secondary. Interesting research done in classrooms is available. Inken et al [21] describe their experience with 'Give and Take' control passing protocol examining the effects of having one mouse per user for two users of the same computer. Like MultiPoint research the study focused on Computer-Aided learning methods on much younger group of students. KidPad [9] , a collaborative drawing tool aimed at young children showed that having separate input devices eliminated passive user shortcomings in task engagement while promoting peer-teaching. Tivoli [11] is an electronic whiteboard that introduced novel interaction methods (such as gestural commands). Another whiteboard project is Pebbles [14]. It allows multiple users to send inputs to a shared PC from individual PDAs without having to use keyboard or mouse. All these applications allow multiple users to share one system overcoming the input bottleneck while reinforcing collaborative possibilities. However given their existing requirements of hardware and infrastructure, their relevance in Third World classrooms is questionable, even if interesting concepts can be incorporated.

Companies like *N-Computing* [15] offer multi-user computing solutions for classrooms with multiple consoles connected to a host computer. Each console

includes a monitor, keyboard and mouse for each user. This is an encouraging solution for classrooms rich enough to afford one display per student. However, collaborative possibilities are yet to be tested.

Chapter 2.

Split Screen User Interface

Split Screen User Interface (SSUI) is a GUI in which two Windows sessions run concurrently on one display. Essentially, the screen is split into two halves each running independent Desktops. Each Desktop takes input from independent pair of USB mouse and keyboard. Therefore two users can simultaneously engage in Desktop sessions from one PC, without having to share a mouse and keyboard.

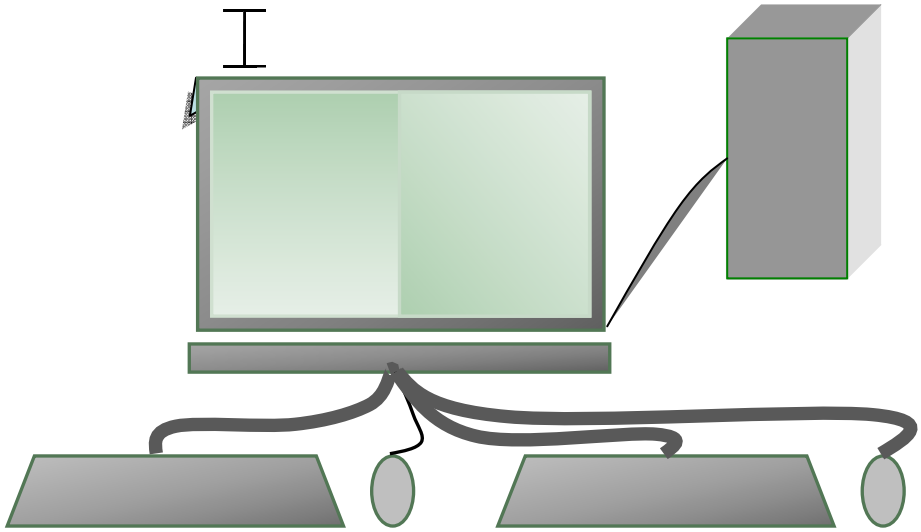


Figure 1. Diagram of Split Screen hardware

The current prototype delivers two instances of Windows Server 2003 to each screen. Each screen is allowed half the screen's horizontal resolution. The prototype allows each Desktop to run many applications (MS Office, Web Browsers) concurrently without noticeable difference in user response time. SSUI application

supports input only from USB mice and keyboard. Each Desktop corresponds to a different user account. Neither user has the privilege to access another user's directories.

For the sake of clarity, a user will henceforth be addressed as left or right user based on which Screen he occupies. Corresponding screens and devices will also be termed left and right (Left mouse, left keyboard and so on). A co-user refers to the left or right user who occupies the other screen. Owner is termed as the user who occupies a screen i.e., owner of left screen is the left user.

2.1. Screen Lock

The Screen Lock icon at the bottom of each screen, when enabled confines the keyboard and mouse inputs from the user to their respective screen. By default, the screen lock is enabled. A screen can be locked or unlocked only by using the owner's mouse. When disabled, the co-user can move his mouse to this screen and interact with the applications. However, the prototype does not extend this privilege to keyboard inputs from the co-user. This means that if a user wants to enter data into his co-user's screen, he would have to use the co-owner's mouse. This is only the limitation of the prototype and this could be overcome in the final Split Screen product.

2.2. User Privileges

Since the rest of the hardware is shared, users access common devices such as hard disk, CD drives and external devices. Currently, both users are given the same privileges to access files from other's directories, install applications etc. A short-cut

was present in both desktops that served as a common folder for both users in case they wished to share files. In places were SSUI was tested, security was not an issue and hence no changes were made to enforce security.

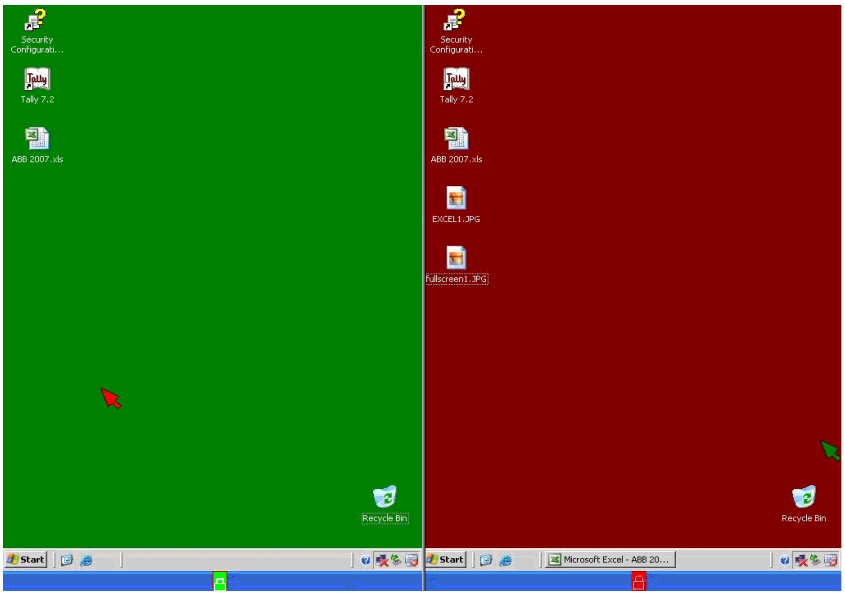


Figure 2. Split Screen UI. Screen lock enabled on right screen and lock disabled on left screen

2.3. Mouse Cursor

Two unique mouse cursors are hard-coded to red and green arrows respectively to distinguish the two cursors. Disambiguation becomes necessary when both users are moving their mouse on the same screen. Therefore for all the interactions, both the cursors remain as colored arrow icons and do not take other forms (crossbar, hourglass etc.).

Chapter 3.

Experiment Design

Hope Foundation is a non-governmental organization that provides computer skills education for thousands of students across the country. The qualification to enroll in Hope's program is a certificate for having completed 10^{th} grade or the provable ability to read and write English. Students register for a three-month course and are taught MS Word, MS Excel, PageMaker and Corel Draw, along with other basic computer skills. A final exam is conducted at the end of the period and a government approved certification is given to the students. Students enrolled in college are eligible to be taught Tally (popular financial account software).

The profile and infrastructure of a Hope computer center represents a typical computer training classroom in developing countries- shortage of computers, tutors and high student enrolment. The Hope center that volunteered for the experiment had 20 full-time students who participated in the program. Student participants came from a variety of backgrounds and ethnicity- Hindus, Muslims, Christians, Tamil, Kannada and Hindi language speakers.

3.1. Program structure

The idea is to replicate a course pattern and structure, very similar to the center's existing setup. A curriculum teaching MS Power Point was chosen since it was an application relevant for job-seekers and none of the students had any experience in it. The curriculum was designed with the supervision of the tutors and

many PowerPoint tutorials and handbooks from leading IT training schools were referenced.

3.2. Class structure

There were 11 one-hour long classes in all. Each class began with a 5-15 minute long tutorial of new features introduced to the class. Following this, all students are given assignment sheets and spend the rest of the hour practicing exercises. Each exercise was drafted to reinforce a new skill. The question is decomposed into a set of binary tasks to be completed. For example,

1. Creating Custom Animations:
   "Add an animation called 'Blinds' to the picture in Slide 5"
   - Select the picture on Slide 5
   - Select Slide Show-> Custom Animation
   - In the Custom Animation task pane
     - Select Add Effect-> Blinds
     - Select the following options
       - Start: On Click
       - Direction: Vertical
       - Speed: Medium

The final exercise in each class involves an open-ended task where students are expected to create PowerPoint presentations employing newly learned features. For example, 'Create a PowerPoint file with at least 3 slides, describing your favorite religious festivals.' The final exercise was attempted only after the student successfully completes all other exercises with the approval of the tutor.

There were two Hope instructors who served as tutors for the students in class. It was ensured that both batches of students were given the same instructions from the same tutor at a given day. Although there was no formal evaluation of assignments, at

the end of the class tutors review the files and students make respective corrections. This feedback served as a way to hone skills and ensure that students have understood the day's lesson.

3.3. Pretest

A practical exam was conducted at the start of the program to determine existing computer skills of the students. The exam consisted of basic computer skills questions (such as creating new folders, moving files) and some questions on PowerPoint, to understand students' proficiency in transferring skills from other known MS Office applications. Students also took a self-assessment questionnaire providing details on their computer experience, education and language proficiency.

