'Hole-In-The-Wall' Computer Kiosks Foster Mathematics Achievement - A comparative study

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ABSTRACT

Earlier work at unsupervised playground computer kiosks in rural India, popularly called 'hole-in-the-wall', showed that children exposed to these kiosks learn to use computers on their own and that they are able to clear school examinations in computer science, without any classroom teaching for it. Extending this, our recent research work examines the possible impact on attainments in other curricular subjects, arising from self-directed use of these kiosks. This paper investigates the impact of use of the playground computer kiosk, on school examination results, of students in a rural school in India over a 2.5-year period from 2002-2004. A comparative study was conducted, of students from a kiosk school and a non-kiosk school, as well as of frequent and infrequent users of the kiosk. The study covered groups of a total of 161 students who were aged 13-14 in 2004. Students were measured for differences in their intelligence, creativity potential, leadership potential, and frequency of kiosk use. The school results show a significant impact of kiosk usage on Mathematics achievement.

Keywords

Hole-in-the-wall, Collaboration, Learning, Technology, Mathematics

Background

Seymour Papert's seminal book on computers in education titled - Mindstorms: Children, Computers and Powerful Ideas (1980) - presented frameworks for the use of computers in education. Later Papert spoke of stages in learning, as stages in the relationship between the individual and knowledge (1980s discussion between Papert & Freire). The three stages mentioned go from self-directed, experiential learning in early childhood to 'teaching' and 'being told' in school and comes back to experiential learning among creative adults. By providing exploratory opportunities of immense complexity, during the school years, technology brings self-directed, experiential learning back into the second, 'school' stage. In 1996, Papert saw the proliferation of personal computers in homes as a welcome change from computers in schools and described frameworks for using the computer as an educational tool within families (Papert 1996, interviewed by Bennahum). There appeared to be problems, according to Papert, with the deployment of computers in education. In school, computers were sent into computer labs and hijacked, so to speak, into the structure of school instructional curriculum, class timetables and a strict age-wise segregation.

The home environment, while providing possibilities for self-directed, experiential learning, does not offer as many social opportunities for interactive learning with others in peer groups.

In 1999, the 'hole-in-the wall' experiment in New Delhi, India, moved the computer out of schools and homes into playgrounds. A computer was connected to the Internet and embedded into a brick wall around an informal playground next to a residential slum. Slum children were able to use the computer to browse, play games, create documents and paint pictures within a few days (Frontline World 2002, Education Guardian 2000, Businessweek Online 2000, Mitra 2000, Mitra 2003 and Wullenweber 2001). Children aged 8-14 worked together in groups at the computer, making exploratory discoveries, generalizing their learning, describing it in a local context and teaching each other. The press called the experiment "hole-in-the-wall". Researchers called it "Minimally Invasive Education" (MIE). Research showed that groups of children could learn how to use public computers on their own, without adult intervention (e.g. Mitra and Rana 2001; Mitra 2003; Inamdar 2004).

The delivery mechanism for MIE uses 'hole-in-the-wall' kiosks with computers embedded in holes in the outer walls of a hut like structures, the monitor screens facing outside. Presently (November 2005) there are over 105 computers deployed through Minimally Invasive Education kiosks (MIE kiosk) in rural and urban India. An estimated 40,000 children have used these kiosks. The kiosks are placed in playgrounds and are not supervised by teaching staff.

The computer has been a 'material' for constructionist learning (Papert 1980's) in classrooms and homes. Moving it to playgrounds marks a change in the way it has been used, and hence its potential, possible impact. In this paper we examine the impact of playground MIE kiosks on achievement in school examinations. A significant impact is found on results in the subject of Mathematics.

A Hypothesis for the present study

MIE kiosks were set up in the villages of Sindhudurg district of Maharashtra State in India, in April 2002 (see photo 1). The kiosks are placed in playgrounds or close to schools.

