Does Involving Girls as Designers Result in Girl-Friendly Science Education Software? Comparing processes and outcomes of same-sex 5th and 8th grade girl and boy design teams

Summary

OBJECTIVES: Virtual environments are increasingly being called upon to advance science learning. With possibilities for interactive multimedia displays and learner customization, these environments hold great promise. But are these environments friendly to girls? Computer games, designed by young men for boys and young men, epitomize technology's exclusion of girls, their interests, and values. Less obvious but more devastating, this technological estrangement exacerbates girls' lack of interest and self confidence not just in computers but in science. Technology itself and even the design of technology-enhanced science experiences may disadvantage girls, turning them away from SMET instead of engaging them. Experts urge more women and girls to become involved in software and hardware design, to begin to transform computer culture. The "Involving Girls as Designers" (IGD) project will look at what can happen when girls design their own technology-enhanced science learning experiences. Do girls and boys approach the design process differently? If so, what are the characteristics of a girl-friendly design process? Do all-girl design teams create products that are more appealing to other girls than products designed by all boy teams? Are gender differences more strongly polarized by the end of middle school, or are they equally evident even in fifth grade?

METHODS: IGD will invite small teams of girls to experience and critically assess a series of high quality science-learning experiences diverse in their technology and extent and form of interactivity, ranging from planetarium show to role play simulated mission to Mars, from CD-ROM games to exploring space science on the web, television to immersive virtual reality. These young, newly expert technologists will then design their ideal science learning experience, with the goal of teaching science and inspiring kids to be interested in SMET. IGD will profile girl reactions to the diverse forms of science learning. The design process and design outcomes of the all-girl design teams will be analyzed and compared to all-boy teams. IGD will compare fifth grade girls (whose enthusiasm for science parallels boys) with eighth grade girls (whose enthusiasm and self confidence in science has declined), looking for similarities and differences in technology attitudes, design process, and design outcomes. Professional software developers will create visualizations of each team's prototype. With no indication of the gender of the designers, each set of visualizations will be shown to same-age students to discover whether boys and girls prefer prototypes developed by their own gender.

INTELLECTUAL MERIT: IGD will test the assertion that involving girls as designers can impact design process and product and describe gender and age differences. IGD will contribute concrete understanding of girls' attitudes toward diverse forms of technology-enhanced science learning.

BROADER IMPACTS: IGD could provide compelling evidence to software developers about the critical importance of involving girls as designers and ways of enabling girl-friendly design processes. IGC could provide guidance to teachers and curriculum designers about choosing among technology-enhanced science learning experiences. The PIs teach graduate design research classes (in education and digital media design). They will involve their students in the research and integrate findings into their courses. New understanding about girl-friendly science education designs will be incorporated into the Mars Pioneer Learning Adventures initiative and into the overall Comm Tech Lab software design process and College of Education and Digital Media Arts curricula.

Project Description

Technology holds great promise for advancing science education however there exists a troubling computer culture gender gap.

In contemporary culture, the computer is no longer an isolated machine: It is a centerpiece of science, the arts, media, industry, commerce, and civic life (American Association of University Women, 2000). As AAUW Commission on Technology, Gender, and Teacher Education co-chair Sherry Turkle writes, the computer culture has become linked to a characteristically masculine worldview, such that women too often feel they need to choose between the cultural associations of “femininity” and those of “computers” (American Association of University Women, 2000, p. 7). Most computer games today are designed by men for boys and men. They often have subject matter of interest to boys, or feature styles of interaction known to be comfortable for boys. (American Association of University Women, 2000). Statistics on girls’ participation in the culture of computing are of increasing concern, from the point of view of education, economics and culture. We need a more inclusive computer culture that embraces multiple interests and backgrounds and that reflects the current ubiquity of technology in all aspects of life. As the AAUW report describes, girls assert a “we can, but I don’t want to” attitude about participating in computer activities.

The computer culture gender gap mirrors adolescent female and male attitudes toward science and math. The National Center for Educational Statistics documents achievement gaps related more to attitudes than to coursetaking (Bae, Choy, Geddes, Sable, & Snyder, 2000). Female high school graduates have taken as many or more upper level math classes, biology, and chemistry. However, 8th and 12th grade females were less likely than males to like math and science, and less likely to think they were good in math and science. Elementary school girls and boys have comparable perceptions of their own abilities. By ninth grade and throughout high school, girls gradually lower their perceptions of their own abilities compared to boys (Phillips & Zimmerman, 1990). Girls at age 8 and 9 report feeling confident, assertive, and authoritative about themselves and their abilities. But they emerged from adolescence with poor self image, constrained views of their future and their place in society, and much less confidence in themselves and their abilities. (American Association of University Women, 1991). Since the early 1970s, women have made dramatic gains in postsecondary education in terms of enrollment and attainment, and are successful relative to men in aspirations, enrollment, and bachelor's degree completion. Gender differences in college majors persist, however, with women still concentrated in fields like education and men more likely than women to earn degrees in engineering, physics, and computer science (Bae, et al., 2000).

The fundamental goal of science education is to communicate scientific information and to encourage a deep comprehension of scientific concepts, reasoning and problem-solving skills (Kim, Jackson, & Yarger, 2000). In an effort to reach this goal, many science education reforms have occurred over the past decades—all in the name of preparing the next generation by making science learning more applicable and pertinent (Yager, 2000). However, many of the customary science learning activities, such as lectures and labs, do not adequately and effectively promote the learning of science; students are either required to passively accept textbook- or teacher- provided knowledge, or must attempt to reconcile discrepancies between their flawed experimental results and the expected outcomes based on established scientific ideas (Nott & Smith, as cited in Kim. Jackson, & Yarger, 2000).

