Interactive DVDs as a Platform for Education

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***Abstract*—While many technologies remain out-of-reach for households in the developing world, one exception to this rule is that of entertainment technologies. Even in poor communities, there is a strong drive to own devices such as TVs and, increasingly, DVD players. Though they are typically used for video content, ordinary DVD players also support rich interactivity and programmability, including the capability to browse over 100,000 menus using the remote control. Our vision is to leverage these capabilities to support interactive applications – such as encyclopedias, language tutoring, and medical decision systems – without any dependence on a computer.**

As a step towards this vision, in this paper we explore two novel applications of interactive DVDs in the context of education. The first is as a platform for PowerPoint presentations, where TV-DVDs have the potential to replace computers while reducing costs and improving teacher familiarity. The second is as a platform for children's books, where one can provide thousands of books on DVD for the same price as printing a single book. We evaluate each of these solutions – which have already found uptake with NGOs – via case studies in Indian schools.

I. Introduction

The steady increase in computer penetration in many developing countries has spurred broad interest and debate regarding the potential role of technology in improving education for underserved populations [1]. This dialogue is especially relevant in India, where 14% of the nation's 1.3 million schools are now equipped with a computer [2]. Efforts to utilize technology in the classroom have ranged from video-assisted lectures [3], to self-paced learning on CD-ROMs [4], to collaborative engineering design [5].

However, despite the perception of computers as a portal of opportunity for underprivileged schools, there remains a large gap between vision and reality. While schools might own computers, the demands of training, maintenance, and support (which can cost up to three times as much as the initial installation [6]) imply that computers often go completely unutilized. And even when there is ample technical support, it remains a challenge to integrate the technology – unfamiliar to most teachers and students – into the daily routine of the classroom.

In this work, we explore the option of using a low-tech alternative to computers – TVs and DVD players – as a platform for interactive educational content. As summarized in Figure 1, TVs and DVD players (or TV-DVDs) have several advantages over computers in developing regions. In addition to their lower cost, 72% of Indian households have TVs; DVD penetration is currently at 13% of households but is expected to rise to 24% by 2013 (exceeding the penetration of computers, which is projected to be 13%) [7]. In addition, there is a very robust network for copying and distributing DVDs in India (in villages, they are often watching movies that have not been released yet!) Unlike computers, TV-DVDs are familiar and unintimidating to teachers. TV-DVDs are reliable, can be maintained with local expertise, and are also standardized (they do not require specific software, video codecs, disk space, etc., to support multimedia applications). TVs are also designed for group usage, offering a big picture, loud sound, and remote control, while computers are designed for individual use. On the flip side, TV-DVDs are of course less flexible than a computer, both in terms of input modalities and supported applications, and are generally perceived as providing entertainment rather than providing opportunity.

While TVs and DVD players have been widely used for displaying educational video content [3], [8], [9], we contend that the interactive features of DVD players have been underutilized in the context of education. Just as one can use the DVD remote control to select a chapter of a movie, it is possible to map over 100,000 hyperlinked still menus for interactive browsing on a single DVD. Ordinary DVD players are also capable of executing simple programs, encompassing arithmetic, control flow, and local storage. Our vision is to leverage these capabilities to provide rich interactive applications, such as encyclopedias, language tutoring, medical decision systems, and world atlases. As detailed in Section VI, all of these applications should be within reach of TV-DVDs, though are currently reserved for those who have access to computers or the Internet.

As a step towards this vision, in this paper we explore two novel applications of interactive DVDs in the classroom. The first is as a vehicle for PowerPoint teaching aids. While PowerPoint content is typically associated with computers, it turns out that all of the commonly-used features – including animations, hyperlinks, and embedded multimedia – can be supported by TV-DVDs. Working in partnership with an NGO that develops PowerPoint slides to enrich the state board curriculum in Karnataka, India, we studied the potential of TV-DVD as an alternative to computers via a month-long case study in a local school. Based on feedback from teachers, students and parents, our study suggests that TV-DVD is not only as acceptable, but sometimes is preferred to the computer as a technology in the classroom. Our partner NGO (CLT India) has responded to this study by converting all of their content to TV-DVDs, and is excited to expand their reach by using TV-DVDs in the future.

As our second application, we focus on the domain of children's books for language and literacy learning. Though children's books do not depend on a computer, they are

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	TV with DVD Player	Computer
Cost	+ $200 (or less)	− $400 (or more)
Familiarity	+ very familiar	− not familiar
Reliability	+ very reliable	− not reliable
Standardization	+ very standardized	− not standardized
Designed for	+ use by group	− use by individual
Input devices	− less flexible	+ more flexible
Computation	− less flexible	+ more flexible
Perceived as	− providing entertainment	+ providing opportunity

Fig. 1. Tradeoffs between TV-DVD and a computer in the classroom.