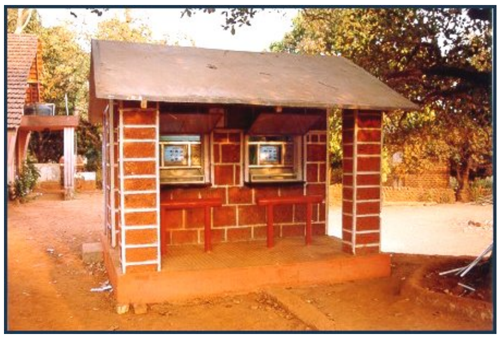

Photo 1. MIE kiosk, Kalse Village, Sindhudurg District, India

Each kiosk in the Sindhudurg district houses 2 computers and incorporates special design features to allow for public access, tropical conditions, remote monitoring, and usage by children (Inamdar 2004). The computers in the MIE kiosks offer an English language Microsoft Windows environment. Three kiosks were connected to the Internet via VSAT in June 2004. Offline content on the kiosk computers includes both educational games and videos, as shown in table 1.

Table 1. Off-line educational material on computers at MIE kiosks

	Mathematics	**English**	**Science**	**Total**
Educational Games	8	8	5	21
Educational videos	21	2	15	38

Educational games installed on the computers were free downloads from the Internet. The educational videos were provided by an Indian educational agency.

The Mathematics games covered activities related to learning numbers, shapes, sizes, quantities, patterns, basic addition, subtraction, division, multiplication, and basic algebra (translating word problems into solvable equations).

Games for English language learning included learning the alphabet, letter sounds, spelling, common English words and phrases, rhyming words, adjectives and word families.

Science games included content on electricity, time, space, gravity, kinetics, continents, oceans, animals and deserts.

The local language as well as the language of instruction in the village schools is Marathi. English is learned as a second language from Grade 1.

Rural children aged 8-14 use these kiosks in groups in a process characterized by collaboration, discovery and knowledge construction. Adults do not supervise the kiosks and there is no formal coaching/teaching. A study of the impact of the kiosks on school achievement in the computer science subject showed that children who had learned computers on their own at the MIE kiosk were able to clear the Grade VIII computer science examination without being taught the subject during the school year (Inamdar, 2004). The study also describes group based self-learning patterns at the kiosks. Learning did happen in the school subject of computer science. Could the kiosk impact learning in other academic areas?

The primary method of evaluation in Indian schools is examinations that are conducted twice during the school year. We investigate if learning at the MIE kiosks shows up as improved performance in these examinations in the subjects of English, Science and Mathematics. The following are hypotheses for our research:

1. If given appropriate access, connectivity and content, groups of children can learn to use computers and the Internet to achieve a specified set of the objectives of education, with none or minimal intervention from adults.
2. Academic/School performance will be impacted by the frequency of use of the MIE kiosk.

In this paper we analyze the impact of the kiosk on objectives of education as measured by performance in school examinations.

Method

Villages Shirgao and Kuvle, of the Sindhudurg District, are at a half hour driving distance from each other. The Shirgao School has an MIE kiosk in the school playground. Kuvle has no computers at all. All of 161 children aged 13-14 in 2004, from both villages, were included in our study. Scores on school examinations in the subjects of English, Science and Mathematics were chosen as the dependent variables observed for the impact of the kiosk.

As mentioned, field observations at MIE kiosks show that the learning process at MIE kiosks involves random exploration, collaboration and discovery. Factors of intelligence and personality could play a role in these processes. Hence tests for intelligence and personality tests for creativity and leadership were conducted on all students. The intention was two-fold - to check for any differences between the two villages, before the kiosk, on variables of personality and intelligence and to check for differences between the two villages on the dependant variable – scores in school examinations.

Since kiosk usage is voluntary it was necessary to know the kiosk usage patterns of the group at Shirgao. Hence, a second level comparison was conducted of frequent and infrequent users of the kiosk within the Shirgao population. Therefore, the two levels of comparison conducted were as follows:

1. Between kiosk village (Shirgao) vs. non-kiosk village (Kuvle)
2. Between frequent kiosk users vs. infrequent kiosk users within Shirgao

The comparison of villages could tell us of differences, if any, due to intelligence and personality factors impacting school scores. Data from Shirgao could provide a reference point for understanding differences, if any, between frequent and infrequent users within the kiosk village population. Additionally, the two levels of comparison could provide us useful information on another independent variable that could critically affect school scores – school coaching quality. Differences in scores for comparable groups between villages could point to changes in school coaching quality and/or MIE kiosk. Clearly, this factor of school quality would apply equally to frequent and infrequent users of the kiosk from the same school (Shirgao), and serve as a crosscheck.

The following tests were conducted on a population of 116 schoolchildren from Shirgao and 45 from Kuvle:

1. Test for Intelligence - Raven's Standard Progressive Matrices (SPMRS)
2. Test for personality - Catell's High School Personality Questionnaire. The composite scores on leadership potential (LP) and creativity potential (CP) were considered
3. Test for kiosk usage – Frequency of Usage Test (FUT).

While the first two tests are standardized and well known, the third test was devised for the specific needs of this research project. Its design is elaborated under the heading 'The Frequency of Usage test' below.

School examination scores (Mathematics, Science, English) of the 161 children were collected from the time before MIE kiosk implementation – March 2002 – and 2.5 years after – October 2004.

The method of analysis of variance (ANOVA) was used to examine differences between categories of data. The differences were regarded significant if $P < 0.05$ and highly significant if $P < 0.01$.

The Frequency of Usage Test (FUT):

The Frequency of Usage Test (FUT) was devised by one of the authors of this paper (Inamdar) to arrive at an empirical measure of that independent variable - individual's frequency of MIE kiosk usage. The FUT is a one-page questionnaire that yields a self-report as well as a peer report of an individual's frequency of kiosk usage. This method of arriving at a consensus-based judgment of an observable behavior is not unknown in human personality research (see Box 1).

Consensus-based judgment
A significant body of research on human personality judgment has established the method of consensus between self and peer reports for making human personality judgment. These studies suppose that if personality differences can be observed then there should be a consensus among independent observers on the relative standing of the observed person on personality traits. The personality judgment approach as described by Funder in 1999 centered on judgments of individuals by knowledgeable informants. In 1994 Hofstee stated "The averaged judgment by knowledgeable others provides the best available point of reference for both the definition of personality structure in general and for assessing someone's personality in particular". In a validation of the five factor model of personality McCrae and Costa (1987) used two data sources - self reports and peer reports – to validate the 5-factor model of personality. Studies typically show interobserver agreement correlations in the region of .50 (e.g., Funder, Kolar, & Blackman, 1995; McCrae, 1982). Further, personality studies extended to dogs personality have used this approach and have shown human owner to peer correlations for owner personality judgments at .55 and for the dog personality judgments at .62 (Gosling, Kwan, & John2003). Judgments by knowledgeable others is considered an acceptable method.

Box 1

Each individual in a group of 6 peers was administered a one page questionnaire wherein s/he indicated his/her peers' frequency of kiosk usage as well as his/her own. One of the following options were indicated by each student, for each student:

1. Never visit
2. Visit once in a fortnight
3. Visit one to three times in a week
4. Visit four to seven times in a week

This means there were 6 scores to be analyzed for each individual. The mode value was taken as the indicator for frequency of the individuals kiosk usage. It represents the score reported by the largest number of students within the group. In other words, this is the judgment of the majority of students. It does not rule out the extreme values within the group if the Mode is at these values.

The first two categories listed above were combined in the results to define *infrequent users*. Categories 3 & 4 were combined to define *frequent users*. Correlations between peer and self-reports were at 0.61, an acceptable confidence level, as shown by prior work on judgments by consensus.

Results

Differences between two villages in CP, LP and SPMRS scores

To begin, we attempt a comparison between the two village groups of Shirgao & Kuvle on Leadership Potential (LP), Creativity Potential (CP) and Standard Progressive Matrices Raw Score (SPMRS).