Many authors have recommended that new technologies, specifically computer simulations of natural science phenomena, the Web as a “virtual classroom,” the inclusion of multimedia, among others, melded with proven pedagogies such as experiential learning, constructivism, collaboration among students, and teachers’ role as facilitator of learning instead of provider of knowledge, might provide a feasible alternative to previous ways of learning science (Colburn, 2000; Kim. Jackson, & Yarger, 2000; Moor & Zazkis, 2000). Due in great part to the generous support of the National Science Foundation, this essential transformation in science education is presently underway. One way NSF is supporting this transformation is by seeking $200 million to initiate a new partnership project—the President's Math and Science Partnership—which is part of the President's initiative No Child Left Behind (http://www.ehr.nsf.gov/mathandsciencepi.asp). The reality behind the initiative is complex: too many children are not receiving the math and science education they need to succeed in an increasingly technological society; too many girls, students with disabilities, and minority students are underserved and underrepresented in science classes and fields (Synergy—NSF, 1999; Monhardt, 2000; Swiatek, 2000); teachers are inadequately prepared to teach math and science; and not enough U.S. schools offer demanding and challenging science courses (http://www.ehr.nsf.gov/mathandsciencepi.asp; Kumar & Libidinsky, 2000). The consequence is that not enough students are pursuing science study that will equip them for future opportunities and contributions in science areas.

New technologies hold great promise for enhancing science and math education. Teachers reason that if designers can make computer games so entertaining as to be termed "addictive," why can't some of that talent be used to design equally compelling educational materials? (AAUW, 2000) However, computer culture itself is male-dominated and computer games are designed by young males to appeal to young males (Laurel, 2001). A proposed remedy to achieve gender equity in the computer culture is to get more girls and women involved in the creation of hardware and software and thus themselves participate in the evolution of computer culture. To wait only compounds the problem; it is far better to involve females in the creation of this culture now than to try to reshape it later.

What do girls say they really want?

A growing body of research details differences in what girls and boys say they want from computer games and their attitudes toward computers. Girls and other nontraditional users of computer science –who are not enamored of technology for technology's sake- may be far more interested in using technology if they encounter it in the context of a discipline that interests them (AAUW 2000). Brunner, Bennett, and Honey (2000) point out "we have never actually investigated the design features that make games more attractive to girls -- we are merely applying the characteristics we have found to make good electronics learning environments for girls to the domain of electronic games." AAUW reports that girls object to the violence in today's computer games. Laurel's (2001) research on girls and computer games concluded "girls didn't mind violence so much as they disliked the lack of good stories and characters." Laurel (2001) also reports girls are much more likely to blame themselves rather than the machine when something went wrong Girls perform less well than boys at tasks involving mental rotation under time pressure – they tend to prefer more body-centric navigational methods than boys, relying more on landmarks for cues. If these things are true then the featureless mazes and left to right scrolling of traditional videogames have privileged male players. Games have traditionally advantaged "victory over justice; competition over collaboration; speed over flexibility; transcendence over empathy; control over communication; force over facilitation (Brunner, Bennett, & Honey, 2000).

Boys' status hierarchies tend to be based on explicit factors such as strength, speed, and skill at some tasks. Competition among boys tends to be fairly explicit. By contrast a girl's social status among her peers is more likely to be influenced by her network of affiliations than by any explicit measure. Covert tools such as exclusion and secrets are prominent means of social competition. Laurel notes this finding upset feminist critics. She describes a tension between designing games for political correctness and designing for the reality of girls' lives. Should software for girls reflect their concerns over popularity and social competition, or should software deal only with politically correct issues about which society wants girls to be concerned?

Brunner, Bennett, and Honey (2000) asked adult computer and multimedia professionals to invent a science fiction story about a perfect instrument in the future and what it would be like. Women fantasized about small, flexible objects that facilitate sharing ideas, staying in touch and that can be used anywhere to fulfill a number of quite different functions -- something that can be a camera one minute, for instance, and a flute the next. In contrast men's fantasies were about mind-melds and bionic implants that allow their owners to create whole cities with the blink of an eye, or to have instant access to the greatest minds in history. They summarized how men and women thought about technology. For women, technology was a medium that brought to mind the terms– a tool, communication, creation, expressive, flexibility, effectiveness, sharing, integrating, explore, empowered. For men technology was described with the terms– a product, a weapon, control, power, instrumental, speed, efficiency, autonomy, consuming, exploit, and transcendence.

In a gender study of adult reactions to a virtual reality prototype, Heeter (1994) found that females would pay significantly less additional money than males would pay to experience higher resolution images. Moreso than males, females would prefer to see their real hands inside of a virtual world instead of a computer generated hand. Females are significantly more likely to say they want Virtual Reality experiences to have meaningful real life parallels. And they are more interested than males are in being able to (virtually) meet and talk with people from around the real world who appear in the virtual world.

Brunner, Bennett, and Honey (2000) propose alternative scenarios for play to appeal to girls:

> Technologically sophisticated software to allow interactivity with humans and objects beyond what is easily accomplished with today’s technology;
> Winning and losing where it matters what you win and what you lose;
> Success and sacrifice addressing what are the issues and what sacrifices one has to make;
> Complex stories that raise questions about consequences and social perspectives of femininity;
> Persuasion versus conquest
> Humor (girls are very interested in humor)
> Adventure related to rescue and romance;
> Puzzles and obstacles where the goal is to outwit rather than vanquish;
> Writing and communication across a variety of media;
> Designing living spaces;
> Mysteries with complex plots and intelligent action.