3.4. Final Exam

A final exam was conducted covering all the topics taught in the program. The final exam pattern was based on official Microsoft certified Office Specialist exams. The grading was also based on the same lines. Each student has individual PCs for the exam alone. Results of this hour long exam showed that both groups faired equally, with 65% accuracy. Since the number of students in each group was unequal and not large enough to be of statistical significance, this research will refrain from quantitative analysis.

3.5. Groups

Students were sorted into two groups based on Pretest results and experience. Both groups were given the same lecture, tutorials, assignments and instructions. The first group saw pairs of students using a computer in Shared Screen mode, while the

second use of groups used the computer in Split Screen mode. Each student was given an individual task sheet, all exercises stayed the same. The Shared Screen group never got to use the PC in Split Screen mode and vice-versa.

In both modes, students were allowed to attempt the exercises anyway they wished- by working collaboratively or independently.

3.6. Shared Screen Mode

Two students share on PC. The PC runs only one Desktop session and is provided with only one keyboard and mouse. This simulates the resource-constrained situation in traditional classrooms. This is also how Hope students have been accustomed to using a PC- by sharing it with another user.

3.7. Split Screen Mode

Two students share a PC that runs SSUI. Therefore there are two Windows sessions running and each student is provided with independent mouse and keyboard.

The screen lock feature of SSUI was demonstrated to the students and they were at liberty to use it. All files required to complete the tasks were present in both Desktops.

3.8. Laptop Setup

There were 6 laptops in use. All laptops had 15 inch screens. Total screen resolution was 1280 x 1024. A copy of all files needed for the assignments were available in all PCs for Shared Screen group and in all Screens in Split Screen group. External keyboards and mice were connected to each PC. Shared Screen group had one keyboard- mouse pair and Split Screen had two pairs connected to one PC. The

keyboards were placed in a pull-out shelf below the desk and the mouse was places in the same level as at laptop. It was ensured that there was sufficient space to move the mouse and keyboard and students were encouraged to change the arrangements to suit their convenience.

3.9. Student profile

3.9.1. Shared Screen

There were in total 7 regular students (4 male, 3 female). Average score in pretest was 42% for accuracy. The men in the group were part-time college students and the women were homemakers.

3.9.2. Split Screen

A total of 11 regular students (2 male, 9 female) attended SSUI classes. Average score in pretest was 45%. Average age was 18, and students were either in college or high-school dropouts.

3.10. Instructions

Students were instructed to share the screen and attempt tasks anyway they chose. The natural tendency for Shared Screen users was to work together, treating their exercises as one. Students on SSUI saw the personal Desktops as means to work independently, since they have access to their own input channels.

3.11. Recordings

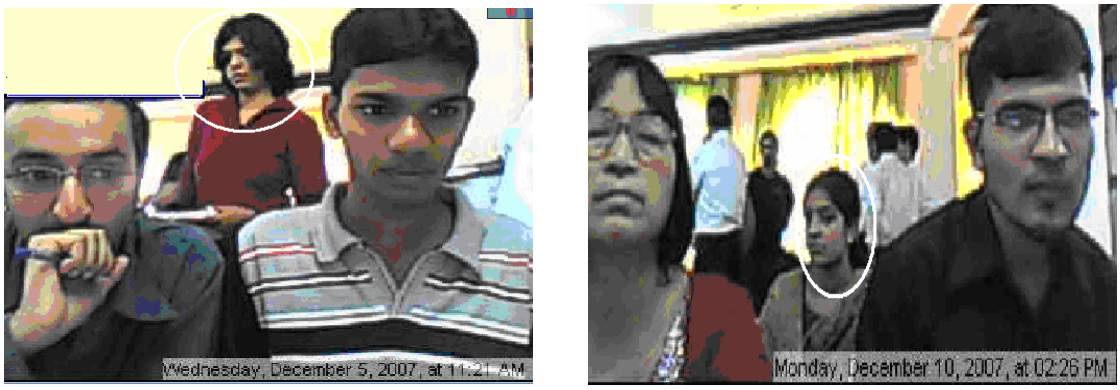
Each PC had one Research Assistant (RA) or Observers manually record user activity. In particular, they noted student's conversations, problem areas, interactions with tutors and other students and other possible observations made from both

students. Observers were rotated so that they do not develop bias over any student. Although there was no audio recording of students' conversations, video footage monitoring the students was taken for all classes. Observers were close enough to monitor the students but not too close that it disturbed the students. Many students reported that they were not aware of an Observer since they were facing the screen and the Observer sat behind them. The Observers also took care not to communicate or respond to the students.



(a) **(b)**

Figure 3. Observers are seen noting student activities in both pictures



(a) **(b)**

Figure 4. Snapshots of camera recording of students with observers in the background. In (a) students are in Shared Screen mode, in (b) students are seen in Split Screen mode

3.12. Post-Program survey

At the end of the 14-day program students from both groups were surveyed on their experience with the class. Interesting results will be discussed in forthcoming sections.

Observer notes, video recordings and survey results are the main sources of qualitative observations made during the experiment. Much of the analysis and conclusions are drawn from these findings.

Chapter 4.

Observations from Shared Screen Group

The following are descriptions of some of the key observations from Shared Screen group. It is worth restating that the experiment simulated a standard classroom environment at Hope computer center. There have been observations of up to 3 students sharing a computer in some Hope classes. In this experiment the only compulsion the students were under is to share a PC in pairs and work on exercises. The tutor could be consulted for any clarification and there was minimal intrusion to the natural behavior and interactions of the students. These rules were applied to Split Screen group as well. During the first four classes, students were allowed to form their own pairs. From the fifth class onward students were randomly assigned to a partner to ensure that all students got the opportunity to sit with every other student in the group. Since the students were working toward the same task they can be addressed as partners rather than co-users (as in case of Split Screen).

4.1. Active user

The active student in a pair is one who is seen spending the most time controlling the mouse and keyboard. In almost every observation the student sitting on the right of the monitor appeared to dominate the mouse and keyboard thereby the more ‘active’ of the two. Since all students were right-handed it could have been that it was more convenient for the student who is closer to the mouse to dominate it. Interestingly, certain students were always keen on picking the right seating position

and they were particularly those who seemed to pick up skills faster than their peers. Correlating this to their pretest scores, except for pairs where both students faired below average, all the active users had above average scores.

4.2. Passive user

The passive user is the partner who at a given class, intermittently uses the mouse and keyboard. This student typically sat on the left.

4.2.1. Collaborative Role of Passive User

Although the active user had maximum control over the input channel the passive user participated in several ways to help complete the exercises. Notably by,

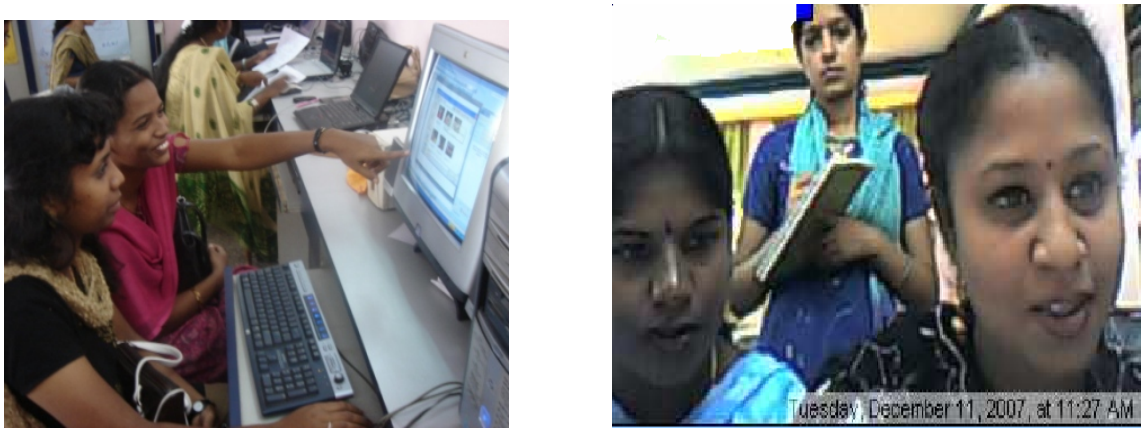
- instructing the active user on a task
- correcting mistakes made by active users
- keeping track of exercises completed
- alternating with the partner on using mouse and keyboard thereby engaging actively with the computer
- interacting partially with the PowerPoint by taking control of either mouse or keyboard

4.2.2. Impact of Sharing on Passive User

Three students in particular always tried to ensure that they were always in active user position. One student even asked his partner if they could switch places so that he can sit on the right. In many partnerships where these students were dominant, the partner appeared uninterested in the task, passively observed the interactions.

> In one class, the passive student only spoke to correct a few spelling errors. An active user once offered the keyboard to his passive partner so that she too got a chance to work on the application. She turned it down saying that she preferred to read the instructions aloud for him.

Some passive users were also noted looking into other computer screens while the active user proceeded to complete the exercise.



(a) **(b)**

Figure 5. Passive Users. In (a) the passive user points at the screen while explaining a step to the active user right seated. The (b) the right user is passive and was seen losing interest in the task when she never got an opportunity to use the mouse

Many passive users have ended up being the faster of the two. One regularly active student decided to take a back seat one class and let his co-user dominate. This passive user was clearly the faster of the two and dictated instructions to the active user through the class. Despite his repeated directives his partner continued to make mistakes that resulted in him taking charge of the task. Although this benefits the slow active student, the role of the passive student is shifted to that of an assistor and not a co-learner.

4.3. Partnering with new peers improves collaborative skills



Figure 6. Examples of Sharing. The two friends in (a) did not find trouble sharing. The right left user in (b) grew increasingly uncomfortable with her active left partner and offered to switch positions. Figure (c) shows the typical distance in male-female pairs. The left user in (d) was always passive, irrespective of the partner. He never showed any interest in using the mouse and keyboard.