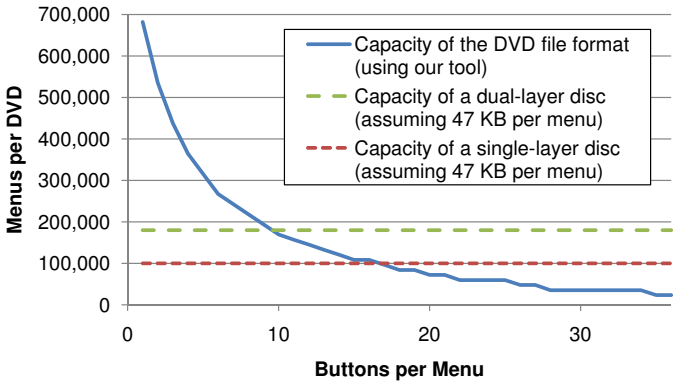


Fig. 2. The number of menus that can fit on a DVD is constrained by both the DVD file format as well as the physical capacity of the disc. Our tool allows many menus to be represented within the DVD file format; the capacity of the format depends on the number of buttons (options) per menu. For the applications in this paper, we are ultimately constrained by the physical capacity of the disc.

nonetheless expensive to copy and reproduce, costing $0.50 per book from non-profit publishers. Using custom tools, we can map over 5,000 twenty-page children's books to a single DVD, providing an entire library at less cost than a printed book (assuming a school already owns a TV and DVD player). Unlike an ordinary movie, our interactive DVDs enable children to read at their own pace by using the remote control to advance each page. We gathered feedback for the concept of books on DVD via short deployments in three schools, spanning structured and unstructured reading activities. We also conducted a one-hour trial to evaluate whether books on DVD lead to comparable comprehension and readability as books in print; the results showed no significant difference between the two mediums. We are working with NGOs and libraries to further scale our deployments in the future.

In the remainder of this paper, we start with a survey of related work (Section II) and an overview of the capabilities of DVD players (Section III). We then focus on the application of TV-DVD to PowerPoint teaching aids (Section IV) and children's books (Section V). We close by presenting our vision for the future of interactive DVDs in education (Section VI) as well as our conclusions (Section VII).

II. Related Work

The use of video as a medium for educational content has been the subject of extensive study; see Goldman et al. [8] for a review. In the context of developing regions, the Digital Study Hall project also utilizes TV-DVDs in classrooms [3]. However, the content consists of videos of charismatic teachers, and does not contain the textual and interactive elements of PowerPoint presentations or children's books. Similarly, the Digital Green project utilizes TV-DVDs to facilitate agricultural extension [9], but does not rely heavily on interactive features. Researchers have characterized the prevalent usage of TVs, DVDs, and other technologies in an urban slum environment [10] and have utilized VCDs as a tool to trace information diffusion through such communities [11]. The prospect of interactive TV has also been assessed in the Indian context [12].

While there are commercially-available DVDs that overlap our goals in this paper, they lack either interactive features or educational content. In India, there are children's books and reference materials available on VCD and DVD (e.g., from BookBox, Pebbles Infotainment or Vision Interactive Systems); these are sold widely in both formal and informal markets. However, interactivity is almost completely absent; a children's book on DVD is played like a subtitled movie, without giving teachers or students the ability to advance the page at their own pace. Also, the available discs do not exploit the flexibility of the DVD specification; they appear to be limited to (at most) a few hundred screens. Conversely, in the United States, companies such as Screenlife have exploited many of the interactive capabilities of DVDs, but have focused on the domain of games rather than educational content.

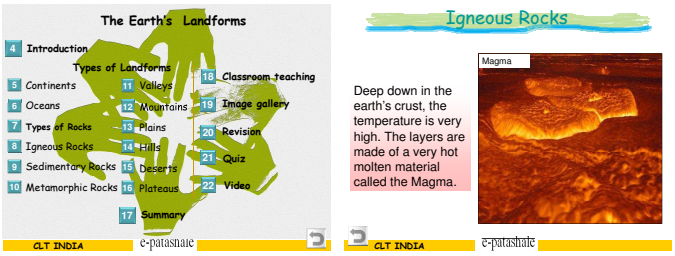
There also exists a commercial tool to convert PowerPoint presentations to interactive DVD, and we utilize it for the sake of our study [13]. However, we are unaware of any prior evaluation of interactive DVD-based teaching aids in the classroom.

There has also been extensive research and debate regarding the merits of PowerPoint as a teaching aid; see Levasseur and Sawyer [14] for a review. While we do not aim to advance this dialogue in the current paper, one unique benefit of using interactive teaching aids in developing regions is the prospect of engaging students when the teacher is absent, either in the classroom or in a home environment.

III. Capabilities of DVD Players

Off-the-shelf DVD players support rich interactivity as part of the normal DVD standard. Just as one can use the remote control to navigate menus and select the chapters of a movie, it is possible to map hundreds of thousands of hyperlinked menus to a single DVD. The exact number of menus that can fit on a DVD depends on two factors: 1) the number of menus supported by the DVD file format, and 2) the number of bytes that can fit on a physical disc. As most of the common DVD authoring tools (such as Microsoft DVD Maker and Apple DVD Studio Pro) do not allow more than 1,000 menus per DVD image, we implemented a custom tool that maximizes the number of menus admissible under the DVD format. The achievable number of menus depends on the number of buttons (options) that appear on each menu screen.

The number of menus allowed by our tool is illustrated in Figure 2. Except for applications that require more than 16



(a) Topic selection (b) Content

Fig. 3. Example of interactive teaching aids in PowerPoint format.

(a) Computer (b) TV-DVD

Fig. 4. Classroom instruction with (a) computer and (b) TV-DVD.

buttons per menu, our tool prevents the DVD format from being a limiting factor in the capacity. Instead, the capacity is limited by the physical constraints of the disc. For a standard 4.7 GB disc, approximately 100,000 high-quality photo menus (47 KB each) can be stored; our tool allows 16 buttons per menu. For a dual-layer 8.5 GB disc, approximately 180,000 high-quality menus can be stored; our tool allows 9 buttons per menu. Higher capacities are possible for simple menus that compress well. The technical details of our tool are beyond the scope of this paper, but will be the focus of future publications.

