

# EDUCATION IS A NON-FLAT THINKING VENTURE

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**Abstract** *This paper discusses the design, testing and future of a project called interCONNECTIONS™, a new kind of book series designed for middle school girls. The series explains abstract concepts such as magnetic fields and the Pythagorean Theorem three-dimensionally through metaphor and imagery more familiar at a young age. Moreover, this work is about a fundamental idea called 'off-the-page'. OFF-THE-PAGE works™, Inc. is a company seeded in the belief that education is a 'non-flat' thinking adventure, particularly for girls. off-the-page is a multidimensional concept that challenges traditional ways of learning. It suggests that there are more immersive ways of explaining intangible ideas. Research continues to show that girls tend to ignore or drop out of science and engineering studies at the college level. off-the-page is an idea developed to help girls connect to abstract phenomena at an early age, thus allowing them more accessibility and comfort in scientific and engineering fields as high school and college students.*

## INTRODUCTION

With sets of pages that are physically interactive, books can become a metaphor for how we learn and think, rather than two-dimensional entities bound on the left. interCONNECTIONS™ is a book series made up of such living pages. The first three books of the collection were developed with the help of a National Science Foundation grant (NSF Award No. 9979287, 1999-2001). These books are unique in that:

- They are a concrete demonstration of less concrete ideas—ideas such as magnetic fields, electricity, light, sound. The books are designed for girls in that they bring intangible concepts to the physical world through the metaphors that girls are most engaged in (e.g., their faces, each other). A significant body of research supports that women and girls have a more symbolic and interpersonal approach to learning [5].
- The books are made up of unattached boards that, when joined, demonstrate graphically and textually the idea and narrative. To *read* the book then invites a visual, intellectual and mechanical exercise.
- Each book has special boards that have mechanical and interactive mechanisms embedded in them; this is unlike the popular "pop-up" construct. The interCONNECTIONS books have a layered system of

components in between boards and are activated by levers and dials. (See Figures 1 and 3.)

The beginning of interCONNECTIONS stems from a market research study commissioned in 1993 by Interval Corporation in Palo Alto, California. The author was hired as part of a research team studying gender differences in play activity—specifically, girls' lack of interest in computer games. The objectives for the project were clearly commercial, but general educational issues became apparent as the study progressed. Multiple dyad (one girl and a female friend, or one boy and a male friend), focus group and expert interview sessions were conducted as part of the research.

The Interval study inspired a series of product studies in 1994 by the author. In order to test this series, a small-scale qualitative investigation was conducted with a group of nine third grade girls at Peninsula School in Menlo Park, California. The study involved sharing evolving prototypes with the girls over a six month period. One hour visits with the girls occurred every three to four weeks. The girls were asked to spend time with the prototypes, interacting with them and with each other. The key findings from both the Interval and the Peninsula projects were four-fold:

- the interests of girls are consistently socially-oriented;
- girls tend to want things to be tangible, collectible and communal;
- girls are specifically inclined to look for and create character and storyline in most activities;
- technology is more embraced when its purpose is transparent and related to girls' interests.

These observations are consistent with a growing body of sociological and psychological research on gender differences. For example, in looking at women's interaction with computers, sociologist Sherry Turkle discusses girls' inclination to identify computational objects as physical objects in order to connect to them and play with them [10]. She describes this tendency as a relational encounter with a formal system [10]. During a critical moment in her breakthrough discovery of genetic transposition, Noble laureate Barbara McClintock described herself as being part of a system of chromosomes: I was right down there with them. I was part of the system. I was right down there with them, and everything got big...As you look at these things, they become part of you [6].

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FIGURE. 1

PHOEBE'S FIELD FROM 2001 INTERCONNECTIONS PROJECT.  
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Research continues to suggest that girls need to understand a broad purpose—for example, social relevance—in order to feel drawn to fields where technology is being created. Pam Haag, Director of Research for the AAUW educational foundation, states, "The problem is that they [girls] are underrepresented in computer classes, as network engineers, software developers—areas that are growing." This same report concluded that girls are "turned off by technical careers that they view as full of geeky guys in windowless offices who toil at keyboards for hours" [3].

