A Private Universe Explored:

The Story of a Poster Child for Science Misconceptions and the Documentary That Changed Science Education.

Heather Mars

Naropa University

Critical Thesis

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Dedicated to those who ask the questions others are pondering

and to Ms Frizzle, “Take chances, make mistakes, get messy!”

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Forward: Finding Heather

by Adam Johnston

I met Heather sometime in the mid-1990s, only she didn't know it. I suppose that's the downside of being a science education video celebrity.

I was a grad student in physics and science education when I first viewed *A Private Universe* (APU) and her highlighted contribution to the documentary. Granted, her "contribution" was a bit accidental. Here was a kid, projected through the miracle of VHS and a rolling cart with a clunky TV box turned to channel 3, who portrayed a thoughtfulness and articulateness such that interviewers and camera people would naturally latch on to how she represented orbits and phases.

As a result, Heather became an unwitting poster child for awareness of and research into students' "misconceptions." This was the exciting wave of educational inquiry that I rode in graduate school and beyond. I was fascinated with all the diverse ways that an individual could get an idea right or wrong, whether it was moon phases or photosynthesis or anything else. Maybe most intriguing was how a human could get a simple question "right" (it's warm in the summer or it would feel warmer if the Sun were a lot closer) and also construct things all wrong (seasons being caused by the Sun's nearness). We can hold multiple ideas in our head that might technically contradict one another, but we might also never have a chance to sit down and resolve their differences in some deliberative space in our minds. So much of the time we can compartmentalize sets of ideas and reasoning that are at odds with one another.

Moreover, traditional classroom instruction can be completely disconnected from how we most naturally and intuitively think about the real world. Heather and *APU* showed us that what looks like good instruction doesn't necessarily translate into meaningful conceptual change. My graduate advisor quipped to me once that the real asset of human learning is that we are naturally sensemaking creatures; but the real problem for human learning is that we are still, also, naturally sensemaking creatures. We are so good at creating sophisticated and elaborate mental constructions, but that doesn't mean they're compatible with reality.

The *APU* interviews also demonstrated the value of qualitative research. While this documentary was not a formal study (and there's a litany of interesting distinctions and consequences here), it definitely demonstrated to budding researchers and teachers like me that the value of talking with students, eliciting their ideas, and giving them capacity to model their conceptions is all incredibly valuable. Heather was prompted, listened to, and given tools to formulate her ideas. She was encouraged as she knotted up and untangled concepts. Rather than just contributing singular responses on a bubble sheet, Heather could depict how she was thinking about something. She'd even change her mind right before our eyes. This could only happen, and we could only witness it, with the conversation that was part of this documentary. Many of us came to better appreciate this thoughtful approach to how we work as teachers as well as researchers.

But for as much as I benefited from this work, there were also features that left a lingering dissatisfaction that would continue to grow. As described in *APU* and a follow-up project, *Minds of our Own*, misconceptions were regarded as something like infections. We needed to inoculate and sanitize, find the educational equivalent of antibiotics so that our patients

could lead healthy science lives. There was this imperative that we needed to fix our learners and their illformed ideas. And yet, this creates a tension. At what point do we get so enamored with fixing the wrong ideas that we forget about the process of creating new ones? Since that time of *APU*, a few things have happened in the science education arena. First, while we still consider student thinking in more and more ways, not just what they can recite as answers but how they construct their thinking and where that comes from — cognitive and cultural, emotional and environmental — we also have started to shift our perspective about the "wrong" answers as having some kind of student led guidance towards "correct" answers. That is, a student who thinks the seasons are caused by Earth-Sun distance being near or far doesn't describe the right answer, but they do have an association of how energy is transferred and what those distances could do. They're using experience as evidence and building models from it. This isn't something we should discourage, but instead build upon. As a friend and colleague, Doug Larkin, describes it, we can regard these misconceptions as "bright shiny pebbles" that can be collected. We can better understand our students' ideas and logic rather than squelch these; we don't see any of these ideas as an endpoint. In turn, we can build from those ideas, providing opportunity for learners to test them. Instead of pouring disinfectant on these, we're helping the learner cultivate the ideas into something that's more fully formed but still their own.

But here's the biggest lesson for me: After doing work in science misconceptions and sharing *APU* with countless teachers and teachers-to-be, it occurred to me that in spite of all of the angst and handwringing we exercised about students not learning science exactly as we'd imagined, a lot of these students — most of them, probably — went on to live perfectly legitimate and fulfilling existences. When I'd asked my own students what they think happened

to Heather, no one imagined that she was living under the meager shelter of a bridge, still trying to sort out orbits with an oversized Sharpie marker. In fact, they figured that she was probably doing just fine. She probably learned lots of wondrous and meaningful things, probably made some sense of seasons later; or maybe she didn't and really what did it matter?

What I've come to embrace most from Heather's experience, even if I had never had the opportunity to know her and share experiences about physics and family and learning, is that she, like any of us, is much more than that snippet of time in which she was filmed. She's not a reduction to some collection of things she understands or communicates. Like all of us, Heather is a human, flesh and bone, heart and soul. Education, after all is said and done, isn't about what we understand or can do. It's a tool to help us become. Ultimately we would be wise to lift up schools and learning experiences that celebrate the child as a fully formed person and also continuing to morph. We all deserve to be this matrix of complexity and possibility. We collectively deserve an education that recognizes all that we are and all that we have yet to become. Heather, in all that's she's done and continues to do, personifies this.

Prologue

What school are you from? choruses through the plane as travelers find their seats. The Portland, Oregon to Boston flight is primarily populated by grade school teachers going to the National Science Teacher's Association convention. It is 2008.

"Are you a teacher?" my seat-mate asks as I stand to shrug off my coat.

"No, but I'm going to the NSTA convention. I'm on a panel for a documentary."

As my arms slipped from my coat, the man in front of us looks up. "You're Heather." he states with wonder. He turns to his seat-mate, "That's Heather! From *A Private Universe*!" His seat-mate is unimpressed, but other people turn to look.

That's Heather... echos around me.

I sit down, settling into the protection of my seat, wondering what my fourteen-year-old-self has been doing for the past two decades.

A Private Universe: An Introduction

When I was a freshman in high school, a team of researchers from the Harvard-Smithsonian Center for Astrophysics (CfA) came to my freshman science class to interview us about the seasons and the phases of the moon. It was 1987 and there was no available research about what students knew about astronomy.[1] The team was part of a project to create a high school astronomy curriculum called Project STAR[2]. They had chosen Cambridge Rindge and Latin High School because of its diversity and location.

From my perspective, as a fourteen year old student, they were a welcome distraction from the grind of high school. My interactions with them were limited to a lecture in my class and two interviews. Permission slips were sent home, class was disrupted, interviews were conducted, and they left.

It was three years later, when I was a senior, that I realized those interviews had been crafted into an award winning documentary. Something happened during their time in my classroom which changed the trajectory of the research from gathering supporting data for a textbook to creating a new field of science education theory, and my fourteen year old self was its poster-child.

♋

The documentary *A Private Universe* opens, rather iconically, with interviews of graduating students and faculty from Harvard University. It is June 12, 1987, and in the dappled sun of Harvard Yard interviewees are saying that it is warm in summer because the earth is closer to the sun. The narrator, Oscar nominated actress Lindsay Crouse, explains in that 21 out of 23 people asked quote this misconception.[3] Demonstrating that despite years of education, misconceptions first formed in childhood remain firmly in place. (To be clear, it is the tilted axis of the earth which causes the seasons, not the distance from the sun.) The film then cuts to footage at a public high school located a few blocks away. The documentary showcases how misconceptions inhibit learning through interviews given by the high school students before and after a lecture on the seasons and phases of the moon.