In addition to supporting a large number of hyperlinked menus, the DVD format also supports flexible computations. Embedded in every DVD player is a virtual machine that interprets a stream of instructions from the DVD image. The machine has 16 general-purpose 16-bit registers; instructions include arithmetic, comparison, branching, and primitive timing operations. However, there is no access to a random-access memory (such as a stack or heap) and there is no indirect jump instruction. All graphics that are rendered on the screen must be bundled as MPEG-2 videos, including all still images and text (even subtitles in DVD movies are encoded as bitmaps).

In terms of input modalities, the remote control remains the only off-the-shelf means of interacting with a DVD player. However, even here some flexibility exists, as there are two ways to select a given button on a menu. One can either use the arrow keys to highlight the button of interest, before pressing return; or, one can enter a number key to immediately select the corresponding button on the screen. We have found that numbering each button leads to easier navigation for pages with complex button layouts.

Synthesizing the primitive capabilities described above, interactive DVDs can support many sophisticated functions, for example:

- *Large branching factors*. DVDs can hold large hierarchical or hyperlinked databases that are navigated with many choices at each level.
- *Counting*. DVDs can keep track of a user's button selections using the registers. This can enable (for example) giving a score for a quiz, or learning the interests and preferences of users.
- *Calculations*. It is theoretically possible to implement a calculator on a DVD player, so long as values do not exceed (approximately) 100,000. This also opens the door to several math-based games.
- *Pseudo-randomization*. It is possible to have a pseudo-random playback sequence on DVD; for example, to show questions out-of-order.
- *Instrumentation*. The DVD player can track usage patterns and store it in the registers, then display usage statistics to a supervisor upon pressing a special button. For players that support suspend/resume functionality, such instrumentation can even span intervening usage of another disc.

In the rest of this paper, we focus our attention on two applications of interactive DVDs: PowerPoint teaching aids and children's books. However, these represent only two of applications that we have envisioned; Section VI proposes other novel applications that leverage the advanced features of interactive DVDs for education.

IV. PowerPoint Teaching Aids on TV-DVD

In this section, our application of interest is that of electronic teaching aids, which in the Indian state of Karnataka are being developed to correspond directly with the state board curriculum. Authored in PowerPoint format, the electronic content aims to help teachers to deliver effective lectures (esp. in subjects where they lack expertise); to engage students with rich multimedia elements; and to offer self-directed exploration and review (e.g., in the event of teacher absence). An example of this content, which is produced by an NGO called CLT India, appears in Figure 3. It consists of index pages, content pages, as well as quiz pages that check student understanding via multiple-choice questions. Because LCD projectors are expensive and difficult to set up, the content is displayed directly on a computer screen (see Figure 4). It is currently being deployed across 40 schools in and around Bangalore.

To convert the content to TV-DVD, we employ an off-the-shelf PowerPoint-to-DVD converter that supports animations, hyperlinks, and embedded multimedia [13]. We leverage hyperlinks to create interactive presentations, including multiple-choice questions with different feedback for each answer. Such functionality proves to be very popular in the classroom. Due to some restrictions in the converter that we employ, our DVDs assign "1" to advance to the next slide; "2" to rewind to the previous slide; and "3" to return to the main menu. As shown in Figure 3, other links are numbered starting from "4".

Subject	Classroom	Elapsed Weekdays														
		1	2	3	4	5	6	7	8	9	10	11	…	15	16	17
Environ. Science	TV	✓		✓✓		✓		✓	✓✓	✓	✓	✓				
	Computer		✓	✗	✗		✗	✓	✗	✓	✓	✓				
Social Science	TV							✓		✓				✓		
	Computer								✓	✓						✓

✓ indicates technology use ✗ indicates class was skipped

Fig. 5. Usage of TV and computer in the classroom. Where indicated, the computer classroom was skipped (due to unrelated teacher absence) and the TV classroom had a double period for one subject.

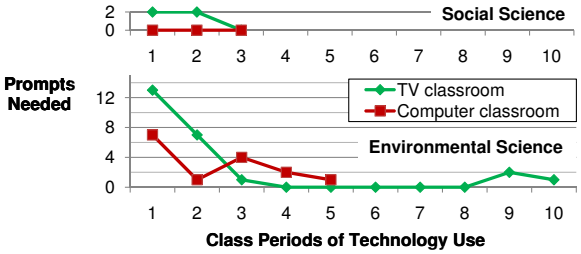


Fig. 6. Prompts required to use the devices during each class period.

In the remainder of this section, we describe a case study in which we evaluate TV-DVDs as an alternative to computers for PowerPoint content in a classroom setting. We deploy a TV-DVD and a computer in two adjacent classrooms and observe their use over a 3.5-week period, gathering feedback from teachers, students, parents, and content developers. While our study is only exploratory and leaves several questions unanswered, to the best of our knowledge it represents the first evaluation of TV-DVDs as a platform for interactive presentations in schools.

A. Study Setup

The goal of our study is to evaluate TV-DVDs versus computers as a vehicle for interactive presentations and teaching aids within a real classroom environment in India. While the ultimate metric for the success of either technology is its impact on learning, in this study we restrict ourselves to the simpler proxies of usability (by teachers) and acceptance (by teachers, students, and parents).

We partnered with the Vidya Bharati English school, a private English-medium school serving middle-class students in urban Bangalore, that had expressed interest in using the electronic content from our partner NGO. While the school runs an active computer lab, they did not employ audio/video technology in regular classrooms prior to the start of our study.