In “Rethinking Girls’ Games” (AAUW, 2000) the AAUW Tech-Savvy Commissioners conducted focus group interviews with middle school and high school girls, talking about what their ideal game would be like. The commission suggests many design approaches “to make play in the digital universe as appealing to girls as it is now to boys” (AAUW , 2000). Girl-friendly design approaches include:

> Games to create rather than to destroy;
> Games involving simulation and identity play;
> Opportunities to work through real life problems;
> The chance to swap identities;
> The chance to face struggles one has not encountered yet in life but will someday;
> Computers used as tools not toys;
> Computers as tools, not an extension of self;
> Instrumental possibilities of computers;
> Computers as artistic tools;
> Games that use “real power,” not the “false power” girls complain that boys like;
> Computers that can be used to get things done;
> Technology used in ways to promote human interaction
> Technology used in ways to build human relationships;
> Meaningful activities, not merely playing with machines;

The ten recommendations they offer at the end of the chapter are admirable, challenging design goals that, for the most part, will be far more difficult to conceptualize and implement than typical computer games (AAUW, 2000, p. 36)

1. Software that is personalizable and customizable. This type of software allows students to create their own characters, scenarios and endings, and allows them to work independently or collaboratively
2. Games with challenge
3. Games involving more strategy and skill
4. Games with many levels, intricacies, and complexities
5. Flexibility to support multiple narratives
6. Constructionist design – one that allows students to create their own objects through software
7. Designs that support collaborative or group work and encourage social interaction
8. Coherent, nonviolent narratives
9. "Puzzle connections," such as rich mysteries with multiple resolutions
10. Goal-focused rather than open-ended games

What will girls designers actually create?

Brunner, Bennett, and Honey (2000) extrapolate from attitudes toward technology and characteristics of good electronic learning environments to the design of computer games. The AAUW commission bases their game design recommendations in part on focus group interviews with girls where the girls described what they wanted in a game. A key recommendation of the AAUW report is a call to rethink educational software and computer games.

> Educational software and games have too often shown significant gender bias. Girls need to recognize themselves in the culture of computing. Software should speak to their interests and girls should be treated as early as possible as designers, rather than mere end users, of software and games. (AAUW, 2000, p. xiii)

Ching, Kafai, and Marshall (2000) worked with mixed educational software design teams including fifth and sixth grade boys and girls and found that the configuration of social, physical, and cognitive spaces in the project environment contributed to a positive change in girls' status as participants in the design team. Being involved in educational multimedia design is a positive learning experience for children (Kafai, Carter, & Marshall, 1998).

Passag and Haya (1999) studied gender differences in kindergarteners' learning interest from different designs of multimedia interfaces. They found a significant difference between boys and girls in the influence of the design of interactive multimedia stories on time on task and on level of satisfaction with the interfaces.

The argument is computer culture (and by extension, computer software) "could be positively transformed through the integration of girls' and women's insights" (AAUW, 2000, page x). Our proposed research seeks to test this assumption. If the assumption is true, then the gender of a software designer in a setting where she can express her true perspectives and preferences would be expected to have a measurable impact on her design process and/or her design outcome. We can turn to studies which have asked girls what kind of experiences they want in a computer game to generate a set of expectations about what girls might design. When girls are in charge of design, do they actually conceptualize software learning experiences consistent with those preferences? Does gender influence the design process? Will teams of girls approach the design process differently than teams of boys? Finally, when the single-sex developed designs are complete, will the all boy designs appeal more to boys and the all girl designs appeal more to girls?

We think so. But we also think the proposition should be tested. If we document that gender does influence the software design process, or the software design outcome, this compelling result could help motivate the computer industry to integrate girls and women onto their teams. It would also advance our understanding of the impact of gender on design. **Specific research outcomes from our project are to better understand gender-based differences and preferences for learning through educational software, and to garner insights into gender barriers and incentives to learning science which might arise from the gender of software design teams.**

There are certainly business reasons for the computer industry to develop software that appeals to girls. Beyond this, there are critical social reasons for doing so. Increasingly computer environments will provide the rich educational terrain for a generation of virtual learners. Intervention at this stage in the development of computer-mediated educational software can shape our educational future and to fail to do so may allow the computer culture to develop and settle as a male based design industry for predominately male users. Our multidisciplinary project team came together with the goal of developing innovative online and virtual reality science learning games to build upon the excitement of space exploration and in particular the challenge of a mission to form the first scientific human settlement on Mars. This gender and design research proposal is independent of our other various Mission to Mars and Galactic Garden initiatives, but the gender proposal is strengthened by our background experiences and by the strong partnerships already established.

Project Design Overview

We will empanel four design teams of fifth graders (two all male and two all female) and four design teams of eight graders (two all male and two all female) to participate in a two week summer "Design Camp." We select students who have just completed fifth and eight grades because these grades share the same set of National Science Standards, yet they are on opposite sides of the drop in girls interest and perceived competence in SMET.

In the first week of Design Camp, students will become experienced critics of many different kinds of technology-enhanced science learning experiences, most of which will teach about space exploration and, in particular, Mars. Experiences will include a Planetarium Show, a museum-based group role-playing simulated Mission to Mars, a videotape, a CD-ROM replication of a Space Camp shuttle mission, web-based learning materials, a combined hands on and virtual growing plants in space experiment, a simulation, a computer game, and a virtual reality experience.

In the second week of Design Camp, each design team will envision and prototype aspects of a virtual learning experience about forming a human settlement on Mars. Using pencil and paper and electronic design tools and working with a teacher/facilitator, the teams will be guided to develop a blueprint for a virtual learning experience they feel will effectively teach science and inspire girls and boys to consider careers in SMET.

