Cross-Platform Learning:
What Are the Benefits of Learning from Multiple Media?

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Abstract

Many informal science and mathematics education projects employ multiple media, but studies typically have investigated learning from a single medium, rather than multiple media. This research uses *Cyberchase* (a multiple-media, informal mathematics project for 8- to 11-year-olds) to investigate synergy among multiple media components and how they interact to yield cumulative educational outcomes. The study incorporated both naturalistic and experimental methods, to investigate children's use of *Cyberchase* media, ways in which use of one medium feeds into use of another, and the educational impact of *Cyberchase* on children's problem solving and attitudes toward mathematics. Data suggest: (a) In naturalistic use, children do use multiple media. During the naturalistic phase, children who chose to use one form of *Cyberchase* media (e.g., television) were significantly more likely to use another (e.g., the *Cyberchase* Web site). (b) During the experimental phase, children exposed to *Cyberchase* media improved significantly more in mathematical problem solving than children who were not. In some cases, the strongest effects were observed among children who used multiple media. (c) Children showed evidence of transfer of learning, not only from the treatment to the posttest, but also from one medium to another. In contrast to a treatment group that only played online *Cyberchase* games, children who used multiple media demonstrated more sophisticated mathematical problem solving while playing the games. (d) Children who used multiple media also demonstrated greater motivation to play the online mathematical games, as indicated by their significantly greater tendency to continue playing after completing the game. Thus, it appears that one of the great advantages of multiple media is that children can apply the lessons learned from one medium *while learning from a second medium*, to yield a richer interaction with the instructional material. Implications for the design of effective materials for informal education are discussed.

Purpose

Many informal science and mathematics education projects employ multiple media, assuming that educational benefits will extend beyond those of a single medium. However, this assumption has not been tested empirically. This research uses *Cyberchase* (a multiple-media, informal mathematics project for 8- to 11-year-olds) to investigate synergy among media components and how they interact to yield cumulative educational outcomes.

The study is designed to address the following research questions:
1) How does the mathematics learned from multiple media differ from mathematics learned from a single medium?
2) What outcomes derive from engagement with different types of media and what types of synergy occur?
3) How can reliable research methods be developed to assess contributions of individual media and their interactions?
4) How can informal education projects capitalize on the strengths of each medium?
5) How can media components be designed and employed to best complement each other?

Cyberchase media used in this study include:
- The *Cyberchase* television series
- Interactive games from the *Cyberchase* Web site
- Hands-on *Cyberchase* games and activities

Sample

Participants were 672 children (transitioning from third to fourth grade), in nine public elementary schools in Michigan and Indiana. The sample was fairly evenly divided in terms of gender (52% girls, 48% boys), mathematics ability (31% high, 42% medium, 27% low), and whether math had been their favorite school subject prior to the study (43% yes, 57% no). Approximately 29% of the sample was comprised of minority children (17% African-American, 6% Latino, 4% Asian, 3% other).

Research Design and Measures

To be able to attribute causality while maximizing generalizabilty to real-world contexts, we employed a hybrid research design that incorporated both naturalistic and experimental methods:

Naturalistic Phase

The naturalistic phase was designed primarily to provide insight into children's naturalistic use of *Cyberchase* media and the synergy among these media (i.e. how use of one medium feeds into another). Over a 12-week period (six weeks in the spring and six weeks in the fall), children completed the following measures:

- Baseline measures, to provide demographic information (e.g., age, gender, ethnicity, past use of *Cyberchase*, etc.).
- A weekly journal in which they recorded their self-selected, voluntary use of the *Cyberchase* television series and Web site. For comparison, they did the same for a popular non-educational TV series and Web site, *SpongeBob Squarepants*.

(Note: Several pretest-posttest and posttest-only measures of problem solving and attitude were also administered. However, the children's naturalistic levels of *Cyberchase* use were too low to elicit significant effects, although such effects did result from more widespread and extensive use in the experimental phase.)

Experimental phase

The experimental phase employed an experimental/control, pretest/posttest design, to investigate the impact of various combinations of *Cyberchase* media on the growth of children's mathematical problem solving (and, secondarily, their attitudes toward mathematics).

