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We need not look far these days to find evidence of computer games' cognitive benefits. A documented increase in IQ scores across all societies that administer standardized tests of intelligence over the last few decades—called the Flynn Effect—cannot be attributed easily to education, nutrition, or other factors, leading some to attribute this increase to the cognitive complexity of video games and other forms of mass entertainment (Johnson 2005). While we are a long way from establishing any causal links for such a hypothesis, numerous studies indicate that video game play benefits knowledge structures and transfer (Day, Arthur, and Gettman 2001), mental rotation and spatial intelligence (De Lisi and Wolford 2002), motor skills (Fery and Ponserre 2001), computer-aided drafting/design (CAD) training (*Design News* 2001), cognitive skills (Ko 2002), symbol use and self-regulation (Licona and Piccolotto 2000), and collaborative learning and text processing (Ravenscroft and Matheson 2002).

While educators are beginning to accept the idea that video game play has cognitive and learning benefits, current game discussions generally ignore the corollary effects on attitude toward the content of games and toward the related fields of technology, math, and science. If we ignore collateral learning and attitudes as they relate to games and technology, we risk expanding the digital divide into a cognitive and attitudinal divide. Some argue, for example, that consistent sex differences in attitudes toward technology are already a case in point, suggesting that girls' less positive attitudes toward technology are due to differential experience with technology (Durndell et al. 1995; Gehring 2001; Lim 2002; Shashaani 1997; Young 2000). Such experience could certainly include computer game play, for as noted by Sherrie Turkle, "Girls are critical of the computer culture, not computer phobic. Instead of trying to make girls fit into the existing computer culture, the computer culture must become more inviting for girls" (AAUW 2000, ¶ 4). Sharon Schuster agrees and states, "We have to think less about 'girls' games' and 'boys' games' and more about games that challenge our children's minds. When it comes to computer games and software, girls want high-skill, not high-kill" (AAUW 2000, ¶ 5).

Indeed, attitudinal differences can have effects beyond personal likes and dislikes. According to the American Association of University Women (AAUW) (2000), girls make up only 17% of computer science Advanced Placement test takers, 28% of computer science graduates, and 9% of engineering-related degrees. Overall, women comprise a mere 35% of the IT workforce, and this trend has also emerged in enrollments for technical degrees in higher education (Murray 2005).

If we can find ways to change girls' attitudes toward technology, we may also impact their attitudes toward math and science. Alternatively, breaking the association between technology and math or science might change girls' attitudes toward math and science careers. One strategy for achieving these goals involves providing girls with more positive technology experiences such as computer game play (AAUW 2000; Brown 2001; Busch 1995; Liu, Reed, and Phillips 1992) and game design (Siann et al. 1990), especially in the classroom. The following case study explores the potential for such a strategy by assessing the attitudes of girls and boys towards technology, as well as towards as math and science, before and after their exposure to a variety of games and game design activities.

The Study

In 2002, my colleagues and I at the AIM Lab at the University of Memphis designed a two-semester curriculum to test the concept of using video games in the classroom. For this project, we recruited 92 fifth- and sixth-grade students from a public elementary school in an urban setting in the mid-south. Because this school is associated with the college of education at a large urban university, the majority of students in our study were children of university faculty and staff. This population may be atypical; most of these students had been exposed to technology in the home and had good role models for technology use. Indeed, 93% reported having at least one computer at home, and 83% owned at least one gaming console. In addition, approximately half of the participants reported that at least one parent's job required significant technology use. The 2003 census shows that 62% of all households at the time owned a computer (U.S. Census Bureau 2005, 1).

We formed 12 groups of five students through random assignment: 4 groups of all boys, 4 groups of all girls, 2 groups of three boys and two girls, and 2 groups of three girls and two boys. Additionally, half of the groups (two all boy, two all girl, and one boy majority mixed and one girl majority mixed) consisted of fifth graders, and the other half consisted of sixth graders. Participants took the Pupil's Attitude Toward Technology (PATT) survey at both the outset and conclusion of the study. This instrument and report—created in 1989 by Bame and Dugger and based on an earlier survey used in the Netherlands—was sent by one of the authors (William Dugger) to us in September of 2003 for the express purpose of conducting the research project discussed here.