### THE INTERCONNECTIONS SETTING

The early prototypes and research findings were the groundwork for the NSF *interCONNECTIONS* project. *interCONNECTIONS* as a collection will ultimately comprise ten different books that connect thematically in series. The first three books (see Figure 2) and associated Book Bags (see Figures 3 and 4) were refined and developed with the NSF grant. Portability and multiple context use of the books was an issue in the Peninsula work that was ultimately addressed in the NSF project with the introduction of a Book Bag.

What is now book two, *The Universe Is in My Face*, was actually the first book to be designed (1994). The short film, *Powers of Ten* by Charles and Ray Eames, was used as a model for constructing the movement in the narrative. The film is a sequence of progressive steps taken by an imaginary space traveler, moving from Earth to the edge of the universe and back, all the way to the atomic particles of his skin [7]. Correspondingly, *The Universe Is in My Face*

moves from large to small images: face to eye to iris and molecule to atom to electron.

This metaphorical premise became the foundation of the series. Following that it became clear that there was something more fundamental to discuss before atoms and molecules—fields. Hence, book one became *Phoebe's Field*, which explores magnetic, gravitational and electrical fields and also introduces electrons and the concept of electrical charge. *The Universe Is in My Face* then follows with a more in-depth discussion of atomic structure. Book three, *My Horizon*, takes the lead from book two, and discusses the concepts that formulate the Pythagorean Theorem.

Refining the actual storyline of the books was a point driven by the early research and resulted in narrative as conversations between a young girl, Phoebe, and a talking atom named Phleck. *Phoebe's Field* introduces both characters and the concept of a wildflower *field* as Phoebe's theater throughout the series, as shown in this excerpt from the book: "There are many types of fields, Phoebe: fields of daisies, a field trip, a field of dreams, a magnetic field. They are different, but they are all made up of the same tiny invisible flecks just like me, called atoms. A field is a thing that can help explain everything."

### INTERCONNECTIONS RESEARCH THE MODEL

The books and the Book Bag were tested with the help of a user research firm called Gravity Tank, Inc. located in Chicago. They conducted field interviews in Chicago to test

early prototypes of Phoebe's Field and established a testing model for later tests in California and Virginia. Gravity Tank recruited—from suburban, city and inner-city schools—teachers, librarians and girls in 3rd through 8th grades. Gravity Tank produced an extensive document of their findings from the Chicago and California venues.

A prototype of Phoebe's Field was sent to Chicago for testing. Afterwards many suggestions were made to improve both the book and the bag. Substantial changes were implemented, and revised versions of both Phoebe's Field and The Universe Is in My Face were taken to California for testing. After results from California were obtained, the first prototype of My Horizon was completed and tested along with the first two books in Virginia.

### USER RESEARCH

In late 1991, ethnographic field research began to be used to understand patterns of user behavior. Chris Conley, Director of Gravity Tank, states that Insights about what people do with a product and why they do it can be contrasted with what people think about a product—whether they think it is good or nice looking or comfortable. While people are able to tell you what they like or don't like, it does little to help one generate insight in order to make fundamental ideas about the product better [2].

The goal of user research in interCONNECTIONS was to obtain insights about the educational value of the books for young girls and how the book could be improved. Gravity Tank discovers what people do, what they want and why. The research team discovers why people use (or don't use) products, services or software. What distinguishes their methods from more conventional market research is their emphasis on understanding. They have spent eight years developing their approach to user research, which is based

on several social science methods employing a variety of tools. These tools include observational research, one-on-one show and tell interviews and targeted usability testing where participants perform a particular task. Their approach makes use of digital video technology, thorough data coding, constant comparative analysis and a prototype shop that can be used to create models for use during interviews.

### RESEARCH FINDINGS TOP-LINE SUMMARY

The research found that there was a need and desire for an unconventional way to learn about science. The notion of combining a fictional story with science and math concepts was very well received. The first prototype of Phoebe's Field, tested in Chicago, was too rich and complex for the targeted audience of 4th graders. After making revisions to the story and introducing it to older girls in California and Virginia, it was better received and understood. Ultimately, it was determined that 5th through 7th grade is the ideal age range for the interCONNECTIONS series.

Gravity Tank found that through simplification and a reduction of the number of concepts explored in the book, there is a greater chance of adoption of the complete series by both teachers and students. Since there was an overall positive reaction to the book-in-a-bag concept, only a few design changes were suggested.