The film was used to raise money for science education, instruct pre-service[4] as well active science educators, and to rebuild funding for the National Science Foundation's education budget. It inspired further educational videos, workshops, major expansions of pedagogy, an educational tv channel, and later a website. This documentary shaped the careers of the primary production team. It served as a first step into a new world of educational theory for the people who viewed it. Moreover, it continues to be inspirational. The film is still in use, and is still sparking conversations about how we learn.

This paper is an exploration of how the film came to be, how it changed lives, and how it shifted the role of the misconception in science education. This is also the story of how small moments influence entire lives. When I told Bassam Shakhashiri, former assistant director of the NSF and science education advocate, about this project, he said, "writing is for the self as well as for others. It's not an act. It's what you think as a human being to be captured in the written

form… Write your own story. Not just a playback, but the meaning." *A Private Universe* revolves around the misconceptions of my fourteen-year-old-self, but it is more than that, it is an exploration into what happens when we ask questions and listen deeply to what comes from them.

Timeline

1981 President Reagan eliminates educational spending for NSF

1982 Irwin Shapiro becomes director of CfA

1983 NSF regains educational funding but with limitations

1984 Bassam Shakhashiri becomes assistant director of
National Science Foundation for Science and Engineering Education

1985 Irwin Shapiro applies and gets grant for Project STAR
for $890,000 approved by Shakhashiri after peer review and program officer recommendation,

1986 Irwin Shapiro hires Phil Sadler to run Project STAR

1987 Filming begins at CRLS May 20th
Harvard graduation film clips June

1987 Silver Apple, National Educational Film and Video Festival, Seattle

1988 Gold Medal, Documentary, Houston International Film Festival

1989 Gold Plaque Award, Chicago International Film Festival

1989 Shakhashiri uses *APU* to secure Congressional funds for NSF

1990 Blue Ribbon, American Film and Video Association

1990 Science Media Group founded by Matthew H. Schneps

1993 Project STAR: The Universe in Your Hands (Teacher Series)
video series released by Alex Griswold producer/videographer

1993 Project STAR textbook is published
complete with 2 VHS and teachers guide

1995 Private Universe Project in Science Education

1996 Annenberg Channel is created and run by the Science Media Group

1996 *Minds of Our Own*

2000 *Private Universe Project in Mathematics*

2004 Irwin Shapiro retires

2006 Annenberg Channel folds
Content moves to Annenberg Learner Website

2008 Twentieth Anniversary Panel at NSTA, Boston MA

2014 Science Media Group folds
CfA Science Education Department continues, led by Phil Sadler

2023 "Still a Private Universe? Community College Students' Understanding of Evolution"
Thesis by Meredith Dorner

2026 Annenberg Learner Website ceases to operate (Announced Nov 2025)

Creation of a *Universe:* Shapiro and Shakhashiri

A Private Universe came into being at a time when there was little to no presidential support for science education. President Reagan's administration was notorious for its educational funding cuts. In 1981, they eliminated spending for the education directorate at the National Science Foundation (NSF). The United States National Commission on Excellence in Education published the report *A Nation at Risk: The Imperative for Educational Reform* in 1983. This investigation's findings lead to a restoration of the department with a reduced budget of $23 million a year.[5] Bassam Shakhashiri, a Chemistry professor at the University of Wisconsin-Madison and science education advocate, entered the national stage in 1984 as the assistant director of the NSF, heading the Science and Engineering Educational Directorate. When he left the agency in 1990, after six years of vigorous and contentious campaigning, the budget was more than $230 million.[6] Shakhashiri describes himself as a "peaceful man" (some of his opponents might argue otherwise) but one of his weapons during his campaign to raise funding in the late eighties was *A Private Universe*. [7]

I first met Shakhashiri at the 2008 Twentieth Anniversary Panel for *APU.* He was wearing his signature red "Science is Fun!" t-shirt over a button up dress shirt. He shook my hand warmly, and proclaimed me a scientist. Then he presented me with a large red button that matched his shirt. "You know" he said, "once someone told me that he thought your answers were all faked." I was flabbergasted, but he continued. "I wish he was here now, to hear you talk."

Quite frankly, Shakhashiri is a rockstar in science education. His *Chemical Demonstrations: A Handbook for Teachers of Chemistry,* a five volume collection of chemistry experiments, is a resource used around the world by science teachers. He founded the Institute for Chemical Education in 1983, and has hosted "Once Upon a Christmas Cheery in the Lab of Shakhashiri," an annual Christmas television special on public television since 1970.[8] In 2024, Shakhashiri told me that "fun, in the best sense of the word, is making cerebral connections." His ultimate goal at the NSF was to broaden the government agency's mission from supporting scientific research to inspiring a culture in America which valued scientific knowledge. He wanted to create "science fans" which are analogous to sports fans. He sought to develop the "appreciation of science without deep understanding" in the same way that people enjoy music without knowing the theory behind it.[9]

Irwin Shapiro, a widely respected astrophysicist and radio scientist whose work lead to the formulation of GPS technology, became the director for the Harvard Smithsonian Center for Astrophysics (CfA) in 1982. The CfA describes itself as "a collaboration between Harvard and the Smithsonian designed to ask— and ultimately answer— humanity's greatest unresolved questions about the nature of the universe." [10] One of Shapiro's goals in his position was to encourage the love of science for everyone, not just students at the university's level. When his children were in high school, Shapiro was shocked by the impenetrable difficulty of their science textbooks. Students abandoned hope of understanding in favor of memorization and regurgitation to pass their courses.[11] He considered astronomy to be the perfect gateway to all scientific and mathematical thinking because the sky is available for anyone to see. In his words, "It's not as abstract as chemistry and physics, and the sky is always there."[12] Shapiro set out to build a new

high school astronomy curriculum which was concept based to challenge the fact dense, difficult to follow textbooks of the time. According to Shapiro, “facts are easy; concepts are hard.”[13] To fund this new approach to science education, he applied to the NSF for a grant for Science Teaching Through Its Astronomical Roots, also known as Project STAR.

Irwin Shapiro’s grant application for $890,000 appeared on Bassam Shakhashiri’s desk at the NSF in 1985. After peer review and staff recommendation, Shapiro’s grant was approved by Shakhashiri’s office.

In 1987, Shapiro presented Shakhashiri with a VHS cassette of *A Private Universe*. The cassette went into Shakhashiri’s briefcase where it toured Washington D.C. Clips of the Harvard graduation, my interview, and my teacher’s responses were shown to members of both the House of Representatives and the Senate. Shakhashiri used the video as an example of what NSF funding could be used for, and why it was necessary. “It was part of an armament” he said during a conversation with me in 2024[14]. The documentary was used to show, not tell, why science education was so important. “Heather was bright” he said to me, from his home in Wisconsin, eyes twinkling. We both laughed. This is how my fourteen year old self was used to help raise hundreds of millions of dollars in funding for science education.

When Bassam Shakhashiri left the NSF in 1990, he returned to his life as a professor at the University of Wisconsin-Madison. *A Private Universe* continued to be part of his arsenal of educational material with twice yearly showings on the fall and spring equinox to challenge the assumptions of his students.

Filming of a Universe

Irwin Shapiro's vision for the Project STAR curriculum included using film, computers, and interactive activities. These were innovative ideas in the late eighties. He hired Phil Sadler, a physicist, inventor, and educator who had co-written a calculus textbook while getting his bachelor's degree in physics at MIT, as the project's director. Sadler was an outsider who would spend the next 40 years at CfA. For the film aspect of the project Shapiro turned to Matt Schneps who had been with the CfA as an astrophysicist for several years before the advent of Project STAR. Schneps was actually on the cusp leaving the CfA when Shapiro approached him about doing film work for the new educational project. Film was a passion for Schneps, and this redirection of his career was exactly what he needed.