During the first four classes, the students were allowed to form their own pairs. This resulted in friends pairing up and partnerships rarely changed unless there were absentees or late-comers. As a result of pre-established work-relationships, they appeared very comfortable working with each other. From the fifth class on, they were shuffled randomly and each student got a chance to partner with someone they have

not worked with before. This resulted in unconventional pairing of boys and girls, who have typically not interacted with one another. Students were allowed to pick their own seating position.

Curiously, in most male-female pairs, the student on the right was the boy typically the active user in the pair. The women students adjusted their chairs to an acceptable distance between the two and preferred to sit on the left. In all other pairs, the above average or the more experienced student became the active user.

At the beginning of the shuffled classes, students unfamiliar with one another would take more time to perform tasks and the amount of discussion was noticeably less than before. The number of doubts raised per pair was also high. In the early classes, as friends formed pairs, delegation of tasks was simple as both knew what each one was better at. For example, some students always used the mouse while the other always used the keyboard. Some dictated instructions and the others followed. Here the students were not sure how to work with someone they have not worked with before and discomfort with the opposite sex was evident in some students as the spatial distance between the seats were more and some typically talkative girls appears very quiet. However, after two to three classes, both students seemed more involved in the exercises. With the focus on the tasks each student appeared more accustomed to having an unfamiliar partner, resulting in productive cooperative behavior. For example, passive students who were inhibited to correct their partner's mistakes began to change their uninvolved behavior and started dictating instructions, sometimes even taking charge of the mouse. Some active students offered to switch positions or time-

share the mouse with the other. In one case, the students exchanged mouse and keyboard use for every other question. After a few classes, some pairs predetermined who would work on what part of the task- one always used the mouse and the other the keyboard.

4.3.1. Peer Scaffolding

A relatively low number of doubts were raised to the tutor since the students resolved most problems by themselves, collaboratively. The following is a commonly observed pattern of behavior

> An active user read the question that asked the student to edit the Master Slide Layout by changing the font of the Master title to "Times New Roman". Both the students appeared to misunderstand the question and the active partner, rather than changing the font type of the Title, changed the text of the Title to "Times New Roman". On returning to the original slides, the passive user having realized that all the titles were still in the same font started debating the question with his partner who was still sure of what he had done. After reanalyzing the task they both finally agreed that it was incorrect and redid the exercise.

This sort of collaborative problem-solving and peer-correction demonstrates how conventional resource sharing methods could actually be beneficial for learning. As in the case above, the peer offers first-level scaffolding and tutors generally encourage this to promote team-skills. Furthermore the tutors found the system convenient given poor tutor-student ratios in Third World classrooms that make it hard for the tutor to give personal attention to every student pair.

4.3.2. Role of Language

Another interesting speculation comes from the observation that partners who communicated in English spoke less frequently to each other than they did with other partners. It is not clear to what extent native language played a role in determining how much a user is willing to discuss and collaborate. Typically all students who spoke a common native language seemed more conversant and engaged. When partnering with other students, the common language of English was spoken. Since most students were less conversant in English it could be that there was hesitance on part of both students to communicate confidently.

4.4. Partnerships aids Open-ended tasks

Shared Screen students appeared to enjoy working on open-ended tasks and delivered very creative Slide Shows. In almost every class, all pairs delivered at least one or two slides in the open-ended tasks having completed all the other exercises. Students delegate responsibilities amongst themselves.

> In one mixed-gender pair, the male told his partner than he was not interested in the visualization aspect. He offered to enter only the textual content so that she could design the template and add pictures. In another assignment where the students were told to make a slide show on their favorite festivals, one pair ended up with two slides, one on Ramzan and the other on Christmas. The Muslim student said he had made the slide on Ramzan and the other slide was created by the Christian student.

Delegation and ownership of areas was prominent even among pairs without former established relationships. Students were more confident in making decisions and showing off their creations to others in the group.

Chapter 5.

Observations from Split Screen Group

Split Screen classes had 9 female and 2 male students. Pretest results showed that average class accuracy in the test was 29.7%, with 5 of 11 students showing above average performance. Students were given their own copy of assignment sheets and told that they can work with their peer or separately. Since each student was allotted an independent screen, from the start of the program they spontaneously chose to work separately (contrary to the Shared Screen group behavior).

For the first four classes, students were allowed to form their own pairs. Naturally friends chose to share a PC. In all four classes, PCs were occupied by the same pairs, as in case of Shared Screen group. Only when there were absentees or late-comers did the pairs change. Students were also at will to sit on either side of the PC, taking over left or right Screen.

From the fifth class on, students were allotted PCs from a random draw ensuring that each student got a chance to sit next to a co-user with whom they were not acquainted. As the description follows, this was done particularly to understand if and how established relationships affect interactions with other students and more importantly with SSUI.

The following sections analyze key observations in detail providing examples where necessary.

5.1. Independent Task-focused behavior



(a) **(b)**

Figure 7. Students working independently

Consistent with their spontaneous adoption of individual learning behavior, all the students appeared to focus on tasks from their assignment sheets. Starting with the first task that typically instructed them to open specific files students began to work on the exercises rather than discussing how they are going to work with their co-users. Each student treated assignments as means to reinforce skills and practice the day's lessons. This could also be attributed to the specific nature of the tasks, as discussed in following sections, when tasks involved significant level of metacognition to decompose questions, students were prone to get distracted or reproduce other student's work. Discussions on the impact of distraction and peer assistance in sections that follow will put 'individual learning' behavior into better perspective.

Almost all students attempted to answer a question before consulting the tutor. Even if a student did not know an interaction, he would at least try to identify familiar information on the screen before giving up.

> One student was attempting a task that required her to add a new slide an existing presentation and enter some information in it. Having clearly misunderstood the question, she created a new file (which by default has one slide), and continued the rest of the assignments later realizing that there was a mistake somewhere. Only at this point did she call the tutor.

5.1.1. Exploratory learning

Interestingly, there were also exhibitions of exploratory learning behavior.

> In one class when the students were taught how to create organization charts, it was found that at least 7 students in Split Screen group already had experience doing so. When students practiced inserting new pictures to a slide, they discovered an option, sometimes accidentally, called 'Diagram' which by default inserts organizational chart. When the lesson was taught, many of the students remarked that they had done it before but did not know its purpose.

The above incident is an example of how many skills can be picked up by the opportunity and freedom to explore with the software. Since Shared Screen students were restricted by the presence of a partner to focus on the goal of task completion there were very few observable instances skill acquisition through exploration. Even when it was seen, the second student would quickly point the active student saying that that was a wrong option, containing exploration.

5.1.2. Exploration and distraction

Tied closely to how students like to spend time exploring a various features of a topic rather than progressing to the next task in the exercise, many Split Screen students spent time on their individual screens figuring out alternative ways to perform a task. For example, even when all students were taught to use keystroke F5 to view the presentation as a slide show, many students figured out that using Slide Show->

View Show from the menu bar worked the same. Likewise, Split Screen students knew how to insert organization charts well before SS students as they experimented with different sub-options when they were practicing to insert images and diagrams. This often led to incomplete exercises and tasks. Students also had a practice of reviewing presentations before showing to the tutor for approval. More over, students picked up how to use the undo option (Ctrl+Z) from the tutor, even though it was not formally taught to them by observing and repeating the tutors who assist them.

As in the case of students having their own personal computer, it was common to find students getting distracted by new features of the applications that they recently learned about. This resulted in many students not completing the assigned exercise. The contract with Single Screen batch where the goal was to finish the exercise rather than to practice using features. In the Single Screen group, the presence of a partner would make the pair focus on the tasks, preventing either students (particular the one who dominated the input devices) from straying to irrelevant or other tasks.

Most students found animating images and text very interesting. When the task assigned was to apply a specific animation, they would try to apply all kinds of animations and attempt to discover new features. Presence of a partner sharing the computer did not motivate them to concentrate on the task at hand or compete with the partner. Instead they would like to show-off a newly discovered tool to their neighbor, if he or she was a friend.

5.2. Means of peer assistance

The most common case of when students interact with one another in class is while troubleshooting co-user's problems. A discussion will follow on the conditions under which peer assistance takes place. Prior to that, we will explore the different ways in which students tried to help each other

5.2.1. Direct oral communication

> A student did not know what "Bullets" meant. When the task required her to add bullets in a specific slide, she pointed to her sheet and asked her co-user whether she finished the task or if she understood what it meant. Co-user in response point a the questioner's screen and helps her identify Bullets button

Presence of novel means to troubleshoot did not deter students by in large from using conventional mode of asking and receiving help- asking a neighbor for help. In this case, a co-user was the most sought person to ask for help, particularly if he or she was a friend. The student after attempting the task or even trying to understand the question asked the co-user or a neighbor (sitting in adjacent PC) for a clarification. The co-user on knowing the answer would commonly give an oral instruction or point to the screen with a finger and explain what needs to be done. The context of the conversation and the volume of interactions depend on the nature of the problem and the relationship between the users. In any case, these behaviors are similar to those of students sitting in adjacent computers or even the passive user of Shared Screen scenarios. Only a few cases of conversations about topics irrelevant to class work were noted. Apart from clarifications, students also discussed their progress or new

discoveries, elucidated in Section 5.1.1. Direct oral communication is also a predecessor to other kinds of assistance described below.

5.2.2. Indirect assistance

This involved

- Screen peeking at co-user or neighbor's screen
- Eavesdropping into co-user's conversations with other users or tutors.