There is a desire by teachers to combine reading/vocabulary with other subject matter. It is the way inner-city schools are able to meet their required reading and math testing goals without ignoring the other unrequired subjects of science and social studies. This book series could help educational institutions integrate vocabulary and grammar exercises with science concepts, which are frequently overlooked in the curriculum. The girls had a



FIGURE. 2

THE FIRST THREE BOOKS OF INTERCONNECTIONS (*PHOEBE'S FIELD*, *THE UNIVERSE IS IN MY FACE*, *MY HORIZON*). PROTOTYPES FOR NSF GRANT 1999-2001.  
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genuine attraction to the specialness of the book-in-a-bag. Overwhelmingly, the bag was positively received, and the hands-on exercises are essential to keeping the girls interested and wanting to re-read the book.

### THE STORY

With the first prototype, Chicago participants had difficulty explaining what the story was about—including teachers. They did not feel there was a story being told but rather a series of question and answer sessions between Phoebe (the narrator) and Phleck (her invisible guide). After significant revision to the narrative, the California and Virginia participants felt there was a clear and ongoing story being told, and the relationship between Phoebe and Phleck was clearly understood. In addition, the participants recognized that the dialogue between the characters suggested an ongoing relationship in future books of the series.

### ACTIVITIES & GRAPHICS

Previous research underscores the important role of concrete/mechanical activity in education and play—hence the mechanical emphasis in the format of the project. The Materials Division (including Rheonetic Fluids & Systems) of LORD Corporation in Cary, N.C., collaborated with the author to develop a magneto-rheological (MR) connecting component for book one and the Book Bag—the MagneWidget™. The MR technology has particular resonance in book one, Phoebe's Field,

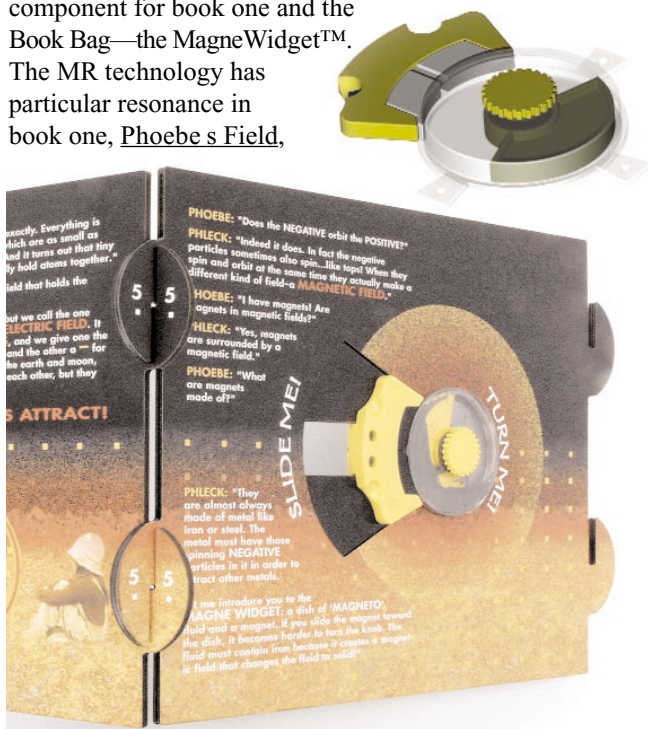


FIGURE 3  
THE MAGNEWIDGET™ FROM PHOEBE'S FIELD.  
PATENT PENDING—LORD CORPORATION.

which is about magnetic and electrical fields. This element in the project brings a concrete connection for girls to new technology while demonstrating a scientific concept. LORD's new technology of controllable fluids not only elicits surprise and wonder from students but has boundless potential for scientific and design education. Controllable fluids are materials that respond to an applied electric or magnetic field with a change in the rheological behavior [1]. In other words, these fluids can change from a liquid form to almost solid in an instant.

The hands-on activities (see Figures 1 and 3), are the main attractions of the book. The MagneWidget was a central feature for the whole product. It shows up on the bag as a locking mechanism and then again in the book explaining magnetism.

### USAGE ENVIRONMENTS

The girls felt the book should be set up somewhere quiet, so they could concentrate. Typically they said their bedroom floor or at a friend's house would be the place. Group usage was not desired by the girls for fear of losing parts or breakage. While teachers had difficulty imagining where they could set it up in their classroom, they were excited about using it as a "learning center or unit" for the kids to explore if they finish their assigned work before the others. The book was not generally thought to be for just girls. "I'd share this with my grandson." "I have a cousin and he loves these kinds of things, so I'd read it with him." Teachers also suggested that the book-in-a-bag could be a science project bag that could be checked out overnight by students to take home and explore.

### THE BAG

Overwhelmingly, the bag was positively received. The removable "magazine" was an exciting surprise and a feature participants wanted to have (see Figure 5). Participants wanted to use the bag to carry other/additional papers and books. They would happily carry this bag in addition to their current backpack. Some 4th grade participants were more interested in the bag than the book.

Participants were pleasantly surprised to find that there was a book inside. "Oh, this is the book!" In the first version of the bag, the zipper closure was frequently overlooked when first taking out the panels and then again when closing the bag. The Phleck pouch had to be pointed out to the participants; however, it was easier to find with the revised location. Red was chosen as the preferred color for this particular book about magnets. "But, I really want it in purple, since that's my favorite color." Participants responded "oh cool" when they discovered it could be carried outside of the bag with the closure/strap arrangement.



FIGURES. 4 & 5

THE BOOK-IN-A-BAG. BELOW: REMOVABLE BINDER OF SLEEVES THAT STORES BOOK BOARDS AND SNAPS INSIDE THE LARGER BAG.  
BAG: PATENT PENDING—VIRGINIA TECH.

There was mixed reaction on the necessity of having a bag for each book. There was concern for the cost of obtaining all the books in the series if they had to buy a bag as well. Most girls preferred to have a bag for each book. A bag for each book was recommended for the classroom setting. "If it's in a bag, it's more organized."

### OFF-THE-PAGE WORKS™

interCONNECTIONS is one piece of a much larger idea called *off-the-page*—a phrase that suggests a paradigm shift in education. It is a concept that combines multiple aptitudes, including analytical learning and a physical grappling with abstract ideas. This concept aligns with Howard Gardner's theory that we are all made up of "multiple intelligences". He suggests that the role of education is to uncover a child's particular spectrum of aptitudes (rooted in their ability to solve problems), thereby enabling their feelings of engagement and confidence [4].

interCONNECTIONS addresses this issue of creative problem solving. The key to its potential success lies in its ability to generate an *interactive* and *integrated* approach towards understanding how the universe works. Removing borders that confine thinking (borders inherent in the standard book) and introducing a more spatial and dynamic

learning module can offer children a universe in which to grasp abstract ideas in context. It's the difference between looking at a picture of the solar system and having direct sensory contact with the effects of light or gravity. The most powerful tool we have is the ability to not only perceive but to directly experience the forces of movement, change and adaptation in the natural laws of science. Children need to 'sense' the fact that we are all moving parts in a constantly changing mosaic.

Though interCONNECTIONS set product development into motion, many other ideas surfaced simultaneously. Some examples of these ideas are: a map of moving pieces explaining land formations, a book of three-dimensional clocks explaining the concept of time through Einstein's theory of relativity, and a collection of wall tiles that explain the structure of music by functioning as audible notes to be physically arranged forming musical compositions.

### LIFE-SIZE AND VIRTUAL PHOEBE'S FIELD

Beyond these off-the-page ideas, there is a new proposal to bring interCONNECTIONS into *life-size* form. 'Life-size' refers to *walking inside a book*, both physically and virtually. The first book of the series, *Phoebe's Field*, will be constructed (with all mechanical features intact) at an architectural scale to form a traveling exhibit. (See Figure 6.) Further, the life-size book will include a small virtual reality (VR) theater. This will allow the participants to enter into the story of *Phoebe's Field* three-dimensionally with navigational and manipulative capability (as if walking into a movie and being able to change it). VR technology is intrinsically positioned to help make concepts *touchable* while creating an environment for the rendering of infinite metaphors.

Though the interCONNECTIONS books are successful in providing metaphors as tools for understanding, the idea of a life-size book surfaced in order to allow one's whole body to experience the story. Additionally, as an exhibit, there might be more mass exposure to the material and more attention to diverse methods of teaching about abstract concepts.