In the first semester, we tried to address girls' limited exposure to a variety of games. Games with content and strategies that appeal to boys dominate the video game market; moreover, girls also tend not to seek games designed for girls because of a perception that games are for boys. In order to address this trend, we decided that students would play a variety of computer games during the first half of the school year. Groups played a different game every Friday morning. We selected games for variety and taxonomy, including games specifically designed for girls (*Rockett's New School* and *Nancy Drew*), adventure games (*The Mystery of the Nautilus*, *Monkey Island*, and *Mysterious Journey—Schizm*), war games (*Battlezone*), sports games (*Backyard Soccer*), puzzle games (*Contraptions*), and simulations (*Sim Safari*). We also included *Dinotopia*, a game with elements of puzzle, simulation, and adventure.

Because studies have shown that game design can be effective in promoting attitudinal change (Kafai 1995; Rieber, Luke, and Smith 1998), students designed their own games during the second semester. While the game design process promotes teamwork and creativity, it also helps to demystify technology by showing students that a great deal of computer game design and programming actually consists of writing, communicating, creating, and collaborating. A programmer assisted each group in implementing their game designs within *Macromedia Authorware*.

As we expected, game play was very popular with the students. At the outset of the study, we were concerned about student engagement, game play management (one computer per five students), and sustained interest in game design. However, groups were generally highly self-organized; students took turns "driving" the mouse and co-directed game play. When the study shifted over to game design, the enthusiasm and sense of cooperation continued. Indeed, some groups went well beyond what was required by the project by working on marketing, box design, packaging, and sales outside of school.

Findings

Game Preference

After each Friday game play session, we asked students to rate how well they liked the game they had just played (Exhibit 1). Both boys and girls liked simulation, puzzle, sports, and adventure games. Three games in particular had noticeable "cross gender" appeal; boys liked *Nancy Drew* despite its status as a game designed for girls, and girls liked *Contraption* and *Backyard Soccer* despite their mechanical and sports emphasis, ostensibly designed for boys. Overall, *Dinotopia*, *Nancy Drew*, and *Rockett's New School* were most popular with girls; *Contraption*, *Backyard Soccer*, and *Schizm* were most popular with boys.

The most striking differences in game preference came predictably from the two games selected for their hypothesized appeal to particular groups: *Battlezone* and *Rockett's New School*. *Battlezone* is a first-person shooter game involving military warfare on the moon; we expected it would be more popular with boys. *Rockett's New School,* designed by Purple Moon and based on research into girls' interests, engages players in the experiences of a girl who is starting at a new school where she must make friends and learn about other people's lives; we expected this game to be more popular with girls. As we expected, girls uniformly disliked *Battlezone*, and boys uniformly disliked *Rockett's New School*.

A complete analysis of game content is beyond the scope of this article, but preliminary findings suggest that the games with the widest appeal among both boys and girls immerse players in exploratory environments that allow for individual control and focus on problem-solving. As expected, adventure games were the most universally appealing; both boys and girls indicated that they at least "liked" these games. This finding should not be over-generalized; most games were at least "liked" by most students. However, because both girls and boys seem to find them especially appealing, adventure games seem most promising as learning tools to promote problem-solving.

For example, both girls and boys seemed drawn to the adventure genre when asked to design their own games. Preliminary analyses of the games they designed as part of this study seem to indicate that boys tend to develop adventure games involving competition and violence. For example, one game designed by boys required players to subdue criminals who had broken out of jail. In another rather complicated game designed by boys, spies had to shoot their way past robots to advance through the game's levels. Similarly, girls overwhelmingly developed games centered around adventure and exploration, including a kind of *Charlie's Angels* game in which girls flew on "Girls Who Kick Butt" airlines and used cell phones and laptops to capture bad guys. In another game designed by girls, players had to circumvent circus animals to advance through the game's levels. A third game designed by girls focused on a mysterious jewelry theft. In other words, both boys and girls designed adventure games that allowed players to explore an environment in the process of solving problems. However, while boys tended to make conflict a central element of the game's story and eventual solution, girls tended to avoid direct conflict as a solution to the game's problems by requiring players to exercise other options, such as tracking down "Charlie" or the jewelry thief through clues or giving the circus animals particular food.