5.2.2.1. Sneak Peeking

The above observations need not always facilitate peer learning or peer-assisted troubleshooting. For example, screen peeking could be involuntary, since co-user's screen is proximal and a user has the natural tendency to be distracted from the screen. Learning could be coincidental. However some observations have been noted where screen peeking and eavesdropping have actually helped a user clarify doubts.

> A task required the student to create an organizational chart with one box and eight sub-ordinate boxes connected to it. The student added a box and then began adding 'co-worker' boxes followed by sub-ordinate boxes. Clearly confused with the question and unable to understand where she went wrong, started peeking into her co-user's screen. The co-user had just finished the task correctly and moved on to the next task. The student in doubt on seeing the correct chart began to redo her task, inserting a new chart and the correct sub-ordinates.

Screen peeking could also be detrimental influence if the co-user had a wrong answer!

> When the question asked to change the slide layout to "Title", this student kept shuffling between two options – "Title slide" and "Title only". Not sure what was asked, this student was seen peeking into co-user's screen to find that the user had incorrectly chosen "Title

> and Text". Following this observation, the student changed his slide layout to "Title and Text", an option he had no considered before and moved on to the next task.

5.2.2.2. Eavesdropping

Eavesdropping into co-user's conversations, particular with tutors, since that was more accessible often made it simple for the tutor to explain to both students. Many students pick up novel skills watching the tutor troubleshoot both the co-user's doubts as well as theirs.

Using the 'Undo' feature by selecting 'Ctrl+Z' was not something known to the students or part of this curricula. However, many students wanted several actions undone since they were incorrect. Once when the tutor used the Undo keyboard short-cut, the co-user was later observed using the short-cut and demonstrated the same to a neighbor, telling the latter that she had listened in on the co-user's conversation and watched the tutor use the short-cut.

In several other accounts, when one student calls the tutor to clear doubts, the co-user would actively participate in the conversations. In others, the co-user though was silent in conversations between the tutor and student, was seen translating the tutor's clarification into local-language

Even though this sort of eavesdropping behavior can be beneficial to students even when the co-user is a neighbor seated in an adjacent computer, proximity to the user's screen and interactions are SSUI affordances that contribute largely to collaborative behaviors.

5.2.3. Mouse Hijacking

This is the phenomenon of a student borrowing the co-user's mouse to perform a task on the co-user's screen. Similar to the passive user's behavior in Shared Screen, students on many occasions simply took control of the owner's mouse to either demonstrate or complete a task. Tutors too gave many clarifications by hijacking the student's mouse and it was a spontaneous action particular when it made explanations faster and easier to give.

Mouse Hijack was seen to be convenient when keyboard hijack was needed. A student tried to resolve a co-user's clarification by giving specific instructions. She told the co-user to select the textbox and type specific text into it. However the student continued to select the wrong textbox. The helper, clearly restless asked if she could borrow the mouse and selected the correct textbox, used the keyboard to enter the text, returned the mouse and continued her work.

Mouse Hijack was seen when the student who was being helped did not know how to disable Screen Lock. Seating position also mattered when a student decides to hijack the mouse. Given that all the students were right-handers, some left users who tried hijacking found it difficult to reach out to the right user's mouse as it was on the extreme right of the monitor and the right user moved the mouse to make it easier for left user. Whereas for right user, the left mouse was conveniently located closer to her reach. This also tied to the duration of troubleshooting and mouse maneuverability space, since one right user was noted to have hijacked the left mouse and realized that

she did not have sufficient room to move the mouse around, so she unlocked the left screen with the hijacked mouse and switched to using her own mouse.

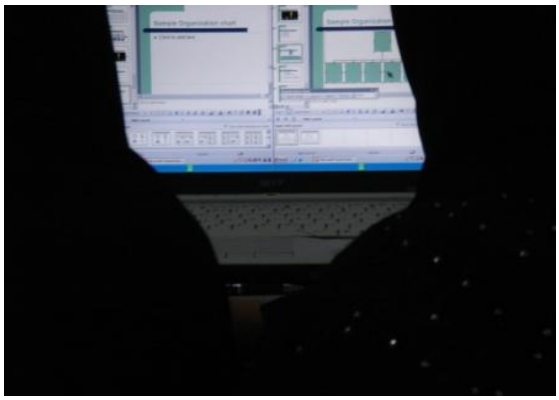
At the beginning there were more instances of Mouse Hijacking observed than the counterpart Screen Unlocking. It was found that many users did not know how to unlock their screen to let the co-user in, so the co-user would borrow the mouse till either of them figured out how to unlock if it was still needed.

5.2.4. Screen Unlocking

The owner of the screen disables screen lock to let co-user's mouse interacted with his screen.

Most common cases of Screen Unlocking were seen when both users were acquainted with one another. Although there was no study of any pattern to offer a reason, it is worthwhile to note that some students were cautious of relocking their screens after they received help, while some were particularly casual about keeping their screens unlocked through the rest of the class. These behaviors were inconsistently seen in both pairs who worked together or independently irrespective of their established relationships. In some pairs both screens remained unlocked through the class. One particular student always had her screen unlocked through most of the classes. There were random observations of a couple of students who told their co-users to lock their screens after initially disabling Screen Lock.

There were hardly any incidents of a user accidentally or mistakenly moving his mouse to the other screen, giving the confidence that screen ambiguity is not of concern in this specific case.



(a) Screen Unlocking



(b) Sneak Peeking



(c) Eavesdropping



(d) Mouse Hijacking

Figure 8. Means of peer assistance

5.3. Peer Assistance a function of established relationship

As explained earlier, Split Screen User Interface gives the student an independent Desktop session that is used to engage in active learning. The students have exhibited successful adoption of SSUI for individual learning. However the presence of a co-user working on the same lesson and the proximity of his screen offers students a chance to work together or learn from each other. This section discusses the situations wherein peers help each other.

Table 1. Verbal Exchanges in pairs with and without established relationship

Combination	Total Pairs	Unique Verbal Exchanges VE (Approximate)
Boy-Girl Pairs (w/e.r.)	2	45
Same Sex Pairs (w/e.r.)	14	8<VE<30
Boy-Girl Pairs (w/o e.r)	12	0<VE<5
Same Sex Pairs (w/o e.r)	16	0<VE<4

Table 1 shows different combinations of students and variations in assistive behavior. Of the total 11 students (2 male and 9 female), there were in all 44 unique partnerships. Of them, 16 pairs of students already had established friendly relationships. Students are in an 'established relationship' with a co-user if they

- have interacted with one another in previous classes
- are friends outside of the classroom
- have been observed to be interacting in one another before or after start of the class
- have acknowledged being friends with one another who have voluntarily sat alongside one another in the first four classes

Students were informally polled on which other students they have established relationships with and this was reconfirmed by regular observations of students' social habits before and after class. Of the 44 pairs in all, only 16 pairs have established relationships. Since there were only 2 male students, and 2 inter-gender pairs with ER, it would be hard to arrive at any generalizations regarding differences in assistive behavior in the context of their gender.

However, between groups of pairs with and without ER, significant differences were observed in the communication frequency. Verbal exchanges can be defined as short conversations between partners that were observed in frequent intervals under all situations. Although student conversations were not transcribed, each PC had an observer to monitor the behaviors of each of the partner. This includes how frequently they talk to each other, point to each other's screens, talk to the neighbor in the next PC, using the Screen-lock feature, occupying the partner's mouse or keyboard. Since the student's conversations weren't recorded, the observer's notes and video-recording of the students were scrutinized to confirm how frequently students talk to another.

A VE was counted for each time either student spoke to the other within a silent interval of 5-10 seconds. Because the observers were intentionally made to sit a bit further away from the students, the counting was only to give an approximate idea of frequency.

5.3.1. Co-user offers first-level scaffolding

Clearly, the total number of VE for pairs with ER was far higher than those who have never known each other prior to that class. Further more, all pairs interacted with one another voluntarily. Many times, students would call the tutor only after consulting their partner. The partner would often listen in on conversations between the student and tutor. Not only did students sharing a PC talk to one another a lot, they were also found speaking to neighbors if they were friends with them. Conversations came naturally.

> For instance, when student Fouzia observed that Ayesha had learned to custom animate pictures, she got distracted from her task and

> remarked to Ayesha, “Show me how to do that!”, and went on to follow Ayesha’s instructions and temporarily got distracted from her tasks.

Post-program survey results also showed that although most of the class liked pairing with a co-user who was not a friend, they enjoyed it more when coupled with friends. Only two students in the poll said that they like to work alone without a partner.



Figure 9. Students communicate and collaborate even with peers in neighboring systems.

For students with ER, typical conversations revolve around

- troubleshooting partner’s problems
- helping partner understand a question
- pointing to specific icons or options on the partner’s screen
- demonstrating newly acquired skill
- demonstrating a creation
- translating a question to local language
- spelling clarifications

- pointing to neighbor's screen
- clarification on errors due to bugs with SplitScreen
- Mouse or keyboard failure
- accidentally closing an application
- opinion on decisions to be made inability to find icons or objects on the application

5.3.2. Peer learning through task synchronization

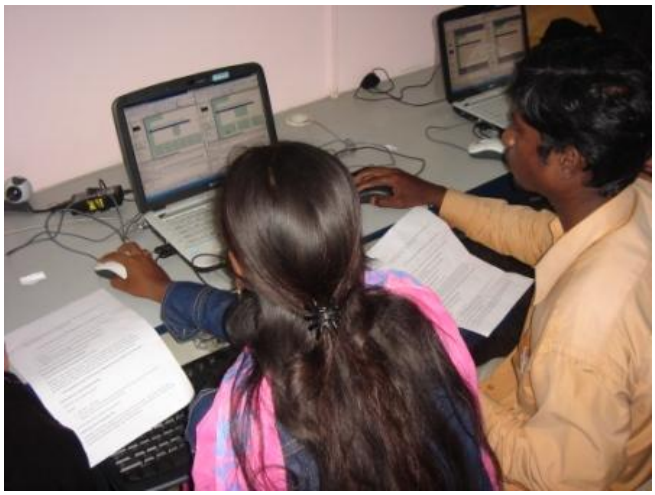


Figure 10. This pair always synchronized their work when they share the system

The pair in Figure 10 always synchronized their work whenever they got a chance to work on the same system. The faster student pauses after every task and only after helping her friend did she proceed. They were seen analyzing questions and strategizing implementation. Both the students produced very similar slides at the end of each class.