Our study represents a between-subjects design, operating within two separate fifth-grade classrooms. (The school maintains two separate sections due to high enrollment; at the start of the year, students are randomly assigned to one section or the other. Teachers rotate between the two classes, teaching the same subject twice per day.) One classroom was set up with a TV, while the other was set up with a computer; this arrangement was held constant for the entire study. This implies that teachers delivered lessons on both TV and computer, while students had experience with only one.

Because the TV and computer were placed in separate classrooms, it is important for us to control for other possible differences between the environments. The classrooms were located opposite one another on the same floor of the school, and had comparable levels of light and ambient noise. Each class had 31 students. The height and width of the rooms, the average distance from students to TV or computer, and the elevation of the TV or computer were all constant to within 10%. We used a 21" TV and a 17" computer monitor, as these are commonly found in schools. (Though the monitor was slightly smaller, it had higher resolution and refresh rate.)

We conducted our study with two teachers (environmental science and social science). Both teachers were female, college educated, aged 32 to 34, and had 9-15 years of teaching experience. They each had a TV, DVD player, and computer at home. We provided a brief (30-minute) training session upon installing the TV and computer. We instructed teachers to use the electronic content only when they deemed appropriate in the classroom. We emphasized that the content is not meant to replace their current pedagogy, but rather to supplement it with occasional teaching aids. As illustrated in Figure 5, considerable usage was observed, albeit somewhat irregular. The social science teacher started later due to delays acquiring the content. Usage was suspended after a few weeks to review for an upcoming exam.

To evaluate the tradeoffs between TV-DVD and computer, we observed almost all of the classes in person (and also recorded them on video for later analysis). The period of observation spanned 3.5 weeks and included over 30 hours in the classroom. Following this period, we administered written questionnaires to students and conducted semi-structured interviews with teachers, parents, and content providers.

B. Direct Observations

While the TV-DVD ran smoothly for the duration of the trial, the computer experienced technical problems. It suffered from disk corruption (we assume due to power fluctuations) and, for reasons we still do not understand, would sometimes hang at random points during the presentation. This is despite the fact that our partner replaced the entire CPU at the beginning of the trial, due to problems accessing the DVD drive from the original CPU. Software upgrades were also necessary to handle certain video codecs. This bears testament to the difficulty of maintaining a computer in a resource-constrained classroom, even when technical expertise is readily available.

During classroom observation, we recorded the number of prompts needed for teachers to successfully utilize a given device; results appear in Figure 6. Generally speaking, teachers required some assistance in utilizing each technology at the beginning of the trial period, though prompts decreased rapidly over time. On TV-DVD, most prompts were related to navigation (how to go to specific slides) as well as how to pause the content. Teachers preferred to use the number keys, rather than the arrow keys, for navigating the DVD. On the computer, most prompts pertained to starting the PowerPoint presentation, basic mouse usage, and pausing video.

	Startup Time	Slide Transition Time
TV-DVD	0:30	0:05
Computer	2:30	0:05

TABLE I
TIME NEEDED FOR STARTUP AND SLIDE TRANSITIONS ON EACH DEVICE.

In the environmental science class, after the third TV-DVD session we offered the teacher a brief refresher regarding DVD navigation, and for the next five classes she utilized the technology without any assistance. The prompts during the 9th and 10th sessions were again related to navigation (as well as an accidental mute of the TV).

We also measured the average time needed for teachers to start up each device (at the beginning of class) and to navigate to a new screen with the mouse or remote control. Results were obtained via video analysis and appear in Table I. While the navigation time is comparable (5 seconds per transition for each device), the startup time is 5x higher with computer than with TV-DVD.

C. Teacher Interviews

Both teachers were very enthusiastic about the value of the electronic content in general, claiming that it enriched the classroom with new visuals and also improved the interactivity. They were excited to continue using the content (and expand it to other subjects) in the remainder of the year.

When queried about whether they preferred to use the computer or TV-DVD, both teachers said that the devices were equivalent. One teacher said:

> Both are same only, no? Same. Only handling is there. Once we start the computer, with the mouse only we can do everything. Here [on TV-DVD] some numbers and all is there, no? So that one only. But we can do both. We are comfortable with both. For both, some practice only is needed... but we can manage both.

The other teacher expressed a similar opinion:

> No difference. It makes no difference for both. Notice all the children also can operate the TV-DVD and the PC also they will operate.

When pressed to choose between either TV-DVD or computer for their own ease of use, one teacher confessed:

> DVD is better for me. [Laughter.] Because no, usually I use DVD at home. I am hearing songs and playing movies and all. Computer, usually I won't switch on the computer, most probably.

In terms of other tradeoffs, teachers noted that the computer can store all of the content locally (on the hard drive) without needing to keep track of external DVDs. Yet the DVD player offers the advantage of navigation from a distance, allowing the remote control to be passed between students. Perhaps one implication of this finding is that computers should also come with a remote control, if they are intended for use in a classroom setting.