These findings suggest that even when a game appeals equally to boys and girls, these two groups do not necessarily like the same things about the game. Just as boys and girls designed similar games with different requirements, girls and boys played popular games very differently. For instance, boys and girls uniformly liked *Sim Safari*, but their approaches to the game were quite different. An open-ended simulation of the African plains ecology, *Sim Safari* allows players to choose a habitat, populate it with animals, and build dwellings. In our study, girls tended to discuss and build dwellings complete with bathrooms, hot tubs, and pools; boys, on the other hand, tended to discuss and create swamps, crocodiles, and jaguars to the exclusion of everything else.

Technology

After considering the findings of existing research, we expected that girls would view technology more negatively than boys. Surprisingly, this was not the case in our study. Girls (m = 28.2) and boys (m = 28.9) initially indicated similar attitudes toward technology, and this pattern did not change during the study. Scores for both girls and boys averaged between three and four points on a five point scale (Exhibit 2), indicating generally positive attitudes toward technology. The presence and use of technology in these students' homes may have contributed to this pattern. Alternatively, this result may reflect the difference between believing an activity to be appropriate and wanting to be a part of the culture of particular professions.

A closer look at the PATT survey results revealed further interesting trends. Initially, girls were slightly more likely than boys to indicate that technology was equally appropriate for both sexes, although this difference was not statistically significant. However, by the end of the study, boys indicated that technology was not equally appropriate for girls and boys, with a mean score of 30.33 compared to a mean score of 34.79 by girls (Exhibit 3). This attitudinal change seemed to be localized to boys who were in the minority in mixed-sex groups although boys' views in the all boy groups also changed. Boys in girl majority and all boy groups apparently came to believe that technology was not equally appropriate for girls and boys; we presume they thought it was appropriate for themselves but less appropriate for girls. Perhaps boys in the girl majority groups felt marginalized and frustrated by not being in control as a result of the gender imbalance, which has been suggested as a reason for attitudinal differences of girls toward technology (Siann et al. 1988; Koch 1994; Hughes, Greenhough, Bibby, and Brackenridge 1989; Durndell et al. 1995; Silverman and Pritchard 1996; Craig 1999; Smith 2000). Boys in all boy groups may have come to believe that technology was less appropriate for girls simply because they had no models of girls using games to consider. Girls had higher scores than boys regardless of the gender classification of their group (all girl, girl majority, boy majority).

Attitudes toward Science and Technology

Over the course of the study, students' attitudes toward the relation between science and technology also changed as measured by the Relation of Science and Technology subscale of the PATT (Exhibit 4). Both boys and girls indicated on the posttest that technology was less related to science, with a mean score of .69, than they had on the pretest, with a mean score of .78. This difference was statistically significant ($t = 2.257$, $p = .031$), indicating that there is a 97% chance of this difference being related to the treatment in the study. This finding might support the hypothesis that the perceived difficulty of science and mathematics is responsible for the perception that technology is also difficult. Studies have shown and researchers have maintained for years that science, math, and technology are related constructs in the minds of students, that they are determinants of the likelihood of selecting careers in these areas, and that socialization includes pervasive messages of the difficulty of these areas for girls in particular (Hess and Miura 1985; Hawkins 1985; Miura 1986; Shashaani 1994; Craig 1999; Smith 2000). Breaking the association of science and technology might thus be hypothesized to impact the perceived difficulty of one or both of these fields; that is, if a student no longer believed that science and technology are related to each other (they are, in fact, no more or less related than math and English), the student would no longer assume that any real or imagined lack of aptitude for science necessarily involves a lack of aptitude in technology.