5.3.3. Peer learning through competition

Two students were seen tracking each other's progress even when they sat in different computers. These students were former learning partners who wanted to compete with each other to be the first to finish the assignment for the day. Even when they were seated too far to talk, they would ask the tutor or nearest neighbor about their competitor's progress.

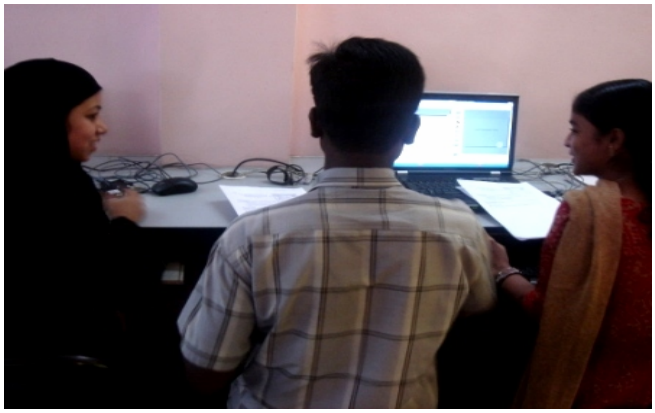
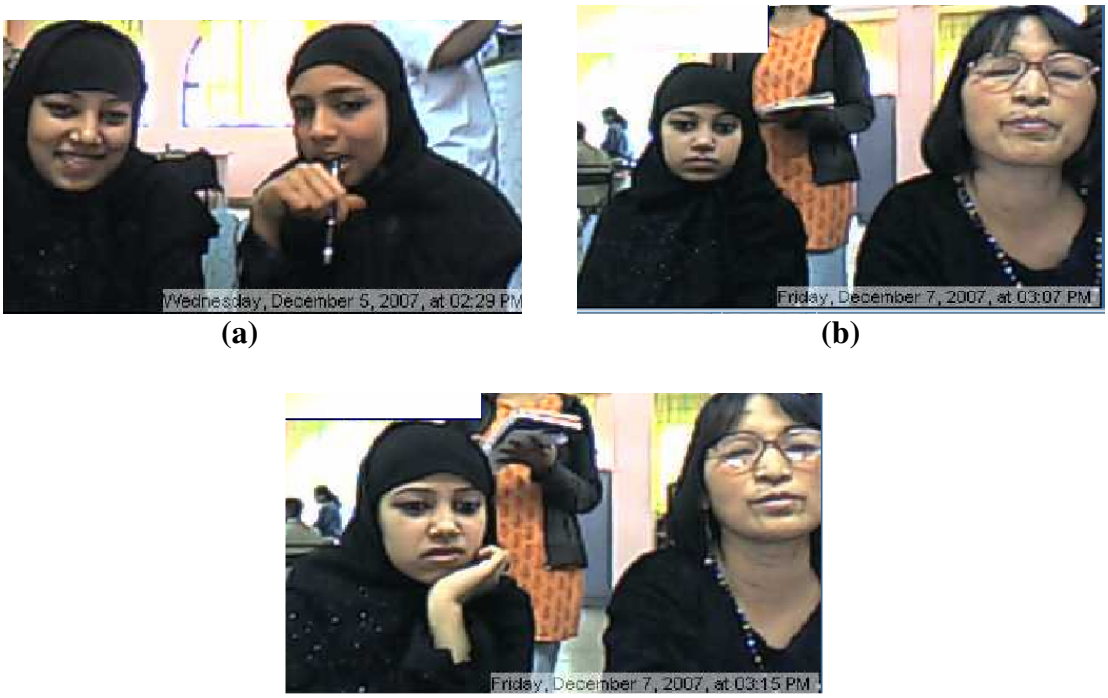


Figure 11. The two girls in the picture were constantly competing to be the first to finish the day's assignments.

5.3.4. Learning from peers with better abilities

Fast learners complete the tasks promptly with fewer doubts raised to tutors and co-users. Fast learners when paired with co-users with slower abilities seemed to voluntarily help the co-user if he or she was a friend. Without ER, the fast learner demonstrated willingness to help only when conditioned to do so. In one example, the fast user wanted to leave since she finished her task and there was nothing left to do. When told that both users of a system have to finish before either can leave, she began to pay attention to her co-user and tried solving some of her problems.



(a) **(b)**

(c)

Figure 12. Learning from peers with better abilities. The student on the left is the fast learner. In (a) she is seen with a friend. In (b) she is seen idle after finishing her tasks. After compelled to help her co-user, she involuntarily assists her peer, as shown in (c)

5.4. Context of Distraction

Sharing the same screen and two individuals working at their own pace could lead to a user being distracted from the task at hand by a peer's screen. As discovered earlier, when the student exhibits goal-oriented behavior with a well-defined problem, the partner's screen does not impair his performance or problem-solving skills. This remained true in case of SS class. All students were very much involved in their own files and there was no real motive to look into the partner's screen unless they were stuck and needed assistance. This observation was consistent with the students' survey

response that they were only at times distracted by their co-user and the other screen. The following are some notable cases of distraction.

- In case of task synchronization, it required the student to constantly watch what his partner was doing.
- Students look around to communicate to friends in nearest systems. This was particularly observed when the distracted student was stuck at a point.



Figure 13. Sneak peeking at neighbor's system is quite common

- During open-ended tasks, when told to create Power Points of their choice, the students were spontaneously curious about their co-user's presentation. Again ER played a role in permitting the extent to which the student was comfortable with a peeping co-user.
- In same-gender pairs, peeking into co-user's screen was much more prevalent. As the tasks involved creative thinking and independent decisions to be made, the students were more prone to distraction and observing their partner or neighbor's

screen. However there were notable instances of a student indicating her reluctance to allow her presentation to be seen by her partner with whom she had not established a social relationship with.

> One student called the tutor and asked if she can see her partner's presentation. The partner indicated that she was not comfortable showing it to her. However the student demonstrated her presentation to her friend seated in another computer, at the end of the class.

5.5. UI limitations

The learning curve due to usability issues was fairly small. There were five main usability problems, mostly specific to the application as a result of reduced horizontal resolution. To new users of PowerPoint these issues did not seem very different from those raised while learning any new application. For each limitation there follows a description of how they were overcome.

5.5.1. Locating Buttons

Several buttons from the Formatting and Standard toolbar, such as Increase and Decrease font size button would be hidden as a result of limited vertical extent provided to a toolbar. As a result, students had to learn how to expand toolbars by selecting the respective expand toolbar button. Once the button was selected from there, it would appear in the toolbar eliminating the need to reselect expand toolbar icon. Students who were not used to the option were instructed to use the same. Once they got hold of it there didn't seem to be a problem in locating frequently used buttons.

5.5.2. Locating Scrollbars

Many students were not familiar enough with GUI that they could recognize scrollbars. For example, when asked to locate a specific file from a directory with a lot of files, from a File->Open Dialog box, many students were not aware of a scrollbar present and had to be instructed to do so. This was attributed to general lack of experience with Windows applications. With sufficient instruction, the number of doubts attributed to scrollbar problems decreased.

However there were other types of scrollbar problems in PowerPoint. The task pane, that provides shortcuts to options like Customizing animations, design templates, animation schemes, typically occupied right position on the screen. This was moved to the bottom of the application to give more space to the slide that was being worked on. This was done as it was required to give the slide the maximum screen space possible. Since the new application occupied more width than length, the scrollbar for the task pane was slightly different. The new scrollbar is now a small arrow button at the bottom of the wide task pane that is barely discernable.

Since the task pane was cramped into a smaller screen space, the user has to scroll both horizontally and vertical by locating the new type of arrow button. Finding the arrow button was an extra binary skill the students had to pick up. Although students seemed to overlook the arrow at the beginning most exercises required them to apply several sub-options hence constant use of the scrollbars was necessary. Therefore after a bit of practice, the arrow button became a small issue.

5.5.3. Locating Toolbars and Task panes

When a new toolbar or task pane appears as a result of selecting certain menu options (For example, the Clip Art dialog box appears when Insert->Picture->Clip Art is selected). The Clipart task pane appears at the bottom of the screen. Since most of the dialog is hidden, the user is barely able to recognize that the task pane has changed or reappeared with a whole new set of options! These problems were reduced by giving explicit instructions and image clues in the exercise sheets, indicating to the students to specifically look for such changes.

5.5.4. Screen magnification

Screen real estate afforded to Slide editing is important in placing text, adding diagrams and aligning the content of the slide. When the slide magnification was at default 75% students had to use scroll across the slide to review it. This is deteriorated furthermore when the task pane is moved to the bottom of the screen. To reduce this problem, the slide was shrunk to 50%. Despite the lower resolution, students indicated they were more comfortable with this setup than having to constantly scroll across the screen.

5.5.5. Disambiguation of mouse-pointer

In SS mode, the mouse pointer is hard-coded to take green and red pointers that stay the same across all interactions. This means that for changes in mouse pointers respective to an action (hourglass, resize, move, drag), will not be available when the user makes a mouse-over specific parts of the screen. For example, when the user moves the pointer to the corner of a text box, it will not change to a crossbar.

5.5.6. Other Notable Usability Problems

When the user double clicks inside a textbox with the intention of entering data inside, there was no indication of certainty that he made the right selection unless he finds the blinking cursor or enters text. This was because the pointer did not change to a cursor-pointer.

When the user wanted to move a text box or image, the crossbar icon does not appear to give an indication that the object is ready to be moved.

When the user wanted to expand or shrink task panes and other toolbars, he would have to click and drag an active edge of the toolbar. However since the pointer does not change at the edge, it was harder for the user to focus on locating and dragging narrow edges.

However as the class on the average had only two weeks of computer experience the students were not all habituated to requiring pointer-changes to facilitate faster interaction. The students even with more experience felt that on most occasions, they never needed pointer-changes as clues. However it was acknowledged that they would rather have a changing pointer to a fixed pointer, particular when the horizontal resolution was already reduced. Moving around the screen would then become a smoother experience.



(a) **(b)**

Figure 14. Keyboard, mouse placement and viewing angle did not cause ergonomic constraints for the students

In the survey conducted after the program, students uniformly felt that the space available for mouse and keyboard was sufficient and the screen viewing angle from their seats was insignificant. However many did make the suggestion to have larger monitors. All students found working on Split Screen more enjoyable and easy when compared to their normal PC usage.

Chapter 6.

Comparing Shared Screen and Split Screen

Table 2. Comparison of Shared Screen and Split Screen observations

Shared Screen	Split Screen
Learning characteristics	
• Collaboration • Joint decision-making • Passive learning	• Individual learning • Instances of competitive and collaborative learning observed • Learning through exploration, trial-and-error
Peer Interaction	
• Seen even in pairs without established relationships • Fewer calls to tutor per PC over time	• Common among peers with established relationships • More calls to tutor per PC
Student engagement	
• Many passive users	• All users are active users
Creative tasks	
• Collaboration helps performing open-ended tasks	• Trouble deconstructing and strategizing open-ended tasks
Usability	
• Right user dominated the mouse • Gender of partner affected sharing	• Initial application specific adjustments needed • Switch from Split Screen to Single Screen was smooth

Table 2 highlights the key discoveries in Shared and Split Screen groups and contrasts them. It is important to analyze the differences for two reasons. The first is to understand if the Split Screen user experience is personal enough to offer students

opportunity to learn independently. If yes, then it leads to the second point- whether this new experience is so personal that it is a radical shift from the old classroom. In other words, is the student now so involved with this individual learning opportunity that he no longer needs to collaborate with his peer?

Shared screen scenarios were designed to understand traditional classroom practices in resource-constrained context. There were several educational benefits from sharing the computer with a peer notably the improved ability to collaborate, practice team work and support each other in performing tasks. These were evident from high rate of task completion, less calls to the tutor and delivery of complete presentations in open-ended tasks. However there were inconsistencies in how the students used the computer, practiced lessons and learned new skills. There were many passive users who were unable to get the best of active learning by reiterating new skills on the software. Faster learners are restricted by slow active partners. Slower learners struggle to keep up with fast active partners. This leaves the burden of redesigning practices to the tutors who have to constantly ensure that while team skills are being honed, all students get directly involved in all tasks and disallow dominant students from monopolizing the system.

With Split Screen the situation is almost reversed, with all students working independently. This is a shift from a shared computer to a personal desktop offering each student a hands-on learning opportunity. Students successfully reiterate new skills, actively engage with the application and learn through exploration. But along with individual learning, students working on Split Screen user-interface have

exhibited peer learning behavior directly or otherwise. As discussed in the previous chapter, Split Screen participants voluntarily seek or provide assistance from a peer based on their relationship with them. But as evidence points out, a student even picks up help indirectly from his co-user by sneak peeking and eavesdropping. Idle students who have completed their exercises help their co-users even if there was no established relationship. Some students were constantly aware of their friend's progress in other computers hoping to race ahead of them. Other students sharing one computer were seen synchronizing their work so that both practice and progress at the same pace while assisting each other. This last behavior resembles a commonality in goal, quite the same basis of collaboration in traditional classrooms. These characteristics demonstrate that at the basic level Split Screen UI provides the support for individual learning experience that is, however, not completely independent. Therefore Split Screen delivers First World classroom experience of personal active engagement space for each student without altogether disrupting traditional Third World classroom behaviors resulting in collaboration and codependence.

Chapter 7.

Discussion and Future Work

Even with positive response to Split Screen from students, it is important not to force fit the solution in classrooms without considering the repercussions on tutoring methods and class design. This study was made in the traditional context, without any alteration to tutoring methods or learning aids. Raw observations reveal interesting collaborative learning behaviors under specific conditions- work and time synchronization. This leads to the possibility that when supportive tutoring strategies and educational frameworks are in place benefits of collaboration can be further exploited by Split Screen classroom. Interestingly recent educational psychology research in richer countries recommends classrooms to encourage collaboration and peer learning [16][17]. Ways of integrating Split Screen into such context could be further explored.

What follows is a discussion of novel pedagogical methods that can better take advantage of Split Screen. As in the case of Shared Screen, classes can be designed such that two students on a Split Screen are made to work on one assignment. It is left to the students to delegate and ultimately combine their work together. Work synchronization can be made compulsory. A First World teaching technique involves the teacher demonstrating a skill on a common screen and the student with a personal computer reiterates the skill as he observes the teacher's screen. Replicating this on Split Screen, one student or even the tutor explains a how-to on his half of the screen

and the co-user watches and repeats on his screen. Thereby without any oral directives students practice as they are taught.

7.1. Future Work

The form factor of the display affects the applications that run on each half of the screen. Even when the users appear to disambiguate the two screens comfortably, with the increased need to horizontal scroll and reduced magnification of the application, users often miss information or mistake the location. Besides increasing monitor size, software solutions too may be possible. Each screen can run a MultiScale [18] interactive layer that can render a large number of items on a workspace. A snapshot of 'hidden' information can be displayed each time the user needs to scroll up or sideways. The user can view the snapshot and determine if he will continue to scroll.

Other features can be supported by the interface to allow easy file sharing between two users. One user can drag the icon of a file and drop it into the other user's screen or common region can be created between the two screens can that be used as a temporal dock for files and notes commonly shared by the users.

Another interesting concept that can be experimented with is to allow more than two desktop sessions run on the screen therefore letting more users share the system, each with they own keyboard-mouse input. Screens can be split horizontally as well, therefore allowing easy interaction with inherently wide applications.

Various methods of reducing distraction in shared display have been discussed and evaluated by Tsandilas and Balakrishnan [19].

Chapter 8.

Conclusions

To summarize the candidacy of Split Screen for various real-world scenarios, conclusions from three independent research studies were taken.

1) The experimental study in resource-constrained classroom
2) Performance analysis of basic word processing tasks in Split Screen (described in Appendix A)
3) Interviews with Small business owners in developing communities (Appendix B)

These findings conclude that Split Screen does not significantly impair user-experience when

- Used for simple data processing applications (MS Word, PowerPoint, Email, Internet applications) where minimal horizontal scrolling is needed
- Privacy of data and interactions are not of concern to the users. Ideally suited for classrooms where knowledge and data sharing are common.

Split Screen is not a convenient alternative when

- Applications running need more horizontal screen space. In particular design applications and 'wide' documents.
- Tasks require user to think abstractly and work privately (for example, creative tasks when the user is prone to distraction)

Qualitative observations from field studies show spontaneous adoption of Split Screen User-Interface by students with interesting peer learning aspects in their

behavior. This Single Display Groupware solution brings the student-PC ratio down from 2:1 to 1:1 at the cost of an additional keyboard and mouse (as low as $10). Therefore Split Screen potentially transports First World classroom advantages to developing countries while enabling them to optimize value of their existing resources and benefits.

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Appendix A

Essential Word Processing Skills on Split Screen- Usability Test Evaluation

Motivation

By using SplitScreen, the user is compromising on screen real-estate as only half the horizontal resolution of the screen is available for his use. The user also has to adjust to engaging with the system from a slightly angular position. However it is important to know to what extent this supposedly "diminished" user experience will affect essential computer usage scenarios.

Task Description

One such frequently used task is typing and formatting of documents. A between-subject usability test with regular computer users was conducted. All the users were given two tasks

Passage Typing

A hard-copy of a 170-word, 1000 character passage was given to the user and the user will have to enter the passage in an MS Word document. As the document will already be opened for the user, he will simply have to focus on entering the data into the application. The key metric observed is the speed (measures in Words per minute) and accuracy (number of words that did not match with original passage- method employed in standard typing tests).

Passage Formatting

A two page long word document is given and the user is given a sheet with the following four instructions, each breaking down to a sub-task of locating specific words in the document that in turn involved scanning the entire document for the words-

1. Changing words to "Bold"
2. Changing colors of words
3. Changing font size of paragraphs
4. Underlining words

The user is not allowed to use the keyboard (or respective short-cuts). Only mouse-clicks on buttons/icons allowed. The instructions were to

be followed one at a time. Observed metrics were speed (Time to complete all 4 instructions) and accuracy of completed tasks. In all four cases, the accuracy was found to be 100%.

Prior to the test, all users were given a self-assessment questionnaire on their computer proficiency. All the users claimed to be

- Proficient in basic computer skills (creating folders, opening applications, MS Word, Internet)
- Have more than one year experience in using computers
- Use the computer regularly (at least one hour a day)
- Regular users of Internet, Communication and Word Processing applications. Some are programmers.
- Fluent in both reading and writing English

Scenarios- Testing Modes

Single User Single PC (SUSP) - One user per system, with dedicated monitor, keyboard and mouse. This is the standard computer usage scenario

Single User Split Screen (SUSS) - One user per system, with dedicated keyboard and mouse, but user is given only half the screen space i.e., Split Screen is running but the second screen is unoccupied (no second user). The second screen is idle and runs a blank Screen Saver. Observations from this mode isolate reduced horizontal screen space impacts user performance.

Dual User Split Screen (DUSS) - Two users per system, each with dedicated keyboard and mouse, given half the screen space i.e., Split Screen is running and each user applications occupies half the screen

Given that two users will be sharing the display and simultaneously performing the tasks (simulating real-world Split Screen scenario), there could be serious or marginal impact of a second user (hence forth called "partner") engaging in concurrent screen activity. There could be distraction due to 'side-glance' effects, invasion of privacy, physical proximity of partner's keyboard and mouse.

Therefore test with two modes of Split Screen (with partner and without partner) were conducted to assess the impact a co-user can have on task-performance. Notes

- The users worked on alternate tasks, if one was given Passage Typing, the partner is given Passage Formatting
- The tasks are designed such that the activities are binary and require no collaboration with the partner or open-ended creative analysis

The presence of the second user together with the reduced screen space factors (as described in SUSS mode) can be considered as variables of influence on user performance. All other conditions of experiment are maintained across scenarios.

None of the users repeated the tasks or were introduced to another mode of the experiment. There was no content familiarity. All users were given the same tasks. The task order was Passage Typing before Passage Formatting, except half the users of DUSS mode (for whom the task order was reversed). The resolution of the screen was consistent for all modes. None of the users were allowed to magnify the text for 'better' visibility.

Test Observations

The following observations were present in all scenarios. For specific cases, scenarios are mentioned. In Passage Typing Test, the range for all three scenarios were contained between 188s- 438s. For Passage Formatting, it was 231s-474s. 7 tests were taken for each scenario. These observations could reflect possible reasons for higher or lower speeds given, across users, across modes, since all candidates have more than 2 years experience with MS Word and use Office applications on regular basis. All users were double-handed typists. On post-test interviews, none of the DUSS users felt distracted during either task. In SUSS and DUSS cases, all users had issues with Horizontal Scrolling, but found that it got better after few seconds of use.

Passage Typing Test

A 170-word passage was given to all test-takers in hard-copy.

- Reading sentences in parts or in full before typing
- Correcting errors as they discover any. None of them corrected errors after typing the document
- Missing lines while typing and correcting them
- Getting confused about the sentences or spellings (e.g. 'cocoa' and 'cacao')
- Did not turn off cell-phone and had to silence it
- Adjusted keyboard to be more comfortable with it

Passage Formatting

A two page word document was given and the following instructions were assigned. Using ONLY the mouse-

1. Bold one instance of the word "ice" from each paragraph
2. Underline 4 instances of years (e.g. 1997) in the document
3. Change the color of at least three flavors of ice cream mentioned to Red
4. Change the font size of alternate passages to 14

- For the first instruction, some subjects avoided Horizontal Scrolling (HS) by scanning only the visible parts of the passage
- One attempted to perform all tasks together without having to go one instruction at a time, therefore trying to save time in scanning the passage
- None of the subjects tried double-clicking to select word/passage. Selecting passages took time and was troublesome because they had to HS while selecting an entire paragraph. The time of apply a change (such as Bold) was minimal.
- Some did not read the questions correctly. Thought that the first question referred only to the first paragraph or the second question referred to the specific year 1997. This resulted in taking longer to complete the task
- Some test subjects were not aware that there was a second page and had to be told

Test Results

Each mode employed seven test users. In DUSS mode there were 8 (so there were 4 testing-pairs).

Passage Typing Test

All the numbers for WPM (Words per Minute) and Accuracy are calculated from standardized methods measuring input speeds. However, as all users being compared were given the same text to type, WPM is measured in words rather than conventional five-character word-units. Since whole-words were used as measurement units accuracy was checked by word-matching. Any word along with its position that did not match with the original, excluding spacing, is considered an error. This covers grammatical and mismatched sentence errors. Error rate is measured over the total number of words (170).

Table 3. Average speed and accuracy across three modes. Time is measures in seconds, WPM (Words per Minute) is the typing speed, Error Rate and Accuracy are measure as a percentage

Average	SUSP	SUSS	DUSS
Time	342.5714	343.1429	338.125
Error Rate	3.193277	3.529412	3.676471
WPM	30.25993	30.24285	32.34901
Accuracy	96.80672	96.47059	96.32353

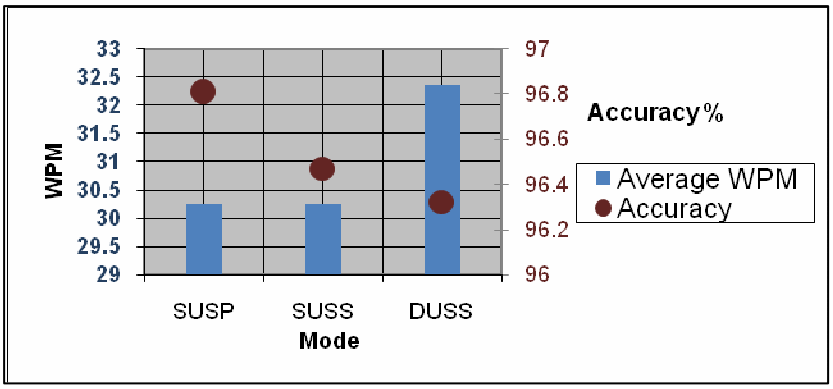


Figure 15. Average speeds and accuracy

Average WPM ranged between 30-32 words and accuracy is 96% across all these modes. Because of the small sample size, we hypothesize mean difference across any two distributions to be 0 and perform TTest data analysis of WPM distributions (Table 4).

Table 4. Speed TTest: Two Sample Assuming Unequal Variance. Alpha=0.05

SUSP	**SUSS**	**DUSS**
t Stat	0.007494685	-0.520506346
t Critical two-tail	2.178812827	2.228138842
SUSS		
t Stat		-0.527553351
t Critical two-tail		2.262157158

In comparison to SUSP, SUSS t-stat is less than t-critical. Likewise comparing SUSP with DUSS and SUSS with DUSS, we have 95% confidence that the hypothesis cannot be rejected, indicating that all samples are from the same distribution (since the mean difference is hypothesized as 0). Table 5, presents the numbers for accuracy rate, leading to the same conclusion.

Table 5. Accuracy TTest: Two Sample Assuming Unequal Variance. Alpha=0.05

SUSP	**SUSS**	**DUSS**
t Stat	0.162133	0.162133
t Critical two-tail	2.178813	2.178813
SUSS		
t Stat		0.250578
t Critical two-tail		2.160369

Passage Formatting

All users completed their tasks accurately, since the tasks involved scanning content for specific words and applying binary effects on them. Totally 4 tasks were completed and average time per task is calculated from total time to complete the task. Average time per mode was consistently between 72 s to 76 s per task.

Table 6. Time Per Task TTest: Two Sample Assuming Unequal Variance

SUSP	SUSS	DUSS
t Stat	-0.36324	-0.21378
t Critical two-tail	2.200985	2.262157
SUSS		
t Stat		0.241258
t Critical two-tail		2.200985

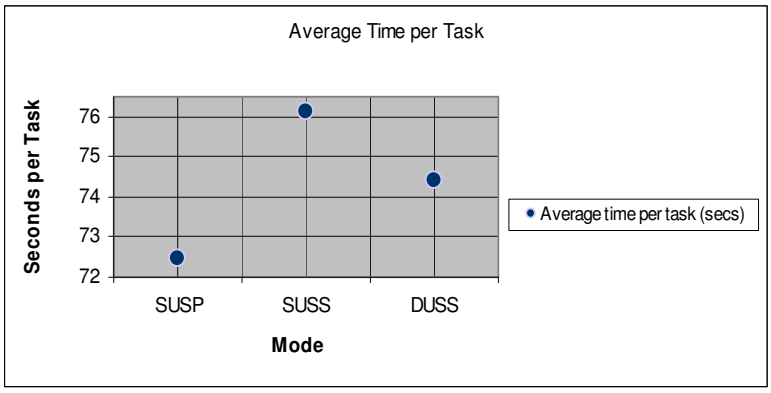


Figure 16. Average Time per Task in seconds

Conclusion

Across all three modes, the mean WPM, Accuracy, Time per Task are well within acceptable bounds of the baseline values of SUSP. Both SUSS and DUSS means approximate the 'ideal' scenario of Single User Single PC. Despite the limited sample size, TTest statistics indicate that we can with acceptable confidence not reject the hypothesis of all distributions occurring from the same sample space. Leading to the possible conclusion that user's performance on passage typing and formatting tasks is not greatly affected by the compact screen content and by the presence of another simultaneous user.

Appendix B

Limited resources environments and multi-user scenarios in small businesses in Bangalore, India

This is a write up on a field study of 16 businesses in Bangalore that own PCs. A quick scan of businesses in Sampige Road, Malleswaram in Bangalore was conducted, providing a glimpse of the variety of firms that own a PC for business-purposes. Most PCs were owned by firms that were franchised- larger businesses that have branches across the city and in many cases, the country. Although all PCs in such places were used for accounts and back-operations, some used PCs for billing at the point-of-sale.