Project Overview

When	Activity	Students	Researchers	Professional Designers
Spring 2003	Preparations for Summer Design Camp	Form 8 Teams 2 female 5^{th} Grade 2 male 5^{h} Grade 2 female 8^{th} Grade 2 male 8^{th} Grade	Develop specific research protocols and tools	Develop design supports and strategies
Summe r	Design Camp Week 1	Students experience variety of learning	Opportunities to collect rich data on 5^{th} and 8^{th}	

2003		activities, mostly about Mars and Space Exploration – virtual and some hands on	grade girls' and boys' reactions to and learning from diverse forms of learning experiences.	
Summer 2003	Design Camp Week 2	Each design team will envision and prototype aspects of a virtual learning experience about forming a human settlement on Mars.	Collect qualitative and quantitative data on design processes and outcomes	Present design guidelines and structures to student designers;
Fall 2003	Design Camp Results		Analyze the design process and design choices related to the ideal virtual science learning experiences envisioned by 5th and 8th grade girls and boys.	Develop student designs into product visualizations
Spring 2004	"Test Drive"	400 5th and 8th grade students "test drive' the 5th and 8th grade designs respectively	Investigate differences in reaction by gender within and between grades	Develop project research dissemination web site
Summer 2004	"Test Drive" Results	Student designers and teachers involved are invited to campus to discuss results	Compile and disseminate "Test Drive" research results	Designers derive advice for future designs

Week 1 of Design Camp will provide opportunities to collect rich data on 5th and 8th grade girls' and boys' reactions to and learning from diverse forms of hands on and virtual learning experiences. Week 2 of Design Camp will allow us to analyze the design process and design choices related to the ideal virtual science learning experiences envisioned by 5th and 8th grade girls and boys.

Our professional design team will develop electronic visualizations of all eight virtual learning prototypes invented by the eight student design teams. A single, mixed-gender professional design team will develop all 8 visualizations to avoid introducing variations due to differences in visualization team skill and style. The visualizations will be as representative of the original student team concepts as possible.

We will have other 5th and 8th grade who are students of the same age as the design teams, but unaware of the gender of the designers of each product, "test drive" each product visualization and report their impressions of each product. We will examine whether students prefer the virtual learning experiences designed by same gender teams that are the same gender as they, and if so, whether this preference occurs in both fifth grade and eighth grade.

Based on the reactions of the students who "test drive" these visualizations, we will investigate the following questions:

1. Is there a difference, by gender of the student software testers, in reaction to the educational software products developed by the all-girl design teams as compared to the games designed by the all-boy groups?

2. If so, do girls prefer the educational software designed by girls? Do boys prefer the software designed by boys?

3. What aspects of the girl-designed software products appeal most and least to their peers, and how, if at all, does this vary by gender? Likewise for the boy-designed software products.

We will compare reactions of same-age peers to the girl-designed and boy-designed games for each age group, and will investigate the following issues:

1. Are there differences between fifth-grade students and eighth-grade students in gender-based reactions to software designed by all-boy teams and all-girl teams?

2. If so, what is the nature of those differences?

We will gather rich quantitative and qualitative data allowing our project to provide a new level of detail and understanding of how girls and boys before and after middle school react to specific kinds of mediated science learning experiences, what kind of technology-enhanced science learning experience girls and boys would create, and whether these same-sex designs appeal most to other students of the same gender as the designer.

Research Plan

Phase I: Educating the Student Design Teams (Design Camp)

We will work with the Director of K-12 Outreach for the College of Education to recruit 20 fifth graders (10 male and 10 female) and 20 eight graders (10 male and 10 female) to participate in a two week summer "Design Camp." The participants will come from diverse backgrounds but will live close enough to Michigan State University to be able to go to Design Camp during the day yet go home nights and weekends. Before Design Camp begins, the participants will be divided into 5 person same-sex, same-grade teams. The entire Design Camp experience will occur within these 5 person teams.

In the first week of Design Camp students will experience many different kinds of virtual learning experiences, most of which teach about space exploration, and in particular, Mars. In the second week of Design Camp, each design team will envision and prototype aspects of a virtual learning experience about forming a human settlement on Mars. Using pencil and paper and electronic design tools and working with a teacher/facilitator the teams will be guided to develop a blueprint for a virtual learning experience they feel will effectively teach science and inspire kids to consider careers in SMET.

Week 1 of Design Camp will provide opportunities to collect rich data on 5^{th} and 8^{th} grade girls' and boys' reactions to and learning from diverse forms of virtual learning experiences. Week 2 of Design Camp will allow us to analyze the design process and design choices related to the ideal virtual science learning experiences envisioned by 5^{th} and 8^{th} grade girls and boys. We will begin with an assessment of interest in SMET, knowledge about Mars and space travel, interest in Space Exploration, career plans, attitude toward computers and technology.

The students will be exposed to a variety of virtual learning experiences, mostly about Mars and Space Exploration, including a Planetarium Show a a museum-based role-playing simulated Mission to Mars, a videotape, a CD-ROM, web-based learning materials, a mixed hands on and virtual growing plants in space experiment, a simulation, a game, and a virtual reality experience.

Design Camp will be held in technology-equipped rooms in Erickson Hall on campus, in walking distance of the Planetarium, the Michigan 4H Children's Garden for plant growth experiments and the MIND Lab for the Virtual Reality experience. Busses will be rented to take Design Camp participants to the Kalamazoo Valley Museum Challenger Learning Center for the two-hour Mission to Mars role play simulation.

Immediately following every experience, each individual child will complete a short survey asking how much they enjoyed the experience, whether there are topics that came up that they would like to learn more about in the future, whether they might be interested in jobs related to the experience when they grow up, whether they think other kids their age would enjoy the experience, and some factual questions about the learning content.

After completing the individual survey, the team will participate in a focus group discussion about the experience, discussing what was good and bad, what was interesting, what it made them think about while they were participating, what the designers should do differently to make it better, and whether they would like to learn this way again.