In our study, students worked with an experienced programmer to design and develop their games, leaving them free to use relatively comfortable skills (writing, drawing, etc.) to create and design. Engaging in those kinds of authentic game design activities may have demystified the process for students who had been intimidated by the perceived difficulty of game design. Since both boys and girls indicated a weaker perception of the relation between science and technology at the end of the study, game play and game design may be appropriate activities for both sexes in addressing attitudes toward technology in general. This assumes, of course, that students initially perceived game design to be related to technology rather than math or science, and we did not ask students if this was their perception. However, these students knew that they would be working specifically to design computer games in the computer lab at the university as the title of the study and the informed consent form made clear (Exhibit 5). It seems reasonable then that they may have viewed computer game design as a technological activity if they also believed that technology was primarily associated with computers and not math or science, for instance. A full discussion of the relationship between science and technology and the perceived difficulty of technology can be found in Exhibit 6.

It is important to remember that the trends noted here are one set of possible interpretations of the decreased relationship of science and technology, and that regardless of their consistency or plausibility, they are not based on statistically significant differences. Future studies should explore these trends in more controlled environments. This study combined game play *and* game design; future studies should examine these constructs separately. Also, more targeted questions could be used to capture data that would help support or refute these conclusions, and other game authoring tools that can be employed by the students themselves might also serve to further isolate the effects of the intervention on the perceptions of technology, science, and mathematics.

Conclusion

Students' problem-solving efforts in both game play and game design during this study undoubtedly had benefits beyond changes in attitude toward technology. However, research on problem-solving suggests that problem-solving skills must be built through exposure to multiple problems in multiple domains; games may be the best way to provide that exposure both within and outside of school settings. Indeed, the real value of many video games is that success is entirely predicated on metacognition, data collection, hypothesis formulation and testing, and problem-solving. We found that games that allowed for open-ended play using different strategies (e.g., *Sim Safari*) and games that focused on mystery, adventure, and exploration (e.g., *Schizm* and *Nancy Drew*) were equally appealing to boys and girls. This wide appeal reflects a natural human propensity to explore, control, and succeed within our environments—an issue of particular relevance to students in this age group who are approaching adolescence and attempting to establish independent identities. Not coincidentally, these kinds of games also reflect educational goals for inquiry-based, collaborative, authentic problem-solving and indicate a related move toward technology integration in our schools (Morrison and Lowther 2004; Grabe and Grabe 2004).

As our study suggests, game play in schools can impact attitudes toward technology and possibly influence career choices. If girls in particular are exposed to a variety of games, they may find that there are games they enjoy, and this perception alone may convince them that technology is relevant to them. Similarly, game design in the classroom shows both boys and girls that technology-related careers, like those in the fields of science and mathematics, often involve a wide variety of activities and skills. As a consequence, both boys and girls may begin to believe that there is room for them in these fields.

The results of this study also suggest that same-sex groupings may not be ideal for game play and game design teams. If IT culture is to change, boys and girls must interact in these educational experiences. Yet the boys involved in our study clearly came to believe that such interaction was inappropriate. This reaction likely reflects a natural resistance to cultural change; however, this reaction also suggests that such interventions might be more effective if offered frequently and over long periods of time.

Indeed, we discourage the belief that occasional exposures to games will magically create meaningful changes in students' attitudes. While this study suggests that we can impact girls' perceptions of technology and science through year-long exposure to game play and game design, we also should not ignore other computer-related activities. Introducing games into the curriculum is a part of the technology integration process, not a substitute for it.

As educators and administrators, we need to advocate game-based learning for the right reasons. We need to combat both the misperception that video games work magically for all learners under all conditions and the belief that games are a waste of time and serve *only* motivational purposes. Changing girls' attitudes toward technology, math, and science is at least as important as any of our other traditional goals for education, and we should be on the forefront of this movement. There is no doubt that this is a long and challenging process, but given the stakes involved, we can hardly afford to do less.

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