Table 2 below shows differences between Shirgao and Kuvle in averages for personality tests. Analysis of Variance (ANOVA) shows no significant difference between Shirgao and Kuvle on average scores of LP, CP or SPMRS. This indicates that the populations of Shirgao and Kuvle are matched on leadership potential, creativity potential and intelligence.

Table 2. Differences between Villages in Averages for Personality Tests

		N	Average	Difference*
CP	Shirgao	116	6.58	
	Kuvle	45	6.31	-0.28
	Total	161	6.51	
LP	Shirgao	116	4.98	
	Kuvle	45	5.74	0.76
	Total	161	5.19	
SPMRS	Shirgao	116	32.51	
	Kuvle	45	35.69	3.18
	Total	161	33.40	

*None of the differences is significant

Differences between two villages in school examination scores

Figure 1 shows the average school scores for English, Mathematics and Science for Shirgao and Kuvle in March 2002, *before the MIE kiosk was setup in Shirgao*. ANOVA shows no significant difference in the average scores of English, Mathematics and Science between the two villages - we could say that both villages well matched.

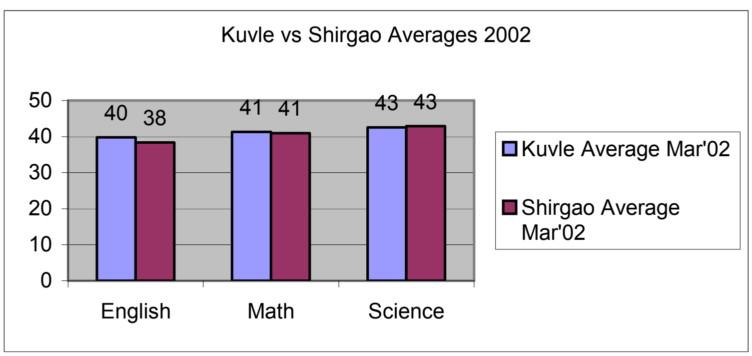

Figure 1. Average school scores for Shirgao and Kuvle

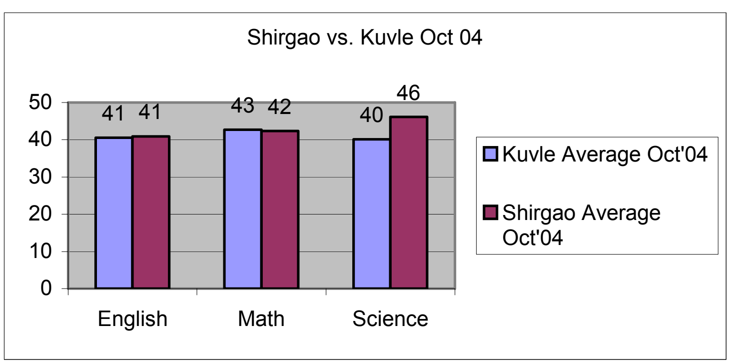

Figure 2. Average school scores for both villages

Figure 2 shows the average school scores for English, Mathematics and Science for both villages in October 2004, 2.5 years after the MIE kiosk setup in Shirgao. ANOVA shows no significant difference between the two villages on average scores for English and Mathematics. However the Science score at Shirgao is significantly higher than Kuvle. Since both village groups are matched on LP, CP and SPMRS, the other factors of school coaching and/or MIE kiosk could account for the higher scores in Shirgao in Science in October 2004.

It could appear that Shirgao's scores in Science are significantly higher than Kuvle's scores in Science in October 2004 due to the presence of the kiosks. However factors related to school quality could have impacted this change too. A more in-depth look within the Shirgao population is undertaken.