Virtual Science Learning Technologies	Learning and Liking Questionnaire	Focus Group Interview
Planetarium Show		
Group Role Play using Technology		
Videotape		
Individual Mission CD-ROM		
Hands on + Virtual Experiment		
Ask the (live) Virtual Expert		
Web-based Information Resources		
Simulation Game		
Learning Game		
3D VR experience		

Individual Quantitative Science Learning and Attitude Comparisons

Ten-item Science Learning Assessments specific to each learning experience and a standardized 5 item preference assessment common to all experiences will be developed to measure learning and liking following exposure to the different experiences. The learning questions will be tie in to National Science Standards for grades 5-8. Student participants will be encouraged to respond "I don't know" rather than guess at an answer. Student participants will be told what is being tested is not so much their performance as the quality of the learning experience. Did the learning experience succeed in teaching them about science? We will quantitatively compare learning by gender, by age, and by the nature of the ten different forms of technology-enhanced science learning. Our sample of 40 participants is small – differences by gender will have to be large to be detected. Combining responses to all 10 experiences we will have 100 learning responses and 50 attitude responses per participant.

Focus Group Analyses

Following standard focus group research procedures (Edmunds, 1999), discussion guides will be prepared for each Science Learning experience prior to the Design Camp. The discussion guide is an outline of major topics, approximate time per topic, and specific questions within each topic. The teacher/facilitators will act as moderator for the focus group interviews. They will begin each focus group by explaining that the moderator role is to keep the focus group discussion on track. Moderators will remind the participants they are expert critics, and we want to know what they think. They will ask the participants to speak clearly and one at a time, stressing that there are no right or wrong answers. They will inform the child participants how important their input is to the project, and encourage the girls or boys to talk on each topic. The moderator will ask questions from the discussion guide, stopping to probe for follow up comments or to encourage participation. If an important topic not anticipated in the discussion outline arises, the moderator may follow up on that topic, then return to the planned agenda. Observers on site will take notes, and the session will be audio recorded. Moderators will review the summary of the focus groups they moderated, clarifying or adding points the writers have missed. The PIs will compare and synthesize the findings across age and gender of the eight design teams and the 6 technology-enhanced science learning experiences. The outcome will be a report including tables and text comparing reactions by girls and boys and 5th and 8th graders to each of the ten forms of technology-enhanced science learning experiences.

We will be able to make quantitative and qualitative comparisons across gender and grade level for the quantitative survey data and the qualitative focus group data. This should yield rich data for designers of virtual learning experiences and for teachers and curriculum designers choosing among alternative technologies for teaching science about how girls and boys in 5th and 8th grade perceive and react to different approaches to virtual learning.

Phase 2: Student Designed Prototypes (Still at Design Camp)

In the second week of Design Camp, after the participants have learned about Mars and participated in a wide range of mediated learning experiences, we will pose the challenge of asking them to think about and design a prototype Mission to Mars learning experience about sending the first human settlement to Mars. They will be told the experience they create should teach important science content and should also inspire kids to want to study science and to think about careers in space exploration. What they create needs to involve technology, not just in person and in class activities.

We will provide some structure throughout the days. The outcome will be a combination of pencil and paper outlines, electronic elements, and other prototype descriptions. On each day we pose specific design questions and make appropriate tools (and training) available. For example, we may begin by giving the teams a menu of science-standard appropriate content and letting them pick five topics to teach about. We will ask questions about identity and representation of self, realism of the environment, navigation, availability of experts (real or computer generated), whether it is a group or individual experience. We will not specifically tell groups to design a game because girls tend to have negative reactions to games. We will ask them to design an inspirational, fun, educational science learning experience. They can design for what technology can accomplish today, or based on their imagination – we will not constrain the design by practical considerations. On the last day they will present their design concept.

Phase 3: Process and Outcome Analysis

Our project separates design teams by gender to increase our chances of observing gender differences. We probably cannot recommend to educational software designer that they always recruit all-female design teams. But perhaps we can identify girl-friendly design processes to enhance the participation and impact of female members of a design team. We will look at:

1. How, if at all, the design processes of the all-girl groups differ from the design processes of the all-boy groups.

2. How, if at all, the design processes of the groups vary by age, and the nature and degree of interaction between age-related and gender-related effects.

3. What impact participation in this software design process has on students' attitudes towards further involvement in SMET-related coursework and careers, and variations of those attitudes by age and gender.

Design activities are one class of activities that fall under the broader rubric of project-based activities. In such activities, students design complex interactive artifacts to be used by other students for learning about a particular subject (Harel, 1991). Design-based projects have involved the development of presentations, instructional software, simulations, publications, journals, and games (Carver, 1991; Guzdial, 1993; Kafai, 1995, 1996; Lehrer, 1991). With such projects, students learn both about design -- through the process of developing complex artifacts -- and a variety of academic disciplines, such as programming, social studies, language arts, etc.

In contrast to teacher-centered or lecture-centered learning environments, design based activities support natural complexity of content, avoid over simplification of concepts and the relationships between them, engage students in construction of products through collaboration, and most importantly contextualize learning within contexts which require problem solving and inquiry. As Barab, Hay, Barnett & Squire (2001) say, “the goal from this perspective is to establish rich environments that encourage explanation and discovery, nurture reflection, and support students in the carrying out of practices that embody personally meaningful and practically functional representations” (p. 48).

Research and theory suggest that design-based activities provide a rich context for learning (Willet, 1992). Within the context of social constructivism (Cole, 1997; Vygotsky, 1978) or constructionism (Papert, 1991), design projects lend themselves to sustained inquiry and revision of ideas. Other scholars have emphasized the value of complex, self-directed, personally motivated and meaningful design projects for students (Blumenfeld, et. al., 1991; Collins, Brown & Newman, 1990; Harel & Papert, 1990; Kafai, 1996). Such design-based informal learning environments offer a sharp contrast to regular classroom instruction, the effectiveness of which has been questioned by many scholars (Papert, 1991, 1993; Pea, 1993; Lave & Wenger, 1991). As one might imagine, adapting such open-ended problem solving situations into the structure and organization of the conventional classroom is often difficult.