Phil Sadler chose questions about the phases of the moon and the reasons behind the changing of the seasons because those were concepts people are intimate with in their daily lives. Everyone in Cambridge experiences the cold of winter and the heat of summer, and the moon is there in the sky with scheduled exceptions. The original mission of the filming was to determine how students took their observations and converted them into understanding. This concept they referred to as NAIVE science theory, which stood for "Non-Astronomical Instructional Values Explored[15]." Classroom observations began in November of 1986 with visits to astronomy classes at high schools in Watertown, Needham, Stoneham, and other towns surrounding Boston. In May of 1987, the researchers came to my school, Cambridge Rindge and Latin High School. This time they approached an introductory science class with no astronomy unit.

Phil Sadler conducted my first interview with charisma, sincere curiosity, and intensity. His voice is the one you hear in the video, prodding me into more detailed explanations. There is a magnetism to the way he holds a room, and the way he held space waiting for a response created a vacuum I wanted to fill.

Where Sadler was a beacon in room, Schneps was the person who made the interview process feel safe. Despite a Phd in Physics from MIT, Schneps's experiences with dyslexia caused him great anxiety. In fact, his dyslexia had been a secret he guarded for decades. The anxiety created by the number heavy and acronym rich world of astrophysics was so intense that he was prepared to leave the field entirely prior to Shapiro's invitation to work in film. Working on Project STAR was a new beginning for him, and a path that would set him on his life's work in education. It is Matt Schneps's deep kindness and understanding based in his own experience that made the space feel so safe. He saw me as a fellow learner whose brain skewed information in a way he wanted to relate to.

There were other people in the room to help with the filming. However, the only other person who I remember clearly from my interviews was Alex Griswold. He was hired as a freelancer to do sound work for the filming. He came into the project in time to conduct my second interview. I have a vivid memory of asking him to pin on my mic. He was quiet, and I think I made him a little uncomfortable, to be honest. In the unedited tapes you can hear me push back and tease him about his own understanding of astronomy.

> Alex: "Where were you sitting? I forgot." (Referencing the classroom lesson)
>
> Heather: "In the back."

A: “In the back?”

H: “Second row over in the back.”

A: “So it wasn’t really safe back there?”

H: “Noooo!” (Laughter)

A: “Well this will be relatively painless.”

H: “Oh, okay.”

A: “.. because what we’re doing is…. we’re not asking for specific answers. In fact, I’m very unclear on this and so is Robb, right?”

H: “Why don’t I believe this?” (more laughter)

A: “We’re the two dorks. That’s why we were chosen to ask the questions”

H: “But wait. Hold on. If you’ve been interviewing all these people, then why don’t you know anything?”

A: “Well. Because everyone has it slightly different… ”

H: “That’s because no one knows what they’re talking about.” (more laughter)

A: “But we’re really interested in what you think and also how we can help teachers like Ms LaBossiere explain it better.”[16]

The “Robb” who Alex Griswold refers to is Robb Moss who is behind the camera. Moss was a film professor at Harvard who Schneps had hired as a collaborator in his new venture as a filmmaker. His instincts of where to train the camera, whether to pan to my hands or my face, are what captured the intricacies of my responses. What is clear in this snippet is how comfortable I am. When I showed this piece of raw footage to my children, they commented about how sassy I

was and how at ease I look. There was no reason why this setting—an empty classroom with men I did not know, wired for sound, with lights and a camera focused on me—should have been comfortable. Especially since I know they are there to ask me questions about theories I know I got wrong the first time. I should be guarded, and I am not.

It was the people in the room who made it feel safe. Alex felt like a comrade in the trenches. We were experiencing the world of Sadler and Schneps together. Matt Schneps was in the background keeping the interview on course. When I struggle with vocabulary (direct and in-direct light), he tries to throw me a lifeline in the form of a drawing of how these concepts work in science. I am so entrenched in my misconception, I cannot catch what he offers me. What was clear in that room was that nothing I said would make them mock or scold me. Every person was curious as to what I was going to say next.

After filming, I was released back into the wilds of my urban high school. However, for the team creating Project STAR, something had changed. What had begun as gathering information for the curriculum transitioned into a new project they titled *A Private Universe.* Storyboards were created, and my footage was whisked away to the editing room. The commencement ceremony at Harvard was filmed, and those university graduates demonstrated they didn't really know more than I did. The filming was my practical contribution to the original project. That fourteen year old version of myself had no idea what was going to grow from those interviews.

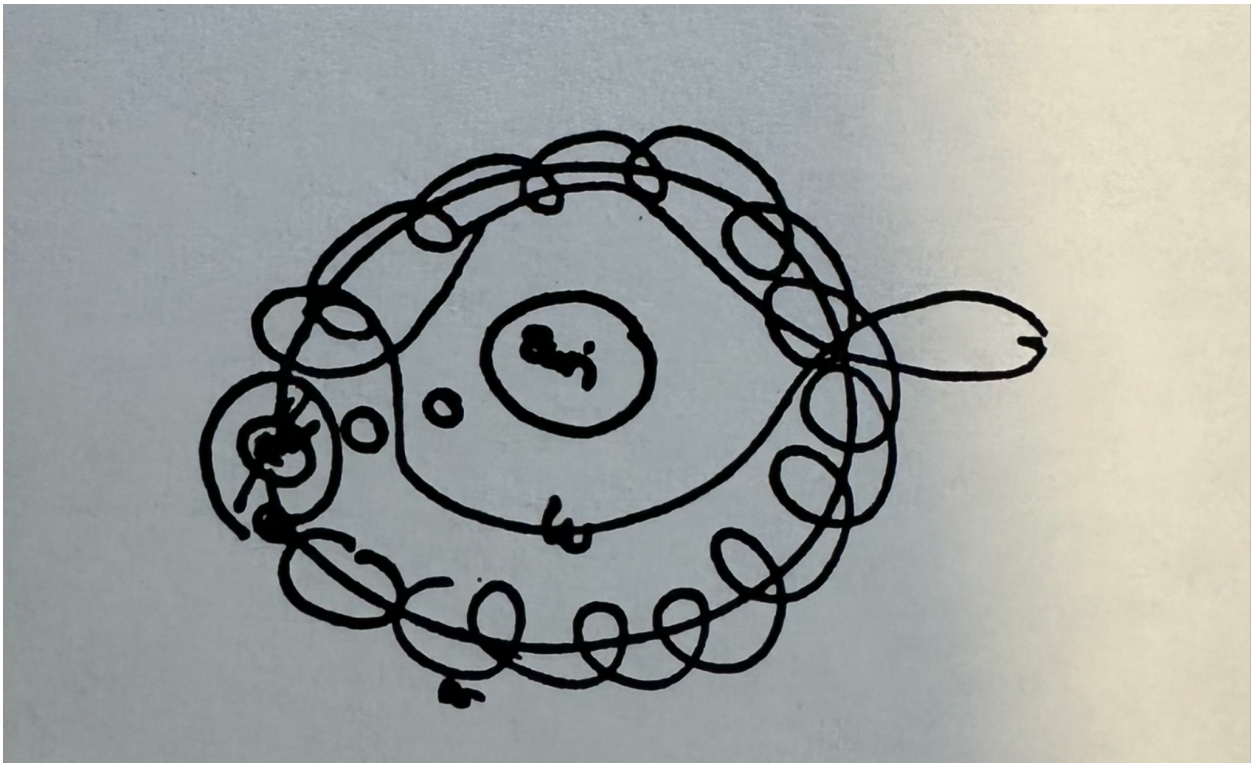
Poster-Child for Misconceptions

It is hard to describe what it feels like to know that hundreds of thousands, perhaps millions, of people have met a fourteen year old version of yourself who draws the orbit of the earth with a double loop. What is undeniable is that my misconceptions hold people closer than my understanding would have. Without that girl in the oversized t-shirt engaging an audience with her errors, the documentary would be a completely different universe. She embodies a student who can recite facts, yet also harbors deep misunderstandings in a way that engages the watcher and highlights Shapiro's concerns about fact-heavy science books. That Heather is both me and not. She is separated from myself through time and tricks of editing, but the eye that stares back from the image imprinted on the DVD is mine.

In my initial interview, I start strong. I voice solid basic knowledge. My presentation and diction are clear and approachable, with only the faintest Cambridge accent. But then I veer. Then I am wrong. Fabulously wrong. The kind of misstep that creates the opening for new beginnings. In the second interview, I admit my error. With a single lesson in astronomy to guide me, I correct my orbit, but when pressed beyond the scope of the lesson, I veer back into my misconception. What made my errors documentary gold was the way I could talk about my thought process.

In the film, I am asked to draw the paths of the earth and moon around the sun. I start by drawing the sun, quipping "but it's a lot bigger," before drawing the earth and its position in the layout of the nine planets (this was before Pluto was demoted). I draw the orbit of the earth

around the sun as an oval, with moon circling it. I'm doing well. This is when I amend my orbit by drawing two loops on either end.



This is the first sign that my understanding of how the orbit works is deeply flawed. It is the warning siren that draws the viewer in. The questions continue and more misconceptions float to the surface. The largest of these is my misunderstanding of direct and indirect light. Previously, I've heard the terms, and I understand that they have something to do with how hot the rays of the sun feel. However, I am convinced that "indirect" means that the light has to bounce from another surface. When I am shown a diagram of light hitting a perpendicular versus a tilted surface, I do not know how to make that definition fit the one I already have.

When my stepfather was driving me to the airport for my flight to the Twentieth Anniversary Panel, he said to me, "It's all my fault. I've felt badly about this since the first time I

saw the movie." My stepfather, Kent Duffy, is an architect. He's an American Institute of Architects Fellow, and his focus on the "interplay between design and education" is one distinguishing mark of his long career.[17] He is absolutely correct that my definition of "indirect light" is an architecturally based one where light does, indeed, bounce. At fourteen, no one has said to me that the scientific definition is different. Without this disclaimer, my brain is struggling to find an object or an entity for the light to reflect from so winter can happen.

The crux of *A Private Universe's* educational message is that misconceptions don't just vanish when the learner is supplied with a correct explanation. People have operating theories of how things work grounded in their own experiences. If those misconceptions are not acknowledged, examined, and tested, they continue to influence the learner. This is like trying to paint a light color over a dark wall. If you don't address the original color, it will bleed through the top coat.

Teachers in 1987 were taught to ignore misconceptions. In a classroom full of students a bad theory was considered a contagion. If time was spent discussing a wrong answer, other students might latch on to it, superseding the information you were trying to teach. This is why when a classmate says the phases of the moon are caused by clouds, my instructor rushes to the next student, ignoring the theory. The training received by my teacher, Ms LaBossiere, leads her to believe that spending time exploring that theory could cause other students to become fixated on lunar clouds.

Through my interviews, the documentary tracks a journey from correct theory, to misconception, to lesson, to revised theory post instruction, to relapse of misconception, all with a dire voiceover proclaiming, "She does not let go of her theory."[18] This single example of how

misconceptions inhibit learning was so vivid it was used to convince congress to approve millions of dollars of funding to the educational branch of the National Science Foundation.

During the discussions surrounding the Twentieth Anniversary Panel at the NSTA convention in 2008, I was asked if I'd had any idea of the impact my interviews would have. I laughed. When I was being interviewed I believed it was part of a graduate thesis project.

Cambridge, Massachusetts is a city rife with universities, and it was not the first time I'd been filmed for a project. When I was quite young, perhaps five, my mother was approached by a friend of a friend who was in need of a child for a problem solving experiment. I was filmed performing a series of tasks. What I remember most clearly was being given a clear tube with an object stuck in its center. There was a tray of items available to clear the obstruction, but my solution was to simply remove the tape holding the tubes together. The woman running the experiment told me I was doing it wrong. This anecdote serves to both explain why I thought *APU* was a student project, and also how I tend to supply solutions which do not fit expectations.

One of the realities of being a test subject in an educational experiment is that you are not informed how your material is being used. With a signed permission slip, the researchers leave with your footage and it goes on to have a life of its own. So when the film crew packed up in the spring of 1987, I went on with my high school experience. I finished freshman year, plodded through sophomore year, manifested a six month student exchange program to Australia in junior year, and returned to scrape through senior year. It was during senior year, in 1990, that I became aware that fourteen year old Heather had been doing her own jet-setting. My mother and I were walking down Mass Ave, near Linnaean St, when a beared man in a tweed jacket approached us.

"I know you," he says, pointing at me.

"No. You don't," I say with teenage finality.

"You're famous. You're in a movie!" he continues.

Seventeen year old me knows of only one type of movie middle aged men see teenage girls in. "Mom, I swear I have made no movies."

"It's a science movie! You're in a science movie," he says triumphantly.

I stop and stare. "Mom, I haven't been in any movies."

"No. You were. I remember that. I signed the permission slip," my mother says. She continues,"You remember, freshman year?"

Then my mother gave his strange man our home address, and he promised to send us a copy of the movie that had "made me famous."

A couple of weeks later a VHS cassette arrived in the mail. It had a dot matrix printed label that made me think it had been manufactured in someone's garage. I was dubious as my mother and step-father loaded it into the machine. And there *she* was. Me but not me. Terrifyingly young and stupid, as all seventeen year olds perceive their 14 year old selves. And she was wrong. All I could think was *I am famous for being wrong*. Of course, my mother and stepfather thought the whole thing was wonderful.

They were right. The documentary was and is wonderful. It is powerful. But it took me years to be able to see that to be wrong is sometimes more powerful than to be right, and that to be known for your misconceptions is freeing.

The Other "Heather"

> "The point is that student, Heather, made an enormous impact on education, okay. She was just being a student. She didn't know what was being involved."[19]

The original invitation to the Twentieth Anniversary Panel for *A Private Universe* was pitched to me as a group endeavor. The panelists would sit on a long table and take turns fielding questions. I was assured that I didn't need to formulate anything in particular to say. I could just come and be myself. It would be, in many ways, a reincarnation of the original interview experience.

Upon arriving at the convention center's hotel, I found myself riding the elevator with Bill Nye[20] the Science Guy. He looked tired from travel, so I repressed my fan-girl desire to ask about his panel. The following morning, fueled by room service, I entered the Boston Convention Center two hours early. The complex was monstrous, and it felt like I walked for miles before finding the room for our event. It was a larger room than I'd expected, but most striking was the stage set with a lectern and a small table for two off to the side. This room was not organized for a panel.

When the staff from CfA arrived, introductions were made. It was my first time seeing Phil Sadler, Matt Schneps, and Alex Griswold since the original filming. Additionally, I was introduced to Irwin Shapiro and Nancy Finkelstein. Finkelstein, a veteran classroom teacher, served as project manager at CfA. I was excited to meet her, as she'd been instrumental in arranging my travel. Once hands had been shaken, I asked if anyone had checked out the room.

After glancing inside, Phil Sadler turned to me and said, “How do you feel about making a speech?” I laughed, and said, “Sure.” After all, I thought to myself, how many people were going to come to this panel?

I sat, chatting with Irwin Shapiro, while the final details of set up were handled. I clearly remember thinking, “If nothing else goes well today, having this conversation will make the trip worthwhile.” Shapiro’s banter was stunningly brilliant, funny, and kind. He told me anecdotes about all of the panelists, and shared his views on science education. The conversation was so riveting the minutes flew by, which is ironic considering that he’s known in astrophysics for discovering the “Shapiro Time Delay.” This test of general relativity states that the speed of light slows from an outside perspective when it passes a massive object.[21] Shapiro quite simply defies physics, as time speeds up around him. When he pointed out that the event was starting, I was stunned to register the full room. Looking over my shoulder, I saw filled seats and people standing against the back wall.

Just before the starting time, Matt Schneps and Phil Sadler turned to Alex Griswold and asked if it was possible to film the panel. They’d failed to arrange for a filming set up (tripods required a permit), but Alex had a camera in his bag which he balanced on his knee or held free-hand to film the event. (This is the video of the event that was available on the Annenberg Learner website.) There is a moment in the recording as I get to the podium where the camera scans around the room and the crowd can be seen. What is not captured is the tremendous love and compassion I felt from the gathered attendees when I stood at that podium. I did not feel nervous or uncomfortable because of the palpable care filling the room.

"Hi," I say, and there is a round of genuine laughter from the audience. I am the girl they all know. "First of all, I have to give credit to my mother because I promised that I would." I pause while they laugh. "She signed the authorization slip so that I could do the interview. So it is all due to her." I say.

The entire speech is off the cuff. It is my very first public speaking endeavor. I am completely transparent, just as I was in the original interviews. And the audience is with me. They laugh and smile. They applaud when I say I got a bachelor's degree in physics. They *know* me. They see the fourteen-year-old-girl they've watched for years appear as a married woman with two children, and they are so happy for me. At the end of my Q&A session, I get a standing ovation.

How did this connection form? What is it about the girl in the film that creates such a bond with her viewers?

One of the experiences I have had again and again as I gather information for this project is how willing and excited people are to speak with me. Emails that begin, "This is Heather from *A Private Universe*" get eager responses. Zoom calls with people I have never met before begin with, "It *is* you!" because they feel they know me. They look at the woman, now in her fifties, and see the high school student who is trying to puzzle out what makes the phases of the moon different from an eclipse, and they want her to be well.

Susan Steinberg Woll, who was the film editor for *A Private Universe,* spent the summers of 1987 working on the documentary. Matt Schneps brought her into the program through his interest in film. She is the one who shaped my raw interview responses to fit the template Matt Schneps and Phil Sadler outlined. "If they hadn't had you, it wouldn't be the film that it is," she

told me in 2024[22]. But it is Steinberg Woll's hand at the controls which shaped my raw interviews into the girl that engages the audience so effectively.

When I watch the film, I can see my image, but she isn't completely me. There is the filter that editing applies making me more concise, more focused in giving the responses the film needs. The power of the editing is also reflected in the way my children perceive the film. The girl in the documentary isn't quite their mother, but when I shared the raw footage of the complete interviews with them, their response was emphatic. "Mom, it's you!" and "Oh, you still do that! You've *always* been like that."

After working on *APU*, Steinberg Woll obtained a free-ride opportunity to do her PhD in Comparative Film Studies at Boston University. Her PhD Dissertation, *Persistence of Vision,* is a study of the Cinema Verité film group's ideas and production methods in which she had been trained as a film student at M.I.T. She used those ideas in her approach to editing *A Private Universe*. As a writer, director and editor she has worked on documentaries that aired on PBS and internationally, as well as screened theatrically and at film festivals. She has taught screenwriting at Harvard for more than 25 years.[23]

In my conversation with Steinberg Woll in 2024, she mentioned that Robb Moss had been running the camera that captured me in my science class listening to my teacher's lesson. In the clip, I look focused, but perhaps bored. At one point, I tilt my head to see around the man and his camera. I remember feeling annoyed that he was in the way, but was careful not to stare into the lens. Moss was also behind the camera in my second interview.

Robb Moss is another person I reached out to with a cold email, and received a near instant response. However, my interview with him began with a different tone. Moss wanted to

know if I was okay. His primary interest in responding to my request was to learn what effect the film had on me. As a documentary filmmaker with a long and impressive career, Moss has a profound awareness of the potential fragility of the subject. In a 2006 interview with The Harvard Crimson, he said "You're making images of people who can't say no to you, exoticizing people who are different and selling their images as a commodity."[24] His concern in his recent conversation with me was that the filming had harmed or traumatized me, and he wanted to support me in anything I needed. I assured him that I was well, and appreciated his concern.[25]

Robb Moss began teaching filmmaking at Harvard in 1983.[26] Moss was already an established filmmaker when Matt Schneps approached him to do freelance camera work. Schneps's empathetic approach to teasing out what was hidden impressed Moss who was intrigued by the concept of how people learn and how science was taught. The classroom scenes were dynamic to film, as there was one chance to get it right. One of the aspects he found key to the film's success was that with a "good school, good students, good teacher—[there was] no way to avoid the premise."[27] He returned to work with the Science Media Group in 1993 on other educational films that became part of the *Private Universe Project*. He is known professionally as a pioneer in the field of Personal Documentary.[28] Moss says "documentary filmmaking is a way to explore the world, a tool to think about the world."[29]

Moss's concerns about my potential lack of autonomy highlight one of the aspects of filming in the late 1980's. There was no peer review as it exists today. Students had to provide signed permission slips, but beyond that the filmmakers were on their own. There was no Human Subjects Approval system, or Institutional Review Board to govern how we were filmed or how that footage was edited. *A Private Universe* would be a different entity if made today, and the

records I accessed at the Smithsonian to research this paper probably would not exist in the same way.

The only official review done of the film was by Irwin Shapiro. He was the person in authority to say if the film was fit for distribution, and his primary concern after he watched the film was that it potentially portrayed Harvard graduates poorly in the opening interviews. He showed the film to Mike Spence the Dean of Faculty of Arts and Sciences at the time. Spence's response was "of course you should do it. We are an open University everything we do of a scholarly nature is open to the world."[30] With that assurance, the film was deemed fit to be released.

A more common concern people have had about the "Heather" of the documentary is wondering if the misconceptions themselves ruined my life. Did I forever wander the streets being confused about direct and indirect rays of the sun? So much pressure is placed upon students being correct when tested, but what is the price of being wrong? If a student never learns the right answer to a question, what effect does it have on their lives?

The very blunt answer to this is that not knowing or understanding the details of how the sun's light reaches the earth isn't as important as having an appreciation for science or being willing to reconsider your own assumptions. Critical thinking and self questioning are more important than specific knowledge. At the 2008 panel, the last audience comment from my Q&A was an educator who says, "You've actually freed us from teaching details. You've actually helped us to see that we, as teachers, can have fun with our students."[31] This is a fascinating take away to me, because nowhere in the actual film is this idea explained. Instead, what you see is how engaged I am in the interviews, and how relatively static the lesson itself is.

Yet, there is something about the fourteen-year-old-Heather of the video that leaves people concerned. Adam Johnston is a professor of physics at Weber State University. In addition to physics classes he teaches pre-service science teachers. He has used *APU* in his science education classes for decades. Johnston co-runs the national conference Science Education at the Crossroads with John Settlage, a professor at the University of Connecticut. They started the conference out of a desire to foster intense educational conversations. They felt that the larger conferences they'd attended (like National Science Teacher's Association conference that hosted *APU*'s 20th anniversary panel) were full of posturing and lacked the deep engagement that they felt lead to actual progress in an individual's teaching career. It was during one of these off-the-cuff conversations about science education that one of them said to the other, "What do you think happened to Heather?" The other one responded with, "Do you think she's living under a bridge?" and "Do you think she's okay?" These questions were often asked by their students when they used the now-dated documentary in class, and they had no answers. So they started to search for me.

At that point, in 2014, I was a stay-at-home mom with two small businesses. One was working as a math tutor, and the other was sewing custom bags for holding table top gaming dice on Etsy. The sewing was a good side hustle. I sold thousands of dice bags to clients all over the world. When I received a request from a J. Settlage for a set of Minion bags (yes, inspired by the movie *Despicable Me*), it was just another order. Each bag was made with a unique face hand crafted from thermoset vinyl and sewn felt. After the bags had been happily received, the client said something to the effect of, "Ah these are for my science education students to carry

recording equipment for when they gather research data." To which I replied, "Oh, I was once in a science education documentary. Have you heard of…"

At this point they came clean, and I was asked if I'd be interested in being a speaker at the 2014 Science Education at the Crossroads convention to answer the question "What happened to Heather?" I was advertised as a "Science Education Celebrity," a concept I still find humorous. Given the opportunity to talk about *APU,* I asked if I could expand the talk into an all day interactive art project. The art activity I designed involved creating collages following a set of prompts using the small increments of time between their scheduled discussion groups. Through the medium of an evolving art piece the participants explored the concept of trial and error as a generative creative process. It was an incredible experience.

In designing Science Education at the Crossroads, Settlage and Johnston utilized a group based process of posing questions and examining them through carefully planned round table discussions called incubators. This process of asking and listening feels akin to the atmosphere of my interviews for *APU*. They are part of a community who loves science, and who wants to share processes and scientific theories, not just facts. The year after I was a guest speaker, I attended their conference as a participant to brainstorm how to gain the experience and knowledge I needed to advance my career in education, specifically tutoring mathematics. My entrance into being a math educator was an organic one, and I found myself needing more of a pedagogical framework to be better able to meet the needs of my students.

Periodically, I have joined Johnston via zoom in his science education classes to talk about my experience in *APU,* as well as my personal theories about what makes for a good

STEM instructor. I answer their questions, and talk about the importance of misconceptions in learning, and of creating an atmosphere where students will share their thoughts.

The Galaxy of Student and Teacher

"You may recognize Heather as typical of your best student."[32]

I was a student teachers don't worry about. My brand of trouble was to ask difficult questions in history class, like "Where were the women?" The most common negative comment on my report card of A's and B's was "Does not work to full potential." It was from this context, that my science teacher Ms LaBossiere responded to my explanation of the seasons in her viewing of my initial interview.

> "Heather's—very bright. On a scale of one to ten, maybe I would probably put her at a nine. A little bit above the other kids, and I'd expect her to know the answers to these things." [33]

What is the goal of education? If the goal is for students to learn the answers to particular questions and to be able to demonstrate their knowledge in tests, then there is pressure on teachers for their students to score well. LaBossiere, as a teacher in 1987, was looking for a student who can demonstrate their knowledge well. She places a sort of educational bet on my ability to shine academically, and then I fall short.

I've heard criticism from people familiar with *APU* about the Ms. LaBossiere who appears on screen. She's Boston brusque in her mannerisms. The classroom's straight rows of desks and the presentation style of teaching are peak 1980s. Her teaching reflects the pedagogy of the time; that students are vessels to be filled by teachers. If a wrong answer is given, it is a

hazard which the class must be steered past. This is all standard teaching theory for the era. Additionally, in the edited construction of the documentary, she is set up to be a fall guy. In the part of the documentary where she is watching me answer questions, the interviewers know I am about to deep dive into a misconception. When they ask what she thinks I'll do next, she is performing in an educational game show.

> "Yeah, I think she's doing very well. Um, yeah, she might have the whole thing."[34]

And then, when I am wrong, she back pedals away from me and my misunderstandings. LaBossiere is a foil being used to prove a point. She is every teacher who believes they know what their students understand. There is no way to anticipate my peculiar orbit. I am a student who fronts well, and my misconception is stunning in its complexity. Perhaps what educators do not like about her reaction to my misconception is that it mirrors their own trepidations.

Matt Schneps told me that his one regret about APU was the treatment of LaBossiere, and how her film was edited. In all of his educational projects after APU, Schneps focuses on the successful strategies of teachers.[35]

The class shown in the documentary was Introduction to Physical Science, a freshman course that was a requirement in the Fundamental program at Cambridge Rindge and Latin High School. The two thousand student school was divided into "Houses" that were tailored to meet different goals. Fundamental was the college prep themed house. LaBossiere's involvement with *APU* began when she heard that the Harvard Smithsonian Center for Astrophysics was looking

teachers to help with a project about Astronomy. She thought the idea was interesting, and was the only teacher to volunteer at the school.

LaBossiere had never been filmed before, and having cameras in her classroom was a novel experience. She was impressed by how unbothered the students appeared, and how unobtrusive the cameramen were. Several weeks after her lesson was filmed, she was asked to meet with the program directors so they could record her reactions as she watched the footage of her students being interviewed. It was an entirely new experience to be able to see herself teaching, and one she built on in further years. In our 2024 conversation, she reflected that being part of the documentary encouraged her to "try new things… not be so timid. [And to] learn how to be a learner."[36]

After the documentary was finished, she was eventually given a copy of the VHS cassette, but there was no personal follow-up. At teaching conferences, LaBossiere was occasionally recognized by fellow educators and asked questions. Eventually she happened across my 2008 Panel talk. She was surprised to hear me say, in response to a question about my relationship with her, that I didn't think she liked me. In 2024, LaBossiere told me,"It just goes to show you how delicate and important relationships between teachers and students can be. In reality, I liked you very much. I recognized you as a student with a very good imagination and a maturity that few of your peers had." This is another example of a misconception and how difficult it is for a teacher to predict the experiences of their student.

The student and teacher in *APU* never change. As a fourteen year old, my growth is expected. It is important to note that Ms LaBossiere's teaching style evolved as her career moved forward. In total, she taught high school science for thirty-five years. During that time, she was

part of a group of teachers called Critical Friends who worked together to critique each other's teaching. Her classroom shifted from the straight rows of *APU*, to small-group work and learning that focused more on the student's needs and base understandings. Towards the end of her career she developed her own curriculum for helping small groups of seniors pass their MCAS exam (Massachusetts Comprehensive Assessment System) so they could get their diplomas. She created a list of topics culled from previous MCAS exams to focus on. From dismantled biology textbooks sourced from the Salvation Army, she created her own hybrid text with the clearest and most concise explanations.

In my conversations with people about *APU*, I am often asked about my teacher and what she was like. LaBossiere was one of the best science teachers I've had, and that includes my instructors at the University of Oregon when I was getting my bachelors in physics. She was engaging, creative, and almost forty years later I remember specific lessons and labs from her class. I can clearly picture her waving her fist in the air as she taught us the abbreviation for gold (AU); "Aaaaye! You! Come back with my gold!" More importantly, she viewed her students as individuals who deserve respect and care.

Expanding Universe

The Smithsonian has a file with my name on it. Inside is a letter in an envelope postmarked 1994 and stamped, “Attempted. Not Known. Return To Sender.” The letter is addressed to me, care of my mother. It reads:

> “October 18, 1994
>
> Dear Ms Mars,
>
> I am writing you from the “Private Universe Project”, which you participated in, as a freshman, at the Cambridge Rindge and Latin High School. “Private Universe” has become even bigger, since we first taped you in 1987.
>
> What does this have to do with you? We at “Private Universe” are wondering, if you have the time to appear in one of our broadcasts. We would appreciate a chance to talk to you, and gain some insight from you once again.
>
> If you are interested (or not interested) please give me a call, or send me a letter, and we can work out the details. I recognize this comes out of nowhere, but we appreciate any time you can spare.”[37]

The Center for Astrophysics was trying to locate me for followup work, but my family had migrated to the west coast. In 1994, I was a first year senior at the University of Oregon majoring

in physics. And to be honest, this letter would have made me very anxious. I wasn't yet able to see beyond the self imposed stigma of my misconception to the broader power of it. I would need to wait a couple more years before I was ready to really understand what my fourteen-year-old doppelgänger was a part of.

With the success of *A Private Universe,* funding became available for further research and more projects. Under the umbrella of the CfA, two new departments were formed. The Harvard and Smithsonian Science Education Department (SED) was created with Phil Sadler and Matt Schneps as founding members. Sadler took the role as department head. The SED studies how people learn science, develops evidence-based STEM learning programs, and actively works to address the needs of students and teachers.[38] The Science Media Group (SMG) was founded within SED by Schneps to create film based educational projects. They created a vast catalogue of works including; "The Habitable Planet," "Dyslexia and Science," and "Physics for the 21st Century."[39]

Project STAR, the high school astronomy textbook which launched *APU*, continued to evolve with further research and refinement. The text book was published in 1993, with a companion video series produced and filmed by Alex Griswold as part of SMG. The curriculum included trainings and workshops, and offered a hands on way to teach astronomy. Griswold would eventually become an Executive Producer at SMG creating a library of content for video based professional development for teachers.

Phil Sadler continued to work in the field of science misconceptions. In his 1992 doctoral thesis, "The Initial Knowledge State of High School Astronomy Students," he created a methodology for compiling student misconceptions. Realizing the difficulty inherent in

discovering all of the “Private Universe”s held by students in a classroom, Sadler devised multiple choice tests for identifying commonly held misconceptions. He also sought to catalogue any patterns between these roadblocks, so teachers could more effectively address them. The model created in his thesis eventually expanded into a suite of multiple choice tests which form the teaching resource known as MOSART (Misconception-Oriented Standards-Based Assessment Resources for Teachers).[40] What began with *A Private Universe* evolved into decades of work analyzing misconceptions and expanding educational models.

In 1991, the NSF funded a project called the “Misconceptions Video Project” to create a series of teacher training videos to address misconceptions in science.[41] With additional funding from the Annenberg/CPB Math and Science Project this new enterprise evolved into the Private Universe Project (PUP). In 1995, their first video was released. Where *APU* introduced the issue of personal misconceptions, PUP offered methodologies for teachers to cope with and discover student’s misconceptions. In 1996, the documentary *Minds of Our Own* was released by SMG. This film moved beyond astronomy into other fields of science and demonstrated the open exploration of thought pioneered by Matt Schneps and used in my interview. This year also marked the launch of the Annenberg Channel. This free satellite channel was an educational resource run by the Science Media Group for teachers in all fields of STEM education, including the Private Universe in Mathematics series which launched in the year 2000.

The growth and productivity of the Science Media Group helmed by Schneps appeared endless until Annenberg’s funding expired in 2006. The Annenberg trust had set aside a lump sum of money for the channel, and when that funding ran out, they ended the project. The

Annenberg Channel folded and the existing collection of programs were moved to the Annenberg Learner Website. In many ways, this marked the end of an educational era.[42]

Irwin Shapiro had retired in 2004, so there was no longer a champion for general science education at the helm of the CfA. While the material created by the Science Education Department and the Science Media Group had brought in close to one hundred million dollars, it was not unilaterally popular within the Center for Astronomy.[43] With a drastically reduced financial footprint, projects changed trajectories, and the CfA moved its primary focus back to the stars.

After the shuttering of SMG, Alex Griswold continued to make science videos for departments within Harvard University. In 2014, he moved to the Harvard Center for the Environment, a Center of the Salata Institute for Climate and Sustainability at Harvard University where he worked as a Senior Mutimedia Producer producing videos and creative online courseware about climate change.

Originally hired for Project STAR, Phil Sadler has been the Director of the Science Education Department at CfA for more than thirty-five years. His work in curriculum building and material development are used by approximately fifteen million students every year.[44] He is also a senior lecturer in Astronomy at Harvard.

Matt Schneps moved forward to create the Laboratory for Visual Learning (LVL) at CfA. As a joint project between the Harvard Graduate School of Education and UMass Boston, the department sought to expand the understanding of learning differences including dyslexia and ADHD.[45] Central to this work was Schneps's theory that conditions like dyslexia created "super powers." In a 2015 article from Scientific American he states:

> The research hints that people with dyslexia exhibit strengths for seeing the big picture (both literally and figuratively) that others tend to miss. And if this is true, the work reinforces the larger idea that differences that people might perceive as a source of difficulty in some domains can become a source of strength in other contexts.[46]

Returning for a moment to *APU*, one of the things that makes my interview successful is how I am able to externalize my thought process. My metacognition, the ability to think about my thought process and share it, comes directly from my dyslexia. To keep from reversing letters and numbers, I am constantly reviewing and assessing my thought process. For example, when considering a math concept, I rarely learn it one way. My brain wants a multidimensional understanding of the situation so that it can check and recheck itself. What you hear in *APU* are my internal thoughts made external. Schneps's work in dyslexia ties directly into one of hidden elements of my interviews.

The Enduring Private Universe

One of the revelatory aspects of *A Private Universe* is that it still has discoveries to offer. In the late 1980's when Bassam Shakhashiri was carrying the VHS cassette around Washington DC, the film was an exploration into how and why science education was not working. What started as a research project into what students knew and did not know about astronomy became a statement about how unexplored misconceptions linger and resurface. This was the first metamorphosis of the film, from astronomy concepts to how we all harbor misconceptions.

APU also acted as a prototype of what recording a classroom and students could reveal. As my science teacher Ms LaBossiere found, seeing yourself teach changes your approach. The externalization of the learning process is key to expanding it. The film projects which came as a direct product of *APU*—and the ones inspired by it—changed the landscape of education.

The film is also a time capsule, not just of my hair style and oversized t-shirts, but of pedagogy. Pre-service teachers watching the film comment about the static style of the lecture, and how passive the students are. What stands out the most, I think, is how rapidly wrong answers are suppressed. This was also a marker of the time. From a modern perspective there is a lot that looks wrong, and it provides an apt point of comparison for current teaching modes. It's important to recognize that teaching practices are constantly changing and evolving. We need landmarks, examples of what has come before, so educators can assess what works and what does not.

There has been a shift in science education over the last forty years from the memorization of facts to concepts which are explored and absorbed. *APU* was at the forefront of

this. Concept based learning was Irwin Shapiro's goal when he first applied to the NSF to fund Project STAR in 1985. Both fact and concept centered learning require the ability to address the internally held understandings of students. *APU* demonstrated the need to navigate these landscapes, but it also reclassified misconceptions. Misconceptions are no longer a minefield to be avoided, but are instead a place to investigate. Previously errors in understanding were quashed, now there is a focus in examining and addressing where these gaps occur. Concepts are scaffolded together, creating a more durable basis of how the universe works.

One of the ways in which *APU* remains a valuable tool for teaching pre-service and serving teachers is the inability to predict fourteen-year-old-Heather's particular orbit of the earth. Pausing *APU* just before I draw my orbit and asking what the girl is going to do next places a new viewer in Ms LaBossiere's shoes. This demonstration of the distance between expectation and reality vividly highlights the challenge teachers face.

Meredith Dorner was first shown *APU* in 2014 by Brian Alters of Chapman University. Dorner was in the PhD program for education and Alters wanted to introduce her to Phil Sadler's work in science misconceptions as a possible direction for her research. As she watched the film she thought, "Oh, I bet that's what my students think."[47] Not that her students created that particular orbit, but that her classroom instruction was encountering their internal universes. Dorner partnered with Alters and Sadler to create her own project focused on community college students and evolutionary science. Her thesis, "Still A Private Universe? Community College Students' Understanding of Evolution"[48] was published in 2023. Dorner's thesis demonstrates that the issues raised by *APU* continue to be relevant.

Heather's *Universe*

For me personally, the most powerful part of *A Private Universe* is how safe I felt in those interviews. All of the tasks I am asked to do are novel to me. I am asked to draw, to use props, and to explain what I think without external guidance. No one is giving me clues as to when I am right or wrong. Instead, there is a non-judgmental space created for me to posit ideas, examine them, retract or redefine them. This new world has none of the expectations I had come to expect of a learning environment. As a student raised to look for cues to guide my feelings of success, I am wandering alone without benchmarks. Yet, I shine more brightly.

In the classroom video, I do not engage in the same way I do in the interview. I seem receptive, but I am quiet and reserved. In the interviews, it is my openness and complete engagement which creates the meaty substance which the documentary requires. I credit this difference in my interactions to the atmosphere of the filming process. That interview space, with the cameras, the lights, the men in the shadows, should have been an uncomfortable, intimidating space. There was nothing natural or familiar about it, yet it was the safest I ever felt in any classroom space in my high school experience. In the unedited video of the interviews, I smile, laugh, and tease. I am completely at ease.

How did this happen? What was it about that space that made me feel so comfortable and supported? I largely credit Matt Schneps for that. Phil Sadler was eager and attentive. Alex Griswold was kind. But it is the steady voice of Schneps in the background who anchored the experience.

In my professional life as a teacher and tutor, one of my goals is to make my student feel the way I felt in that interview room. The first step in successfully teaching a student is to create a space where they feel comfortable enough to be vulnerable. I need to be privy to their way of understanding math, their misconceptions, to be able to teach them. They need to feel able to make a mistakes with me.

I've worked as a math tutor for more than 15 years. Whether I am working with a grade school or college student, my first step is to gain trust. It is not unusual for a student, especially adult students, to cry during a math session. There is a tremendous amount of vulnerability in learning in general, and in mathematics specifically. What makes me a good math tutor is not how "good" I am at math. It's that I struggled with math throughout grade school and college. I love math, yet it has never come easily for me. I am dyslexic to my core. Everything I do with numbers and letters is a continuous process of checking, rechecking, and using techniques to compensate for how my brain likes to work forward and backward at once. I don't enjoy math because its easy, I enjoy it because there are answers. I am here for the beauty.

Most of my elementary and high school teachers were unaware of my dyslexia and how difficult I found it to spell or keep numbers straight. My math teachers were, perhaps, vaguely aware that I transposed answers, but they thought it was inattention, not a learning disability. I am very good at masking my reversals. In *APU* there is a moment when I say, "Oh, now I'm going to get it confused"[49] when quoting the number of days in a year. I glance upward for a moment while I access the order of the numbers 3, 5, and 6. Specifically what I am remembering is smallest number first, then largest, then last. That is still how I remember that there are 365

days in a year. This is a private coping mechanism, and an example of how I've adapted to my brain's ability to reverse order.

I think there are too many people who teach math only because they are good at it. If something comes naturally for you, it is tremendously difficult to explain how it works to someone else. Because my own particular brain needs multiple ways to grasp a concept, I have a toolbox of techniques for explaining math concepts, but my pedagogy begins with that interview room where I felt safe enough to be vulnerable and make mistakes.

The fourteen-year-old-Heather of the documentary has taught me the tremendous value of the mistake. We learn better if we make mistakes out in the open where we can investigate them, pull them apart, and learn how to construct a more accurate understanding. Making mistakes isn't pleasurable. Being wrong is fraught. But, the idea that learning should be pleasant and easy is a fallacy. Learning and growth take work. Many of us share the internalized concept that if we are struggling to learn we are doing a bad job of it. This struggle is, I feel, a symptom of doing the work, not of failing at it. That girl on the screen is working to her full ability trying to make sense of the earth and the sun, but the larger story is that the correct theory was never the most important thing to be found in that room.

A Glossary of Acronyms

APU: *A Private Universe,* award winning science documentary.

CfA: Harvard-Smithsonian Center for Astrophysics.

CRLS: Cambridge Rindge and Latin High School, Cambridge, MA.

LVL: Laboratory for Visual Learning, a department founded by Matt Schneps to carry out research in cognitive psychology to investigate how individual differences in neurology, including those associated with dyslexia, ADHD, and autism spectrum disorders, affect how people learn science.

MOSART: Misconception-Oriented Standards-Based Assessment Resources for Teachers, a collection of resources for teachers which assess students science misconceptions.

NSF: National Science Foundation.

Project STAR: Project Science Teaching Through Its Astronomical Roots. An Astronomy curriculum for developed by the Center for Astrophysics

PUP: Private Universe Project. A collection of workshop videos for elementary school science teachers.

SED: Science Education Department at CfA is a national leader in the study of science learning, and in the research and development of evidence-based STEM learning experiences. It's director is Director Philip Sadler.

STEM: Science Technology Engineering Math

Acknowledgments

I must begin by thanking my mother, Martha Murray. She signed the permission slip which made everything possible. The first time the VHS cassette slipped into the player, my mother and stepfather recognized the importance of *A Private Universe*. Their faith preceded mine, and their support kept me from turning my back on my fourteen-year-old self when all I could see was embarrassment.

Thanks to my husband, Eric Weber, who fielded his share of "We are looking for Heather. She was in a science movie…" phone calls. My daughters, Gwen and Elspeth, for their perspectives of my interviews which helped me see myself in that girl. Do we ever outgrow our fourteen-year-old selves?

Writing about a documentary from the position of research subject presents unique challenges and surprising advantages. In many ways, I am an outsider to this story—I was a child during the making of the film and my first time touring the Harvard-Smithsonian Center for Astrophysics was in 2024. Piecing together the creation story of *APU* was like the best kind of dinner party; brilliant people talking about their passions to someone they know, or at least that they feel they know. "This is Heather, from *A Private Universe"* opens very particular doors.

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Astronomy is a science of looking upward and wondering. A final thank you to Irwin Shapiro whose quest to harness the stars for education started all of this.

Notes

[1] Matt Schneps commentary track, *A Private Universe,* directed by Phil Sadler and Matt Schneps (1987; Cambridge, MA: Harvard Smithsonian Center for Astrophysics, 2003), DVD.

[2] Project STAR: Science Teaching Through Its Astronomical Roots.

[3] *A Private Universe,* directed by Phil Sadler and Matt Schneps (1987; Cambridge, MA: Harvard Smithsonian Center for Astrophysics, 2003), DVD.

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[7] Bassam Shakhashiri in discussion with the author via Zoom, October 10, 2024.

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[10] "About," *Center for Astrophysics| Harvard & Smithsonian*. Accessed November 2025. https://www.cfa.harvard.edu/about.

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[15] Smithsonian Institution Archives. Accession 16-090, Box 45, Folder: Log Book-*NAIVE logbook*, 1987.

[16] Alex Griswold and Heather Mars, in *A Private Universe,* directed by Phil Sadler and Matt Schneps 1987; Cambridge, MA: Harvard Smithsonian Center for Astrophysics, original unedited interview recording.

[17] Kent Duffy, "Design Transmits Values," presented at University of Nebraska College of Architecture-Lincoln, April 8, 2024, https://www.youtube.com/watch?v=WIFMchmMKCU.

[18] *A Private Universe,* directed by Phil Sadler and Matt Schneps, 1987; Cambridge, MA: Harvard Smithsonian Center for Astrophysics, 2003, DVD.

[19] Matt Schneps, *A Private Universe 20 Years Later,* directed by Phil Sadler and Matt Schneps (1987; Cambridge, MA: Harvard Smithsonian Center for Astrophysics) Annenberg Learner, https://www.learner.org/series/a-private-universe/1-a-private-universe/.

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[22] Susan Steinberg Woll in discussion with the author via Zoom, October 3, 2024.

[23] Susan Steinberg Woll in discussion with the author via text, Nov 30, 3025.

[24]Zoe M. Savitsky, "Portrait: Rob Moss," March 16, 2006, https://www.thecrimson.com/article/2006/3/16/portrait-rob-moss-while-we-consume/.

[25] Robb Moss in discussion with the author via Zoom, October 6, 2024.

[26]Scott MacDonald, "In this expansive interview, Robb Moss discusses longitudinal personal filmmaking, his influence as a teacher, and *The Bend in the River,"* August 28, 2025, https://www.documentary.org/online-feature/these-pieces-time-had-ricochet-each-other-robb-moss-discusses-his-telluride.

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[33] Ibid.

[34] Smithsonian Institution Archives. Accession 16-090, Box 45, Folder: Log Book for Project STAR 1987 Marlene LaBossiere, unedited interview.

[35] Matt Schneps in discussion with the author June 16, 2024, Cambridge MA.

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