The other types of businesses that used PCs are the ones where the service itself is computer-based. The role of the PC is limited to the service the business provides such as Desktop Publishing and Tutoring and not for management purposes. The number of PCs are fewer and the businesses are mostly family-owned and operated.

Sections 1,2 and 3 describe the characteristics of different types of PC-owning firms and the issues they face. Section 4 describes the initial reactions of some of these firms to Split Screen.

1. Franchised-Models

Table 7. Businesses and PC use of franchisees

	Store Name	**Nature of Business**	**# PCs, # Users**	**Purpose**	**Software platform**
1	GKB	Optician	1,1	Billing, Accounts	Windows
2	LifeKen	Medical Store	1,1	Accounts	DOS
3	Prestige Showroom	Retail	1,1	Accounts	Windows
4	Health & Glow	Retail	**2,7**	Billing, Accounts	Windows
5	GKS Gold House	Jeweler	1,1	Billing, Accounts	Windows
6	Shanti Sagar	Fast Food	1,1	Accounts	DOS
7	Ganga Sweets	Fast Food	1,1	Billing, Accounts	DOS

GKB Opticals, *Prestige showroom*, *LifeKen* use a PC for maintaining accounts and inventory-management. Orders are taken manually by low-skilled employees. At

the end of the day, an accountant or high-skilled employee enters the transactions into the PC. In *Prestige*, billing software is available (a FoxPro software) along with a printer but manual receipts are given. The manager says that it is more convenient to provide manual bills that are later entered into the system because then all employees can attend to the customer at point of sale. If computer-bills were to be used then the employees have to be trained to use the system.

In *Health and Glow*, a franchised pharmacist cum beauty-supplies store, there are two systems for billing and 7 employees, all of whom are trained to use the computer. However very often you find that there is only one PC used for sales and hence, during peak-hours, queues grow. The manager believes this is because employees work in shifts and they have other tasks to complete within a certain time (such as stocking the inventory). Saleswomen also need to attend to customers who enquire about products. Informal conversations in other stores such as Food World reveal that unless the manager directs an employee to billing, the employee will continue with other tasks. This suggests that internal human resource management solutions could improve efficient transactions more than supplying additional PCs.

In the cases of *Ganga Sweets, Shanti Sagar* and *GKS Gold House*, the proprietor owns several independent businesses that may not come under franchising model. Here PCs are used by his auditor couple of times a month for checking accounts across several shops. In each shop there is an accountant who maintains a computerized data entry of everyday sales.

2. Computer-Training Institutes

Computer training institutes are increasing in number. There is a lot of demand for applications such as MS Office, Tally and programming languages by students who are still pursuing their college degree and some graduates. Sampige Road is ideal for these students as they attend colleges in the vicinity. The classes operate in batches that are based on timing convenience for the students and availability of computers and instructors.

Table 8. Computer Education Schools and PC use

	Store Name	Nature of Business	# PCs	# Users	Role of User	Purpose
1	NICT	Comp. Inst.	20	6+	Tutors, Students	Office, Tally, HTML etc
2	MTA	Comp. Inst.	4	1+	Tutors, Students	Office, Tally, HTML etc
3	IgI	Comp. Inst.	6	2+	Tutors, Students	C, C++, Java, HTML etc.

NICT is the largest of the three institutes that were visited. There are 7 branches across Bangalore. The Malleswaram branch has 20 computers and 6 instructors. Classes are taken in batches varying for 2-3 hours. There are many batches per day, ranging from 12-20 students per batch on an average. Additional batches are made

available during seasons like summer, where demand is high. Malleswaram Tally Academy has four computers and 8-12 one-hour batches per day.

3. PC-based services- DTP

The following businesses provide services that depend on PCs- Desktop Publishing (DTP), Order-Online Delivery, and Digital Graphics Artists. Travel agencies also come under this category. DTP firms are studied in more detailed here. All these stores can be considered resource-constrained as there are more users than PCs.

There are over 15 Photocopying businesses in Sampige Road. They are all located in close proximity with each other and neighboring colleges. Although it is said to be very competitive, the older businesses have an edge due to established reputation and the ability to offer more services. The number of DTP firms is very small when compared to photocopy shops, and all of them provide photocopying as well. Most DTP firms that were studied were originally photocopy shops that expanded to offer more services.

Table 9. Desktop Publishing Businesses (DTP) and PC Use

	Store Name	Nature of Business	# PCs	# Users	Role of User	Purpose
1	Modi Xerox	DTP etc	2	2	Operator	DTP, Net surfing
2	Raghavendra	DTP etc	**3**	**4**	Operator, Typist	DTP
3	PrintO	DTP etc	**6**	**6-7**	Sales, Design	DTP, Scanning, Digital Photo Art
4	Print Point	DTP etc	**4**	**5**	Operator, Typist	DTP, Scanning, Local Language Typing
5	Anand Art	Digital Art	1	1	Designer	Signboards etc.
6	Vignesh	DTP etc	**3**	**4**	Operator	DTP

The value of the PC is not restricted to word processing applications. Each of the above shops deliver services besides printing. These include internet surfing, digital art, scanning, typing, DVD writing, lamination, binding etc.

In small shops - *Modi*, *Print Point*, *Vignesh*- customers come mostly for photocopying or printing small documents. Bigger shops such as *Raghavendra* and *Print-O* get large printing orders from businesses or customers who want to print fancy calendars, touch up photographs.

In almost all the shops, there are more employees than PCs, so it is interesting to understand how resource-management and distribution takes place. The following observations were made-

a) *Not all employees use the PCs*- There is always one employee trained only to take photocopies. The owner is the one who operates the computer in family run shops. In *Print Point*, of the 5 employees, 3 are typists and are not trained beyond opening and saving a file in the desktop. In *Raghavendra*, services include lamination, binding, offset printing apart from DTP. Most employees are busy with non-PC related tasks.

b) *Not all PCs are the same*- In *Print-O*, a retail chain for digital photo printing and design, PCs in the front-desk are for taking orders. At the back-office, PCs are used for digital art, CD writing, scanning, editing photographs. In *Vignesh*, *Print Point* and *Raghavendra*, only one PC has access to laser printer and scanner. The other PC(s) is used for typing and word processing applications. In *Modi*, only one PC has internet access.

c) *Resources are not constrained, customers are*- "We are satisfied with two PCs", says the proprietor of Modi Xerox. "We have a reputation for good quality and customers will *wait* for our service". Many loyal customers often leave their files with the shop and pick up the copies later, when they are not in a rush. Many customers are peons or college students who come in a group. *Vignesh* owner say that because the customers are in no "apparent" hurry and there is no pressing need for another PC to satisfy the demand. Some shop-owners have two businesses in the vicinity and customers in line would be told to visit the shop across the street. Only when the employee is pushed by a customer or the employee himself is in a hurry to finish a task, he borrows a few minutes of another employee's PC. Services like DVD writing, typing, large-volume printing, photo editing take a longer time to complete, so they allocate delivery time based on the demand. There is consistent response that the present level of resources is sufficient to handle the load.

d) *Cost of a PC includes the cost of an additional employee*- Having an additional PCs means having an available employee to man the PC. As mentioned earlier, in point of sale, an employee may be unavailable or at times unnecessary. *Raghavendra* and *Print Point* owners say that the productivity depends on an employee available to service the customer, not simply having a PC available. "When there are 2-3 employees, it is important to trust them with the systems, because if there is any problem then we have to call the service people. It is hard to find someone whom we can trust. Although the typists feel that they can use the PC, we only allow them to type and save the file. Sometimes, they are allowed to edit at the discretion of the customer", *Darshan* of *Print Point*.

4. Reactions to Split Screen

Franchised Retail Outlets

The interviewees equate the need for Split Screen to the need for another computer. They reiterate their perceived satisfaction with existing PC setup. Larger retail stores have more structure and decisions on process enhancements are made by head office management. Stores like *GKB Opticals*, *Health and Glow, Prestige Showroom* do not see the significance of the savings value in Split Screen. As they are high-end stores they do not have high-volumes of customers. If they did need an additional PC, it could be for inventory management and accounts and they would like the flexibility to locate that PC in another room, rather than having to share the display with the system used for billing.

Computer Training Institutes

Computer Institutes manage with limited resources by increasing the number of batches. If students had to share Split Screen then students could demand lower rates for giving a diminished user-experience. They also question the value in real-world scenarios where the students will be using an exclusive system. The transition from Split Screen experience to an exclusive PC experience has not been evaluated. However, all these schools were for-profit and catered to college students and hence they were interested in knowing more about educational benefits given they are often short of computers and tutors. This was seen as a positive indication to explore educational frontiers with Split Screen, that motivated much of this thesis research.

PC-Based Services

In DTP shops, the limitations are due to practical constraints

- The PC with the Split Screen must be able to support all the applications necessary- from connections to peripheral devices to heavy duty software applications (such as Adobe Photoshop). It would not serve the purpose if the system can only be used for MS Office or Web surfing

- Training employees to use Split Screen becomes could become burdensome especial for those who are already low-skilled (such as the typist).

- If the system crashes then both users could be affected

- Co-location becomes problematic when dealing with customers who have tough privacy requirements. Employees could get confused when two customers are being attended to, not sure of which customer is addressing which employee.

- Pirated software use is rampant in these shops. The cheapest second-hand PC was Rs.8000. Given this context, the economic benefits of Split Screen does not seem meaningful to them.
- Some of the rooms with a PC are too small to accommodate enough space for another user, keyboard and mouse.