Over the course of an eight-week treatment period, children were divided into the following five experimental groups:

- *DVD Only group:* Each week, children were shown three half-hour episodes of *Cyberchase* in school (a total of 24 episodes).
- *Web Only group:* Each week, children played a mathematics-based game on the *Cyberchase* Web site (a total of 8 games), but were not shown the TV series.
- *DVD + Web group:* Children were shown three episodes of *Cyberchase* per week. Once each week, they also played an online game whose mathematical content was (in most cases) aligned with at least one of the TV episodes they viewed.
- *All Materials group:* Children followed the same schedule as in the previous group. Once each week, they also engaged in a hands-on *Cyberchase* outreach activity that involved the same mathematical content as in one or more TV episodes (a total of 8 hands-on activities).
- *Nonviewer (i.e., control) group:* Children were not exposed to any of the above materials. Instead, each week, they were shown three half-hour episodes of an age-appropriate series about American history (*Liberty's Kids*).

The amount of exposure to each of the *Cyberchase* media was designed to emulate real-world use. That is, the amount of exposure was informed by past data on real-world use (as well as the maximum that schools could accommodate).

Because essentially the same sample children participated in both the naturalistic and experimental phases, the naturalistic posttest served simultaneously as the pretest for the experimental phase. The following measures were administered during the experimental phase:

- Hands-on mathematical problem-solving tasks, with essentially isomorphic versions of each task administered in the pretest and posttest.
- Paper-and-pencil problem-solving tasks, administered in the pretest and posttest.
- Online tracking data that automatically recorded every click children made while playing three of the interactive games on the *Cyberchase*Web site. The tracking data lent insight into children's mathematical thinking while playing the games.
- Several paper-and-pencil measures of interest and confidence regarding various mathematical activities (administered in the pretest and posttest) and children's orientations toward pursuing challenges (posttest only).
- Finally, to help interpret these data, the posttest was followed by interviews with children (regarding their experience with *Cyberchase*) and teachers (to gather their perspective on children's learning from *Cyberchase*, as well as their own experiences with the materials).

The design of our problem-solving assessments was informed largely by the "thought-revealing activities" approach described in the mathematics education literature (e.g., Lesh et al., 2000). Attitudinal assessments addressed mathematics both inside and outside the classroom, inspired by Hannula's (2002) approach of considering context while measuring attitudes toward mathematics and Hidi and Renninger's (2006) four-phase model of the development of situational and individual interest in academic subjects.

Highlights of Results

Patterns of Naturalistic Use

- Use of each form of *Cyberchase* media (TV and Web site) was fairly consistent over time. Those children who watched *Cyberchase* on TV in one month tended to do so in subsequent months as well. A similar pattern was found for month-to-month use of the Web site.

- Moreover, children's use of *Cyberchase* also tended to span media; each month, children who watched the *Cyberchase* TV series more often also tended to visit its Web site more often. Thus, in naturalistic use, some children do indeed use multiple media when they are available (which lends real-world validity to the question of how children learn from multiple media).

- Because most users' first encounter with *Cyberchase* occurred long before we began collecting data, the present data cannot determine which medium came first. However, past research found that children more often begin by watching the TV series and subsequently expand to using the Web site as well.

Learning from Cyberchase

- Past research (which evaluated the educational effects of the *Cyberchase* TV series alone; e.g., Fisch, 2003) found evidence of significant impact on both the process of children's mathematical problem solving and the sophistication of their solutions. The present study replicated that finding, and extended it by finding more consistent

- Surprisingly, however, children in the DVD + Web group also showed consistently greater gains than children in the All Materials group (which used the same materials plus hands-on classroom activities). Although we cannot be certain, we believe that the less consistent performance of the All Materials group may have been influenced by subtle cues from teachers in response to the demands of having to make time for *Cyberchase* activities every day.

- Effects on problem solving often appeared to be driven more by the TV series than by the online games. We suspect that this is due to the fact that television is designed to serve as the central component of *Cyberchase*, and provides greater explanation of mathematical concepts than the games (which allow children opportunities to exercise skills, but present less overt explanation). Games designed for more overt instruction and explanation (e.g., via online agent characters who scaffold children's performance) might produce stronger effects of their own.

- Although the television series produced stronger pretest-posttest effects than the online games did, online tracking data indicate that the games provided a context for children to engage in rich mathematical reasoning – and that this process of reasoning was detectable, not only through in-person observations, but also through data mining of online tracking data. Parallel to prior research on formal classroom mathematics (e.g., Lesh et al., 2000), children engaged in cycles of increasingly sophisticated mathematical thinking

Multiple-Media Learning

- Data on children's performance while playing the online games revealed evidence of transfer of learning, not only from the treatment to our posttest measures, but also from children's experience with one *Cyberchase* medium to another. This points to a significant strength of learning from multiple media: The lessons learned from one medium can be applied to enrich children's experience while learning from a second medium as well.