Design, broadly speaking, can be seen as "structure adapted to a purpose" (Perkins, 1986, p. 2). Perkin’s definition captures elegantly an essential quality of design: it is a process of constructing artifacts that exhibit “goodness of fit.” Design can be seen both in material artifacts, such as a hammer or a piece of software, as well as in non-material artifacts, such as a poem, a theory or a scientific experiment. This conceptualization of design can play itself out within multiple contexts. At another level, this idea of design applies to us as educational researchers attempting to better understand the pragmatic and theoretical aspects of developing design-based activities. In essence, our perspective sees design as being both "an object of study as well as context for a study of learning" (Kafai, 1996; see also Mishra, Zhao & Tan, 1999). This view of design as adaptation generates several significant implications that can help us understand the pedagogical value of design-based learning activities. Our approach resembles what Brown (1992) called the “design experiment” focusing as it does on the following social and cognitive aspects of the design activities to help us interpret what we observed:

- The role of knowledge in design, technology, and subject matter content in learning to design, the patterns of interaction among knowledge in different domains;
- The role of audience, mentors, leaders, collaborators, and peers in learning and design; patterns of interaction, both face-to-face and online and their effects on learning and design;
- The role of artifacts and ideas as tools for construction, expression, communication and inquiry; and
- The nature of representation and manipulation of symbols in the process of design as well as how the nature of student understanding evolved over time.

As these aspects of the design experiment approach suggest, design works at multiple levels; thus, understanding what happened in the design teams requires analysis at multiple levels as well. This project is based on a social constructivist view of learning and our research design is informed by naturalistic research in education and sociology. This is particularly important in the context of a systemic phenomenon such as design. Within such a perspective the unit of analysis is not merely the individual but rather the interaction of the learner, the practices, the resources being used, the community within which these practices are nested and the constraints of the situation, i.e. the intersection of individual, activity, and context (Lave & Wenger, 1991; Roth, 1998). To better understand the process of design we intend to use naturalistic methods (Guba & Lincoln, 1983; Lincoln & Guba, 1985; Stake, 1983), building descriptions of the design experience as well as creating networks of students' trajectory of participation (Roth, 1996, Barab, et. al. 2001).

An evaluator will be present with each design team through the time that the teams will be at Design Camp. The evaluator will be a graduate student trained in naturalistic methodologies of data collection and will maintain detailed field notes during the entire process. We intend to conduct regular debriefing sessions at the end of the day during design camp. The evaluator will be present for these meetings as well. The evaluator will also conduct interviews with participants and team leaders. Another trained evaluator will video tape and audiotape selected segments of the sessions. One of the most important by-products of the design process are the artifacts generated (and rejected) while developing the final designed artifact. These artifacts instantiate both the levels of understanding that the designers have about the problem at hand as well as offer insight into how tools change and mediate activity. The evaluator will periodically collect artifacts in the form of physical tools, and products created by the design teams.

Two different investigators will code the data collected. In this we shall follow established research practices in letting the categories emerge from the data. We shall organize the data based on key concerns that drive the research by using specific analytic techniques such as data arrays, categorization, data displays and temporal ordering of the data. In this process we shall identify themes and subthemes in this mass of undifferentiated ideas and behavior by collecting pieces of information, comparing, contrasting and sorting gross categories and minutiae until a discernible thought or behavior becomes identifiable. We will look for confirming and disconfirming evidence, which helps to circumscribe the activity and clarify its meaning. We also intend to make matches and identify differences between categories both within and between cases. This coded data will then be used to identify how these themes are linked to each other then to look for negative instances that disconfirm the links or that suggest new connections that need to be made. As suggested by other qualitative researchers (Erikson, 1986; Fetterman, 1991; Lareau, 1989; Miles and Huberman, 1984) we will compare data sources looking for key linkages among the data that support and refute the major themes and assertions in the study and patterns of generalization within and between cases. We will review the data sources multiple times to get a more holistic conception of the content, to seek out confirming and disconfirming evidence, and to uncover unanticipated side issues. Our goal, as Fetterman (1991) says, is to test "hypotheses and perceptions to construct an accurate conceptual framework about what is happening in the social group (or individuals) under study" (p. 359). We shall ensure validity in our results by collecting data from multiple sources; seeking out, within the data, confirming and disconfirming evidence to support and refute themes and assertions; triangulation of data; and procedural challenges to explanations and checking with informants to see if our interpretations seem accurate (Denzin, 1989; Goetz & LeCompte, 1984; as cited in Stake, 2000).

Phase 4: Electronic Visualizations

An experienced electronic artist and programmer will work under the direction of Heeter to develop polished five-minute concept visualizations of each of the eight design team's prototypes. The visualizations will be based on video of the final presentations of each group, along with debriefing notes and artifacts of the design process in week two. These visualizations will be a promotion for the science learning experience, similar to the way game companies promote their games online. The visualizations will not be entire science learning experiences but will illustrate the interaction and features of the experience in a linear, electronic presentation. Partway through the creation process we will show the partly completed visualization to the teacher moderator and to the project team, teacher/facilitators, and advisory board for feedback as to whether the visualization is capturing the spirit intended by the child design team and, if not, how to improve it.

Phase 5: Reactions to Visualizations

A hybrid CD-ROM and web-based questionnaire will be developed, using CD-ROM to contain the visualization and the web to hold the HTML pages and survey interactivity. We will use hybrid technology so the visualization experience avoids potential slowdowns due to network connection speed, but still uses the Internet for data collection. The survey will assess gender, age, and interest in SMET. It will introduce four visualizations of science learning experiences, telling the respondents we want their reactions to and critique of these experiences, to help us know which one to produce. The respondent will view a visualization, then answer questions about how much they think they would enjoy the experience being described, whether they think other students would enjoy it, whether they think it is a good way to learn about science. They will answer these kinds of questions about each individual visualization. At the end they will be asked to rank, from most favorite to least favorite, the four experiences.

We will work with College of Education's extensive network of Michigan educators to recruit a total of 200 fifth grade and 200 eighth grade participants for the electronic survey. We will recruit from schools representing a diversity of income levels. Parental permissions as well as teacher consent and student assent to participate will be obtained. Respondents will go to a computer lab in their school and our researchers will introduce the survey and help with technical issues during a 50-minute period of participating in the study.

We will look at the relationship between the gender of the design team and the gender of the respondent, as well as relationships of prototype preference to science and computer orientation. Our analysis will allow us to draw conclusions about whether there is a preference for prototypes designed by the same gender, and if so, whether this correlation occurs both in fifth grade when girls and boys express equivalent interest and confidence in SMET as well as in eighth grade when that interest and confidence has dropped. Data will be collected and stored anonymously, linking the school and grade as well as time of day but no other personal information about the participant, other than their responses.

Based on the reactions of the students who use the products, we will investigate the following questions:

> 1.) Is there a difference, by gender of the student software testers, in reaction to the educational software products developed by the all-girl design teams as compared to the games designed by the all-boy groups?
>
> 2.) If so, do girls prefer the educational software designed by girls? Do boys prefer the software designed by boys?
>
> 3.) What aspects of the girl-designed software products appeal most and least to their peers, and how, if at all, does this vary by gender? Likewise for the boy-designed software products.

Summary

A premise of the computer culture is that participants are also creators of that culture. It is critically important that in an increasingly digital and scientific world where economic and social benefit comes to those who are involved in the digital/scientific economy, girls must claim a rightful place. This research can assist others who are also determining how to open this world to girls while the computer culture formation is still in its infancy. Our research will guide a future demonstration project to build a virtual Mars Pioneer Learning Adventures game that will support the learning of science through the fascination of space exploration. We want this future project to attract and support girls in learning science in a virtual environment. The outcomes of this research project will result in closing the gender gap in the design of virtual science education learning activities. Increasingly educators will look to virtual environments to elevate science competence for K-12 students. Our research will help guide teachers and curriculum planners about what kinds of technology experiences appeal to girls. Our research will promote knowledge of how to create virtual environments to support girls as they develop and maintain an interest in science and as they formulate competence in both science and participation in and creation of virtual environments. We are excited to complete this research and to actively promote our findings broadly to the field. We believe that this is important work to be doing at this moment in time and we are deeply committed to it.

KEY PERSONNEL

Carrie Heeter, Ph.D., is Professor of Digital Media Arts in the Department of Telecommunication currently teaching online graduate courses in software design and design research methods. Heeter directs the Communication Technology Laboratory, where she has developed numerous award-winning K-12 education web sites, CD-ROMs, and VR experiences including the Microbe Zoo CD-ROM and web site, Personal Communicator CD-ROM and ASL Browser (winner of the Discover Magazine Software Innovation of the Year award in 1995), and the Michigan 4H Children's Garden Kids' Tour. She is Director of Development of Tools for Online Learning with MSU Virtual University. Heeter lives in San Francisco and is a full time professor for Michigan State University, collaborating with colleagues, design teams, and programmers, teaching, running the Comm Tech Lab, and participating in university culture remotely over the Internet. Her research includes interactivity, cognitive, social, and physical remote presence, technology-enhanced learning, and the integration physical and virtual realities.

Punya Mishra, Ph.D., Assistant Professor of Learning and Technology, Department of Educational Psychology and a Research Associate with the Media Interface and Network Design (MIND) Lab. Mishra has an undergraduate degree in Electrical Engineering, masters' degrees in Visual and Mass Communications, and a Ph.D. in Educational Psychology. His research has focused on the psychological, theoretical, cognitive, and social aspects related to the design and use of computer-based learning environments. His other interests include cognitive psychology of science, visual literacy, and creativity.

Rhonda Egidio, Ph.D., Director VITAL and REACH, Professor, College of Education. Egidio directs projects that use the advantages of technology to create virtual learning environments. She has developed online course-based continuing education Web sites for Rehabilitation counselors and has taught educators to create online learning courses. Dr. Egidio's course, EAD 860: Concept of a Learning Society, about the future of education, was the first online course offered at MSU in 1995. She has worked with state government to create fully functional knowledge management E-Learn systems and has worked with automakers to create online learning communities and portals to higher education.

Randy M. Russell, Ph.D., Russell is currently an Earth science educational web site developer for the NSF-funded Exploring Earth project at TERC's Center for Earth and Space Science Education. Previously he was a Producer at MSU's Virtual University, specializing in science, math, and engineering courses. He has worked with faculty to develop more than a dozen Web-based courses, and taught a Web Design course for MSU's Telecommunications Dept. He has been developing multimedia educational software (CD-ROM and Web-based) for 13 years, and has a strong background in space science (B.S. in astrophysics, M.S. in aerospace engineering) and education (Ph.D. in educational technology). He was the project manager for the NSF-funded

Microbe Zoo project, which developed microbiology education software (Web site and CD-ROM) for children.