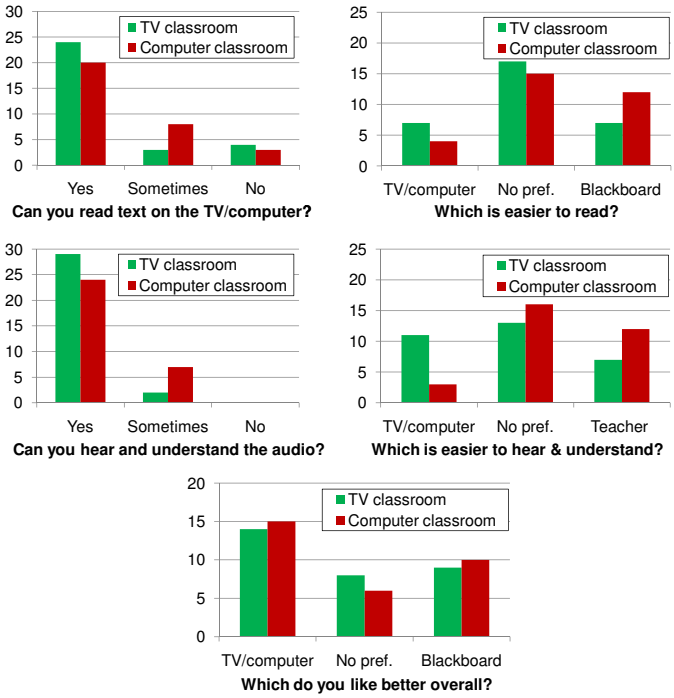


Fig. 7. Results of the student questionnaires.

D. Student Questionnaires

Student feedback was elicited via a written questionnaire. Because each student had exposure to either the TV or the computer (but not both), we did not ask students to compare the devices directly. Instead, we asked them to judge whether the TV/computer was readable and audible, both in absolute terms and relative to the teacher at the blackboard. We also ascertained which medium they liked better overall. We surveyed the same number of students (N=31) in both the TV classroom and the computer classroom.

Results of the student questionnaires appear in Figure 7. Both in absolute terms and relative to the teacher at the blackboard, more students in the TV classroom found the device to be readable and audible than students in the computer classroom. However, the differences are not significant except in the case of relative audibility, where more students in the TV classroom could hear the device better than the teacher ($p < 0.02$). We suspect that the difference in audio levels is partially explained by the difficulty of making frequent volume adjustments on a computer, as compared to using a remote control for TV. With respect to overall preference for the TV or computer versus the blackboard, the results are nearly identical across the classrooms: in the TV classroom, two more students had "no preference" between the alternatives, while in the computer classroom these votes were split between the computer and the blackboard.

E. Parent Interviews

We also conducted semi-structured interviews with 8 parents, representing 4 children from the computer classroom and 4 children from the TV classroom. To our surprise, 5 of the 8 parents expressed a preference for using the TV to display

the content as they expected that it would be easier to see and hear, and to navigate with the remote. Two parents also commented that they considered the computer to emit more radiation, which could be harmful in a classroom.

Two parents preferred the computer in the classroom, since it has a high-resolution display and can be used for purposes other than presentations. One parent insisted that a projector be used, whether or it is connected to a DVD player or a computer. We observed no correlation between the parents' replies and the classroom in which their child was placed.

F. Content Developer Interviews

We also solicited feedback from CLT India, our partner NGO, which develops the electronic content and assists schools in adopting it throughout the state. After observing the successful use of TV-DVD as part of this trial, CLT decided to migrate all of their content (over 10 GB of PowerPoint slides) to the DVD format. Even when deploying to computer-equipped schools, they plan to display the content using DVD rather than PowerPoint.

Our collaborators at CLT pointed out that the TV is simpler to use, almost maintenance free, and less dependent on interventions from their team, as compared to a computer. For example, even in the course of our trial, the computer hardware had to be upgraded, and new software (a video codec) installed, in order to support the CLT content.

Faced with a new school that has neither computer nor TV-DVD, they plan to first equip the school with TV-DVD. Still, if budget is not an issue, they would also invest in a computer to give teachers the flexibility of both mediums.

G. Discussion

While computers may have a range of potential applications in resource-constrained schools, for the purpose of aiding classroom instruction with slideshow presentations, our case study suggests that similar functionality can be provided at lower cost by using TVs and DVD players. Teachers find TV-DVDs to be familiar, reliable, and cost effective, while students can understand it equally or better than a computer.

It remains an important question for future work to assess the learning benefits of electronic teaching aids in resource-limited environments. Our current investigation remains agnostic on this issue, and seeks only to determine the best platform for delivering electronic teaching aids for those who already intend to do so.

V. Children's Books on TV-DVD

Children's books represent an important tool for building language and literacy skills in both rich and poor countries. However, in the Indian context, the cost of printing and distributing books (even from non-profit publishers) often limits their availability in resource-poor areas. For example, in the case of a large educational NGO that has established and staffed over 400 libraries throughout the Indian state of Karnataka, up to 30% of their budget goes towards acquiring the printed books [15], which cost about $0.50 each. The cost of books is especially prohibitive in scenarios in which each student is expected to have a separate copy of the same book; for example, in a classroom environment where students and teacher are reading a book aloud together. In one government-school classroom that we observed, the school library (which was generously funded by the same NGO) could only provide a copy of a book for every four students in the class. For supervised reading lessons, this meant that the teacher distributed a different book to each quarter of the class and read one book at a time, leaving 75% of the class sitting idle at any given moment. While this issue has also been overcome by printing two-page "booklets" at about 10% of the cost of a 20-page book, this also limits the length and visual richness of the storylines.

(a) Table of contents (b) Sample page

Fig. 8. Sample content from a library of books on DVD.