Differences between Shirgao frequent and infrequent users in CP, LP & SPMRS scores

The assumption is that all students at Shirgao are exposed equally to the same school-related factors – resources, quality of teaching and evaluation. Therefore, to analyze the effect of the kiosk on school scores we checked for differences between frequent and infrequent users. The FUT indicated that of the total of 116 children tested in Shirgao, there were 62 frequent users and 54 infrequent users. These two groups in Shirgao were compared on the following factors:

1. Creativity potential (CP)
2. Leadership potential (LP)
3. Standard Progressive Matrices Raw score (SPMRS)
4. School scores – Science, Mathematics English

Table 3 shows that ANOVA found no significant differences between frequent and infrequent users on average LP and CP scores. There is, however, a significant difference between the two groups on average intelligence scores. Therefore the factors of CP and LP are ruled out as affecting differences in school scores of frequent and infrequent users. However it does leave intelligence to be considered.

Table 3. Differences Among Frequency Groups in Shirgao for Personality Tests

		N	Average	Difference
CP	Infrequent Visitors	54	6.53	
	Frequent Visitors	62	6.63	0.10
	Total	116	6.58	
LP	Infrequent Visitors	54	5.01	
	Frequent Visitors	62	4.94	-0.07
	Total	116	4.98	
SPMRS	Infrequent Visitors	54	29.07	
	Frequent Visitors	62	35.50	6.43
	Total	116	32.51	

Differences for SPMRS are significant ($P < 0.05$), but not for CP and LP

Further Method

At this juncture, we could hypothesize that the different SPMRS scores of frequent and infrequent users as well as the frequency of kiosk usage could account for any difference in school subject scores between the two groups. However, any differences in school scores seen between user groups due to the intelligence factor should remain stable over time – before kiosk and after kiosk.

To check for the impact of the kiosk, as distinct from school coaching related factors and SPMRS, we adopt the following approach:

1. Determine value of difference between frequent and infrequent user groups before the kiosk in March 2002. Is the difference significant?
2. Determine value of difference between frequent and infrequent user groups after the kiosk in October 2004. Is the difference significant?

3. Determine the value of change in the differences before (March 2002) and after (October 2004). Is the change in differences significant?

We expect that the *significance of change* in differences between the two users groups over the years should isolate the influence of MIE kiosk usage on school scores, from the influence of school coaching related factors or SPMRS.

Differences between Shirgao frequent and infrequent users in school English results

Table 4 shows ANOVA results that frequent user average scores in English are higher than infrequent users in March 2002. However, this difference in scores in March 2002 is not statistically significant. Again, the differences in English scores between the two groups in October 2004 are positive but not significant. More importantly, there is *no significant change in the differences* between March 2002 and October 2004. *Therefore there appears to be no significant influence of the kiosk on English scores.*

It is useful to recall that there are no significant differences between the villages Kuvle and Shirgao in English before or after the kiosk set up (figure 1 & figure 2). This data seems to indicate that the present MIE kiosk, with the present off-line content has not significantly impacted English scores at Shirgao.

Table 4. English ANOVA Differences

	Differences March 2002	Differences October 2004	Change of Difference from March 2002 to October 2004
Frequent – Infrequent	3.21	4.49	1.28

Neither of the differences nor the change in differences is significant

Differences between Shirgao frequent and infrequent users in school Science results

Curiously, table 5 ANOVA results below show a significant difference between the frequent and infrequent user groups in Science both before and after the kiosk was set up. This is clearly impacted by factors other than use of kiosk, though not necessarily in entirety. Our data shows that frequent users have higher average intelligence. This may have impacted the difference in science scores before the kiosk (March 2002).

There is no significant change in the frequent-infrequent user difference in science scores before and after, indicating, that the influence of kiosk usage has no significant impact here. Clearly, the presumption is that the impact of the factor of intelligence on scores in science for frequent users seems stable over the years. There is a significant difference in scores between the user groups both before and after, and the difference has not changed significantly over time. This leads us to think that it is not frequency of usage but intelligence – a stable factor - that has significantly impacted differences in science scores at Shirgao. This should explain why change of differences from March 2002 to October 2004 is not significant.