VR technology expands the definition of *life-size*. As a computer-generated atmosphere, a virtual environment has the capacity to immerse people in environments that would otherwise be inaccessible due to scale, cost, safety or perception restrictions. The technology also allows for creativity—navigation and manipulation of the environment. These capabilities could create a learning platform that would allow girls to experience, for example, a magnetic field around them while also being in a field of wildflowers—to be *inside* the concept while action is occurring and simultaneously be inside a metaphor for it.



FIGURE. 6

CONCEPTUAL RENDERING OF THE *PHOEBE'S FIELD* EXHIBIT. FIRST PANEL WITH AN ENTRY PORTAL THAT TAKES PARTICIPANTS TO THE VR THEATER INSIDE. SUBSEQUENT PANELS SHOWN BEYOND (TO INCLUDE MECHANICAL FEATURES).

The VR technology brings an otherwise untouchable concept to the physical realm. Furthermore, with the virtual environment software designed for participant interactivity, girls would be able to create some of their own narrative in the existing story and involve other friends as well. Using software called DIVERSE (Device Independent Virtual Environments—Reconfigurable, Scalable, Extensible) and the CAVE Collaborative Console (CCC), participants will be able to invite remote users into their VR environment. Both DIVERSE and the CCC were developed by the University Visualization and Animation Group (UVAG) at Virginia Tech to enhance collaboration by networking desktop computers into a shared virtual environment [9].

Upon leaving the exhibit and theater, participants will be given a CD/DVD copy of their VR experience. Moreover, schools and museums will be left with CD copies of the software after the exhibit ends to continue using it on local computers. After touring across the U.S., the exhibit will return to Virginia where the Longwood College Institute for Teaching Through Technology and Innovative Practices (ITTIP) will manage and continue to use the exhibit as part of their mobile learning projects.

WWW.OFF-THE-PAGWORKS.COM

www.off-the-pageworks.com emerged as an Internet home for interCONNECTIONS in 2000. Though the NSF

grant work did not entail this development, it became clear that this mode of outreach could eventually serve as an expanded learning center for young girls and teachers as well as assisting the dissemination of the books as products.

In other words, participants in the exhibit could record their experiences (and creations) in the environment and return to the web site from any Internet connected computer and see *their* story (e.g., "Jane's Visit to Phoebe's Field"). Alternatively, girls could download their recording from the web site to their personal computer.

The goals of the web site are three-fold: to serve (1) as an extended learning center for the concepts of *Phoebe's Field*, which will include lesson plans for teachers and interactive tools for further learning; (2) as an extension to the exhibit, which will include archiving some of the virtual reality experiences of the exhibit participants; (3) as a place to find out more about the books and where and when the exhibit is being shown.

## SUMMARY

The author Margaret Wertheim suggests we look for..."a time when women will be equally involved not just in *doing* science, but in determining *what science is*, how it is *practiced*, how it is *put to use* in our lives, and above all, what are its ideals and goals" [11].

From a design perspective, the goal of *off-the-page* is to respond to the research findings by using metaphor that is more meaningful to adolescent girls, both in narrative and in mechanical features. In discussing her book, *The Power of Feelings*, Nancy Chodorow states, "Transference is what gives meaning to life. You can have experiences that are not transferentially infused, but they're not very meaningful or important to you" [8]. If Chodorow is right that 'to have enlivened experience' we must 'infuse life with unconscious fantasy and transference', then it is imperative that girls, like boys, be able to make significant associations between things in their lives. Where science and technology are concerned, a relation between these concepts and what is important to girls, especially at a young age, is crucial. And metaphors meaningful to girls are often different from those important to boys. In addition, making the intangible concrete is important at a young age.

If girls want a certain thing to happen in their world, they need first to know how to use technology to get there. Then the technology has transference. For example, if participants in the virtual *Phoebe's Field* wanted to move elements in the story from one point to another, they might be instructed to create a magnet as a tool to do so. In order to make a magnet, they would have to understand the basic principles of magnetism. VR technology can not only simulate cause and



effect but it can demonstrate the fundamental ideas of the science behind technology.

Changing a traditional paradigm in education is not a trivial task; it requires expanding teaching models. By changing the current archetype, a book can really be a world translating learning into non-flat, multidimensional thinking—bringing ideas up "off the page," thus making abstract concepts more tangible. It is a phrase that suggests that science is a non-flat world and how we get there is as multidimensional as we are.



FIGURE. 7

CONCEPTUAL RENDERING OF THE VIRTUAL *PHOEBE'S FIELD*

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