A. Potential of TV-DVD

Mapping children's books to TV-DVD represents one way to drastically reduce the cost of printing and distribution. While books with small text could be unreadable on TV, we focus our attention on entry-level picture books in which the text on the page is at least as large as a subtitle in a movie. In DVD format, each page of the book appears as a distinct DVD still menu, and the remote control is used to navigate from one page to another (see Figure 8). Using our tool, we can fit approximately 5,000 twenty-page children's books onto a standard DVD. Assuming that the DVD costs $0.25, and a printed book costs $0.50, this represents an 10,000-fold improvement in cost-per-book. However, it does require that a school or household is already equipped with a TV, DVD player, and electricity.

In addition to cost, we anticipate other likely tradeoffs between DVD books and printed books (see Figure 9). One advantage of DVD books is that they can include audio voice-overs, coaching students through difficult words in an unsupervised environment. Audio narration can also be valuable in a classroom setting, where it is not uncommon for pronunciation of a second language (e.g., English) to be challenging for teachers in low-income schools. Of course, adding audio does decrease the number of books per disc; for the books that we used, we can fit about 100 twenty-page books (with audio) on a standard DVD.

Printed books also offer their own advantages, including a personal and physical artifact, high-resolution text, and lack of dependence on electricity, TV, and DVD player. They also allow students in a class to progress at their own pace (though sometimes there are also advantages to synchronizing students with a shared display). We explore the interplay of these issues in practice in Section V-E.

	Books on TV-DVD	Books in Print
Cost	+ $0.50 / 10,000 books	− $0.50 / book
Audio	+ can include audio	− no audio
Attention	+ captures attention	− requires some motivation
Resolution	− lower resolution	+ higher resolution
Electricity	− requires electricity	+ does not require electricity
Portability	− must be read by TV	+ can be read anywhere
Pacing	+/− students read in synchrony	+/− students read at own pace

Fig. 9. Tradeoffs between books on TV-DVD and books in print.

(a) Books in print (b) Books on DVD

Fig. 10. Supervised classroom instruction with books in print and books on DVD. Because the school cannot afford a printed book for each person in the class, in (a) only the left side of the room is following the current lesson.

(a) Books in print (b) Books on DVD

Fig. 11. Unsupervised reading with books in print and books on DVD.

B. Usage Scenarios

There are several usage scenarios for books on DVD. First is in the context of classroom instruction, where a teacher is using a book as a teaching aid for structured language and literacy instruction. In this case, a single book is displayed on TV-DVD rather than distributing the book to students (see Figure 10). When displayed on TV, the book is read aloud, either by the teacher, by the class as a whole, or by individual students in turn. Often additional explanation is offered – for example, to define difficult words or to confirm the overall meaning – before the teacher advances the page using the remote control.

A second usage scenario is for unsupervised reading in a school, library, or community center (see Figure 11). In this case, students that were previously crowding around a printed book can instead crowd around a TV-DVD, a device that is arguably more suitable for shared usage. Audio voice-overs guide students through the book, and one of them uses the remote control to advance the page.

The third usage scenario is in the home environment, where students and families can view books that they borrowed from libraries or purchased from vendors. The schools in which we worked included libraries with a weekly borrowing programs for students, offering a simple platform for sending books on DVD into homes. However, this does require the household to own a TV and DVD player, and also to be willing to dedicate the device for educational content rather than entertainment.

C. Implementation and Usage Experience

We implemented a tool that automatically converts children's books to interactive DVD. The tool supports books that are available in PDF or rasterized formats, or that are available online as part of the International Children's Digital Library (ICDL) [16]. For certain books, the ICDL supports interactive zooming for each text box on a page; this functionality is mirrored in the DVD with buttons that enable animated zooming into each region. (Adding animated zooming reduces the capacity of the disc to about 10,000 pages, or 500 twenty-page books.)

Using our tool, we built two libraries of children's books on DVD:

1) A DVD containing 34 English and 15 Kannada books from Pratham Books, a leading non-profit publisher in India. Audio voice-overs were included for 15 of the English books, and 10 of the Kannada books. All of these books are picture books with only a few lines of text per page. The size of the text on TV is comparable to that of subtitles in movies.
2) A set of 4 DVDs, each of which contains 59 copyright-free Mongolian books, drawn from the International Children's Digital Library. Each book has the animated zooming capability. (We do not evaluate usage of these books within the scope of this paper.)

We conducted exploratory studies of each of the preceding usage scenarios for books on DVD. Our experience encompasses the following:

1) One class period of supervised instruction in a peri-urban, English-medium, private school. Students were in 2nd standard, used English books, and were 24 per class. This provided the context for our quantitative study.
2) Four class periods of supervised instruction in a peri-urban, Kannada-medium, government school. Students were in 3rd, 6th, and 8th standards, and numbered 40 per class. The 3rd-standard students utilized Kannada books, while others utilized English books. We also observed a total of one hour of unsupervised reading with the 3rd- and 6th-standard students.
3) One week of borrowing and unsupervised instruction from a library program in a rural, Gujarati-medium, government school. Students were in 8th to 11th standard and borrowed a total of 8 DVDs.

In what follows, we focus our attention on a quantitative case study of supervised classroom reading. We then describe qualitative feedback obtained across all of the deployments.

Fig. 12. Classroom setting for our case study of books on DVD.

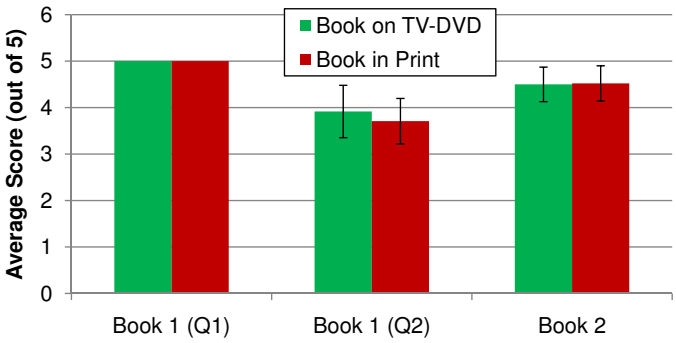


Fig. 13. Results of case study comparing books on TV-DVD and books in print. The quiz for Book 1 assessed comprehension with two separate questions, while the quiz for Book 2 assessed readability. Error bars represent 95% confidence intervals.

D. Case Study

Our goal in this study is to assess whether books on DVD can lead to comparable comprehension and readability in a classroom environment, relative to books in print. We address this question via a between-subjects study (N=24), in which half of the students read a book in print and the other half read it on TV-DVD. We performed the experiment with two books; each student read one book on DVD and one book in print. Each book was accompanied by a short quiz, which was designed to test either comprehension or readability:

- *Book 1 (comprehension)*. Students read a story [17], speaking aloud and in unison as the story was displayed on TV (or was available at their desk in print). After the story was finished, students were given a written quiz in which they were asked to explain two plot elements of the book (one relating to the conflict, and one relating to its resolution). Printed books were collected prior to handing out the quizzes.
- *Book 2 (readability)*. Students read a different story [18], this time remaining silent. The story was structured as a series of six questions and answers; for example, one page asks "Why is a lime sour?" while the next page states, "The acid in the lime makes it sour." Students were handed a quiz *prior* to reading the book, and were asked to complete the quiz as the book was read. The quiz contained exactly the same questions as in the book; students were asked to copy down the answers.

The study was conducted in partnership with Christel House, a private English-medium school on the periphery of Bangalore. The school caters to underprivileged children from slum communities (families earn less than $650 / year) and is free of cost while offering superb facilities, rigorous instruction, and other benefits such as health care. While the infrastructure in this school is far richer than most schools in India, it nonetheless represents a suitable setting for our user study, which intends to evaluate comprehension and readability of the TV-DVD platform amongst low-income students.

Study participants consisted of 24 students in the second standard, which an instructor deemed to be a good match for the grade level of our books. It took place during a one-hour period at the end of the school day, which is reserved for miscellaneous enrichment activities rather than classroom teaching. The class was randomly split into two groups of 12 students each, and the groups proceeded in parallel in separate classrooms; students were given as much time as needed to complete the quizzes. Students in the TV-DVD classroom were seated on the floor, in proximity to the TV (see Figure 12).

Results of the evaluation appear in Figure 13. Each comprehension question (Book 1) was graded on a scale of 1 to 5, with 1 point deducted for missing detail and 2 points deducted for misunderstanding an element of the story. The readability quiz (Book 2) was also graded out of a maximum score of 5, with 0.5 points deducted for each wrong or missing word, and 0.25 points deducted for each spelling or punctuation error. The results can be summarized as follows:

- Students performed highly on both quizzes. Everyone in the class offered a perfect answer for the first comprehension question, and most students offered correct replies for the second comprehension question. For the readability test, almost all answers were perfect, with students averaging a total of 1 spelling error and 1/2 wrong or missing word across all six questions.
- Student performance was not significantly impacted by whether the book appeared on TV-DVD or in print. While students using TV-DVD performed marginally (6%) better on the second comprehension question, this difference is insignificant given the sample size. Other questions yielded scores that were either identical (comprehension question 1) or equal to within 0.5% (readability questions).

We also note that there was no observable correlation between a student's score and the distance from the TV. (Average scores in the back row were actually higher, though the sample size is too small to conclude anything.)

While this study remains only a preliminary inquiry into the suitability of books on TV-DVD for the classroom, it does provide initial validation that the concept is worth considering. Using either TV-DVD books or printed books, students were able to successfully engage in the classroom experience and accurately complete written exercises based on the books. It remains an important question for future work to determine if any learning benefits accrued from reading printed books can also be achieved using books on TV-DVD.

E. Qualitative Feedback

In addition to the quantitative results in the previous section, we also gathered qualitative feedback based on our observations of the classroom and interviews with 3 teachers, 12 students, and 1 administrator.

Firstly, teachers and administrators were quick to acknowledge the potential impact of providing large libraries of children's books at extremely low cost. As each of our partner schools was already equipped with a TV and DVD player, the only cost of accessing books on DVD was that of the DVD itself. As detailed earlier, a DVD can deliver 10,000 electronic books for the same cost as a single book in print.

Apart from cost, the primary advantage perceived of using books on DVD was the ability to capture students' attention. Part of this attention was likely due to a novelty factor, though it could also be related to the fact that TVs are typically used for entertainment, which is perhaps easier to engage with than typical "educational" fare. Students completing the written exercises were polled as to whether they would prefer to read a book on TV or in print the following week, and 75% expressed a preference for TV. The teacher assisting with our study said:

> Kids like to lie down when they have a personal book. But if they lack attention, it is good to have the book on TV.

She also added, "But TV is not good for serious readers."

The ability of TV-DVD to capture students' attention was also noted by teachers in other settings. A government school teacher noted that it was "good enrichment" for the class, as a way of "doing something different". A teacher in a rural school noted that "students gravitated towards the discs, as they were new and interesting". Some (if not all) of this enthusiasm is likely due to the novelty of using TV-DVDs; further study would be needed to see if perceptions change over time.