Norman Lownds, Ph.D., Assistant Professor and Curator, 4-H Children's Garden, Department of Horticulture. Lownds directs all aspects of the Michigan 4-H Children's Garden, including several very successful classroom outreach programs. He has developed the "Connected Classrooms" program where students and teachers connect with the 4-H Children's Garden and Dr. Norm to enhance and expand their science explorations. Through this program classrooms, are connecting to scientists in different parts of the country, exploring science in the garden, creating web pages of their discoveries, and learning that science is interesting and fun. He has also developed a summer garden program, "Kid Curator," and the award winning "Stories in the Garden," where teens read to young children. Lownds works closely with the Communication Technology Laboratory to create the child-oriented 4-H Children's Garden Web site (http://4hgarden.msu.edu) and the various explorations and activities there. Dr. Lownds also serves as the chair of the National Children and Youth Gardening Advisory Panel for the American Horticultural Society.

Advisory Board

Tommie R. Blackwell, Ph. D. Senior Vice President of Spatial Technologies, Executive Director U. S. Space & Rocket Center Foundation

Marcia Brummitt, Chief Operating Officer Imaginary Lines - Sally Ride Science Club

Brenda Laurel, author of Computers as Theater and Utopian Entrepreneur and editor of The Art of Human-Computer Interface Design. CEO and founder of Purple Moon, a CD-ROM company dedicated to designing CD-ROM games for girls. (pending)

Dr. Virginia (Suzy) Young, Deputy Director, Advanced Systems Directorate, Aviation and Missile Command, Research, Development & Engineering Center

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BUDGET JUSTIFICATION

Our research team includes Michigan State University faculty from Education, Telecommunication, and Horticulture. We are multidisciplinary and also a mix of remote and physically present collaborators. Project Leader Heeter has telecommuted from San Francisco for the last 5 years, participating as a full time faculty member for Michigan State University while pioneering remote collaboration and online teaching. Egidio, Mishra, and Lownds are located on campus. And Russell works from his office in Colorado. Our team has been collaborating on the Space Pioneer Learning Adventures concept for more than one year. Our bi-weekly combination phone and physical meetings make it easy for remote participants to call in – we are frequently joined by other remote collaborators, including experts from Space Camp in Huntsville, MarsQuest in Colorado, NASA Ames in Mountain View, the Cranbrook Institute, and more. Egidio will convene the team, keep us on track, connect the project with College of Education, University, and external human and physical resources, and provide input and guidance.

The entire team will participate in the development of Design Camp. Heeter and Russell will take primary responsibility for identifying the 10 different technology-mediated science learning experiences, preparing attitude and learning surveys (related to National Science Standards for grades 5-8), and preparing focus group discussion guides and training materials. The group will together plan the Week 2 design process. Mishra will take primary responsibility for planning and conducting the research on Week 2 design process and outcomes, organizing graduate student observers for each 5 student team and graduate student coders. An undergraduate assistant will be present with each team to assist as needed. One senior graduate assistant will work with Heeter and one with Mishra throughout the project.

Twenty fifth graders (ten girls and ten boys), twenty eight graders (ten girls and ten boys) and eight teacher/facilitators (four female and four male) will be recruited to participate in Design Camp.

Two of the Design Camp experiences will need extra effort to offer to participants. The combined virtual and real growing a plant in Mars soil experiment will be developed by Dr. Norman Lownds, Associate Professor of Horticulture and Curator of the Michigan 4H Children's Garden. A quarter time graduate assistant will help with developing and administering this experience. The 3D Virtual Reality experience will be offered in the MIND Lab in Communication Arts and Sciences. Software for the experience will be purchased and a 25% time MIND Lab graduate student will implement the software on the Immersadesk VR system and will oversee offering this experience during Design Camp sessions.

Heeter will direct development of the electronic visualizations, working with Russell and a Comm Tech Lab computer artist on the designs, and working with the graduate assistant on the electronic research. A Comm Tech Lab webmaster will develop the javascript and web tools for online data collection and will burn CD-ROMs to carry to classrooms. The webmaster and artist will also work with Heeter to develop the project web site for collecting and disseminating project results. A password protected site will be used for project coordination and public site for information dissemination.

Hourly student labor will be used for general project assistance, for data entry, and to assist with data collection. The Copy Services Center will be used for large photocopy research and dissemination needs. When smaller numbers of copies are needed we will rely on computer printers. (The supplies budget includes a line item for printing to cover toner, cartridges, paper, and laser printing costs.)

We will establish a three person advisory board with expertise in the design of technology for girls. At three points in the project they will be sent materials and asked to participate in a one hour conference call discussion. Their input will be sought in spring 2003 about the content and structure of Design Camp. They will be asked for input on preliminary drafts of the electronic visualizations in fall 2003. And they will be asked for comments about the overall study findings in summer 2004.

The majority of our project coordination and collaboration will occur electronically, via email, web pages, and document sharing. We will meet every two weeks as a group by telephone. Russell will travel to East Lansing for both two-week periods of design camp in Summer 2003. Heeter will travel to campus for this project once in year 1 and once in year 2, participating as remote "air traffic controller" as well as directing research and design. Two trips for PIs to present project results at conferences are budgeted for Year II. We will present at both education and design conferences. The required PI trips to Washington for each year of the project are included.

Two high end laptop computers with design software are requested in Year I for use by Comm Tech Lab personnel (the senior graduate assistant, webmaster, hourly students, and graphic artist) throughout the project. These will be the Comm Tech Lab "NSF Girls As Designers workstations", for use only for this project.

The budget includes audio cassettes and digital video tapes to record Design Camp activities. We will rent video cameras to videotape final presentations of each of the eight design teams at Design Camp. Week 1 focus group sessions will be recorded on audiotape. We will purchase four audiocassette recorders to use at Design Camp to ensure availability as needed. These will also be used for playback as researchers review the interviews.

Design Camp expenses include lunch and a snack for the students, teacher participants, observers, and helpers for the ten days of camp. We include a per student fee for the Challenger Center Museum, four school busses (to keep the boy and girl teams separate), and money to purchase educational science software, the Planetarium show, and VR experience.