Table 5. Science ANOVA Differences

	Differences March 2002	Differences October 2004	Change of Difference from March 2002 to October 2004
Frequent – Infrequent	4.66	5.61	0.95
	Significant ($P < 0.05$)	Significant ($P < 0.05$)	Not significant

Differences between Shirgao frequent and infrequent users in school Mathematics results

Table 6 ANOVA results below show that the difference between frequent and infrequent users in Mathematics in March 2002 is not significant, although positive. *In October 2004 however, frequent users have scored significantly higher than infrequent users.*

Additionally, *the change in differences between the two groups over the 2 years is also significant*. In other words, the gap in scores for Mathematics between frequent and infrequent users has widened over the years.

The impact of intelligence on scores of the two groups of users is presumed to have been stable over the years. Two significant findings stand out: first, *higher Mathematics scores of frequent users after the kiosk set up*; second, the *widened gap between frequent and infrequent users in October 2004*. These findings lead us to think that use of the MIE kiosk has impacted Mathematics scores of frequent users at Shirgao.

Table 6. Mathematics ANOVA Differences

	Differences March 2002	Differences October 2004	Change of Difference from March 2002 to October 2004
Frequent – Infrequent	3.39	6.56	3.16
	Not significant	Significant ($P < 0.05$)	Significant ($P < 0.05$)

Discussions of results and conclusions

It appears that frequent users, on account of their higher average intelligence, score somewhat better, than infrequent users on all school examinations during the period of study. This reinforces the premise that scores for Intelligence – and hence its impact – is invariant over time, and hence through the period of exposure to kiosks.

The significant impact of the use of MIE kiosk is seen in the subject of Mathematics for this age level in Shirgao. Frequent users scored significantly higher than infrequent users in Mathematics after the kiosk was setup (October 2004) in comparison to before (March 2002).

The Mathematics software on the kiosk machines includes activities related to learning numbers, shapes, sizes, quantities and patterns; basic operations such as addition, subtraction, division, multiplication; and basic algebra (translate word problems into solvable equations). Any performance in school Mathematics examinations could be impacted by the strengthening of these very basic mathematical skills.

However no significant growth of scores of frequent kiosk users, assignable to the use of kiosks, is seen of post-test scores (October 2004) over pre-test scores (March 2002) in English or Science.

Regarding English and Science results, discussions with the Mathematics teacher, Mr. Shamsuddin Attar, at the Shirgao School, provided interesting insights. School English and Science examinations are based largely on answering textbook questions in a prescribed manner and format from memory. This is often referred to in Indian education as "rote learning". The software for English and Science learning on the kiosk may not help impact scores based on such rote responses, neither is it adequately relevant to the content knowledge expected by the school curriculum. The school Mathematics examination by nature has to do with problem solving. In Attar's opinion, these core problem-solving abilities, developed through self-directed learning by groups through the computer kiosk could have impacted school scores in the subject of Mathematics.

Clearly, the impact of the use of MIE kiosks - with the given off-line content - on attainments in English, Science & Mathematics is not uniform. Factors worth examining in future research are the nature of off-line content on the kiosks, the differences in design of learning software and how well the modes of learning fit the modes suited to each subject.

It may be reemphasized that the modes of learning underlying this impact on Mathematics scores remain to be investigated. Impact could be due to the particular Mathematics software in the kiosk computers – its design and content. It could also be that, deeper cognitive processes within the students, are impacted by collaborative work in the computational environment, to improve Mathematics scores. Or, more likely, a combination of both. This needs further study.

Further investigation into the nature of learning at kiosks - including group learning - and relevant Mathematics content could provide a basis for newer design of a self-directed kiosk learning environment. The goal could be a process that further supports and enhances school achievement in this area. The Mathematics learning environment (off-line content) at the kiosk seems already better suited to self-directed learning than the corresponding environments for English & Science.

A similar approach for further investigation could also lead to creation of a better self-directed group learning environment and software design for English & Science.

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