It was also observed that using books on DVD enforces a tighter synchronization between students and teacher, and between students and each other. If each student has their own book, they can advance at their own pace, and also turn back pages to review content that they missed. This offers benefits as well as drawbacks. As an assistant principal noted:

> If reading is synchronized in front of the class, students who have finished a page may disturb the others. But if students read at their own pace, the teacher can assign spelling or other books to those who finish early.

At the same time, the tightly coupled presentation implied by books on DVD could be advantageous to teachers who seek to do a structured lesson around a book, as it prevents students from being distracted by pages other than the one under consideration. Using books on TV-DVD, teachers can also point to single words on the screen, while it is more difficult to do this with books in print.

Finally, teachers also expressed the inherent advantages that are present in traditional books. A teacher at a government school outside of Bangalore noted the kinesthetic quality of printed books:

> You feel and learn. Whatever you feel will remain in your memory for a long time.

A teacher at a rural school in Gujarat noted the flexibility afforded by printed books in a library setting:

> The [printed] books seemed popular, as the students would not check them out of the library, but they would simply read them there at the table. The other students would have to wait until they got home to play the discs.

Usage of books on TV-DVD in this particular library was also complicated by the absence of a remote control. While pages could be navigated using forward/next buttons, jumping directly to a book from the table of contents remained infeasible.

F. Discussion

On balance, do books on TV-DVD make sense for resource-poor classrooms? Based on our preliminary experience, our feeling is both "yes" and "no". For schools that already have a TV and DVD player, the cost savings afforded by distributing books on DVD are tantalizing. If such schools are lacking printed books, then the DVD platform could provide students with their first or only portal to a library of high-quality reading materials. And even when printed books are available, books on DVD engage students in a different way and can offer comparable comprehension and readability. However, we hesitate to argue that books on TV-DVD should serve as a replacement for printed books, if the latter is within reach of a school. TV-DVDs introduce a new dependence on hardware and electricity, and may transform reading from a personal to a shared experience (although in India, even printed books are shared amongst children).

One aspect of books on DVD that we did not quantify in this work is the tradeoff between text size and comfortable reading distance. We focused on picture books with large text that is readable from a large distance, just like subtitles in movies. Anecdotally, we found that even in a full-sized classroom (25' deep), children sitting in the back row could read the text aloud, though some extra effort was required for certain books; we recommend gathering closer to the TV for prolonged reading activities. Supporting books at a higher reading level, with smaller text, would require enlargement and re-flow of the text.

VI. Future Applications of Interactive DVDs

This paper represents the beginning of a broad research agenda into using interactive DVDs as an educational platform. In particular, we envision the following applications of interest:

- *Wikipedia*. We have already mapped the entirety of schools-wikipedia.org (a validated subset of Wikipedia, intended for use by schools) to a dual-layer TV-DVD. It consists of 5,500 articles, which translates to over

250,000 screens on DVD. The technical details of this mapping, as well as its usability evaluation, are beyond the scope of this paper and will be published separately.

- *Language tutoring*. Popular language-learning software, as provided by Rosetta Stone or the Azim Premji Foundation, is a perfect match for the capabilities of DVD players. Lessons consist of animated audio/video sequences, while exercises consists of multiple-choice questions.
- *Medical decision systems*. The typical hierarchy of a medical decision system maps naturally to an interactive DVD. The system can query a patient about the absence or presence of various symptoms, and make a recommendation (or diagnosis) at one of the leaf nodes.
- *A world atlas*. With 100,000 images on a single DVD, one could provide an atlas that zooms to the level of small towns anywhere in the world; or, alternately, zooms to the street level for individual countries.
- *An Internet portal*. Using the same engine that burns Wikipedia content to DVD, one could map arbitrary sets of HTML pages in response to a user's query. For example, a student could send an SMS query for a report that they are writing. The server could crawl the Web for 4.7 GB of results, which are burned to a DVD and mailed back to the student via the post for browsing on TV.

VII. Conclusions

This paper presents a vision for leveraging under-utilized features of ordinary DVD players to extend the reach of interactive educational materials to resource-poor areas. We are excited about this vision because it relies on technologies (TVs and DVD players) that people are already highly incentivized to acquire and sustain, due to the inescapable draw of entertainment.

As a first step in realizing this vision, this paper makes two contributions. First, we explore the potential of TV-DVDs as a replacement for computers in the display of PowerPoint teaching aids. While we use off-the-shelf tools to convert PowerPoint to DVD, to the best of our knowledge we are the first to examine the usability and acceptance of TV-DVDs in the classroom. Though our case study remains preliminary (involving only two teachers), our experience suggests that TV-DVD is very well-suited for the display of PowerPoint content, while remaining cheaper and more familiar than computers. Our study caused our community partner to switch all of their content to TV-DVD, which has had an immediate impact on their field operations.

Our second contribution is to propose and evaluate the use of interactive DVDs as a platform for children's books. While animated books have appeared on DVD before, they have lacked the interactive features needed for a classroom setting. We developed tools to map up to 100,000 pages to a single DVD, offering a large cost savings over printed books. We find via a small case study of teacher-mediated instruction that students demonstrate comparable comprehension and readability for books on DVD relative to books in print. This suggests that books on DVD could hold promise for schools that cannot afford libraries of printed books. Nonetheless, as books on DVD introduce a dependence on electricity and technology, and require students to read the same book at a fixed pace, we suggest that books on DVD should be viewed primarily as a supplement – rather than a replacement – for books in print.

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