Attitude

- Paper-and-pencil measures of attitude revealed only one pair of significant effects: From pretest to posttest, all of the *Cyberchase* groups sustained their interest and (to a lesser degree) confidence in doing school math, while the attitudes of the control group declined. No significant effects appeared for other domains of out-of-school mathematics.

- However, we also found behavioral evidence of an effect on children's motivation: In two of the three *Cyberchase* online games, users of multiple media were more likely to continue playing beyond the end of the game than children in the Web Only group, pointing to their greater motivation to engage in a fun, mathematical activity.

Conclusions and Implications

Together, these data indicate that children's naturalistic use of multiple media often spans multiple media platforms, and that there are indeed benefits to learning from multiple media over learning from a single medium. Moreover, the data also suggest possible ways in which these benefits might arise.

Benefits for Learning

Our data on problem solving during online gameplay indicate that children can take the educational content that they encounter in one medium (e.g., television) and apply it while engaging with math content in another medium (e.g., online game). This transfer of learning can support interaction with the second medium, allowing children to apply more sophisticated approaches and producing a richer, more successful engagement with the material.

Indeed, it is quite possible that such transfer may even be *facilitated* by the presence of the same characters and contexts across media. Past research on transfer of learning has shown that transfer is more likely to occur when two situations appear similar on their face (*surface structure similarity*) than when they are dissimilar on their surface but rest on similar underlying principles (*deep structure similarity*; e.g., Bassok & Holyoak, 1993). Thus, for example, encountering *Cyberchase* characters in an online game might lead children to think of other times when they saw the same characters (e.g., on television), facilitating the transfer of information and skills from one medium to another (in a way that seeing different characters on television and in a game might not).

Benefits for Attitude

The consistency of characters and contexts across media might contribute to attitudinal effects as well. Under Hidi and Renninger's (2006) four-stage model of interest development, interest in a subject such as mathematics originates as interest sparked by the context in which the math is embedded (*triggered situational interest*). Subsequently, interest can be maintained over a longer period by the context (*maintained situational interest*), after which it may evolve into interest in the mathematics itself (*emerging individual interest* and *well-developed individual interest*). This model fits the present data well, as we not only found significant associations between naturalistic use of the *Cyberchase* television series and Web site, but also found that children who used multiple media were significantly more motivated to continue playing online *Cyberchase* games. When children become fans of *Cyberchase* and spend more time with various *Cyberchase* media, they are spending more time engaged in substantive, enjoyable informal mathematics activities. Such activities have the potential to contribute to emerging interest in mathematics, as well as to learning.

Implications for the Design of ISE Media

When designing future multiple-media projects for informal education, the present data suggest that it is not merely the case that "more" is always better. Children in the DVD + Web group showed more consistent gains than groups that used only one medium – but they also often showed greater gains than children who used all three types of *Cyberchase* media. (Interestingly, another recent study also found that the strongest effects were not always found among the experimental group that used the greatest amount of media [Fisch et al., submitted for publication].) Further research is needed to determine whether we are correct in hypothesizing that there may be an optimal level of media use in

the classroom, beyond which teachers (or even children) find the media less useful – and, if so, what that level might be.

Beyond simply the amount of media used, the data also suggest ways in which media can be designed to maximize their educational power:

- *Explanation and scaffolding:* We believe that one reason why effects were often driven more by the *Cyberchase* TV series than the online games may be that the television series provided more explanation of the relevant mathematical concepts. If so, this argues for the need for educational media (in any medium) to provide, not only opportunities for children to exercise their existing and emerging skills, but also explanatory support and scaffolding when needed.

- *Complementary media:* To facilitate the sorts of transfer of learning and attitudinal effects discussed earlier, consistent characters and contexts, as well as complementary educational content, should be employed across media.

- *Convergent media:* Together, the above points suggest intriguing possibilities for convergent media, in which the strengths of video, interactive games, and other media can be combined in a single media-based experience. For example, consider an interactive game in which the "hint" button pulls up an explanatory video clip, or imagine a video with an embedded interactive game that allows the viewer to use mathematics to help the protagonist achieve her goal in the video.

In these ways, we can build on the lessons learned from past and current research, both to stimulate future research and – even more importantly – to build projects that will take even better advantage of the power of educational media to help children learn.

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TV:

Hands-on:

Web: