Fun Physics Fridays: An After School Program for Grades 3-8 School Students
(including Cereal Spoon Optics for Kids)

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Abstract

We describe a program of after school physics activities that run Friday afternoons as part of a SUNY Buffalo State College sponsored after school care and enrichment program. Each semester, about three hundred grades 3-8 children participated at an inner-city school location specializing in immigrant community families in the Buffalo Public School district. We briefly describe the physics program goals, demographics and instructional philosophy are overviewed, as well as a short list of activities and relevant NYSSLS standards. A unique sample activity (Cereal spoon optics) is described so the reader can both experience and show it to others, and we end with findings and recommendations for others seeking to volunteer for or plan after school science programs. We also comment briefly on moving some of this activity online during the pandemic.

Introduction

Buffalo NY is the second largest city in NY State and has the 49^{th} largest regional metropolitan statistical area (MSA) population in the US. The region is historically important to the economic transportation, energy and industrial founding and expansion of the country. This rust belt city, although still one of the poorest in the US with almost a third of the population living below the poverty level and the second highest number of vacant properties per capita, nonetheless continues to be outstandingly ethnically rich, culturally diverse and socially vibrant (see Wikipedia entries on Buffalo, New York, and Rust Belt).

…Buffalo was designated a "preferred community" major refugee resettlement center by US Homeland Security and the immigrant community doubled, with Buffalo receiving over 10,000 refugees since 2001 (NPR, 2015). The city's New Americans Study (2016) included recommendations to improve access to adult education to help immigrants receive appropriate credentials for employment. Buffalo Partnership for the Public Good (2015) reports that this includes refugees, who were credentialed, educated professionals (including STEM teachers) in their original countries – mainly Burma (Myanmar), Bhutan, Nepal, Somalia, Iraq, Syria and Yemen.
A tumultuous decade: Ten years of secondary school STEM teacher preparation data at Buffalo State. (MacIsaac, 2016)

Buffalo's International School #45 is home to over 1000 of Buffalo's most amazing students, representing over 70 countries with over 40 languages spoken. Our students come from all over the world and our top five languages other than English are Karen, Arabic, Somali, Burmese, and Nepali. We also have many students and families that speak Bengali, Tigrinya, and Swahili!
Homepage of Buffalo Public Schools PS 45: The International School (https://www.buffaloschools.org/PS45)

SUNY Buffalo State College (the college) is historically an important regional teacher preparation center for western NY State teachers, having been founded in 1871 as the Buffalo Normal School for teacher preparation. One of the college's community partnership initiatives is the "Learning Together Changing Lives After-School" program partnering the Buffalo Public School (BPS) District Public School 45: The International School, Best-Self Behavioral Health (a community not-for-profit behavioral health services organization; *https://bestselfwny.org*) and the college's Center for Excellence in Rural and Urban Education (CEURE; *https://edpipeline.buffalostate.edu/ceure*). College after school program goals are twofold: to provide PS45 Grade preK-8 students with intensive instruction to support development and growth of literacy skills; and to provide college education majors with clinically-rich intensive professional development opportunities.

The after school program was envisaged as a stand-alone opportunity to support recruitment, training and supervision of education majors as tutors working with small student groups after school. It has expanded to include many other informal PS45 community ecosystem partners in family support, but still provides formal and informal learning experiences aligned with NYS standards, and direct and supplemental English Language Arts (ELA) instruction (*https://edpipeline.buffalostate.edu/learning-together-changing-lives-after-school-program*). The after school program runs five days per week from 4:00-6:00PM as seen in Table 1. Here, the authors describe their attempt to include physics as STEM instruction for one day a week (Fridays) as part of this well-established and supported after school program.

On any typical Friday session of the after school program, about one hundred and fifty to two hundred children (overwhelmingly from PS45, though some siblings and others also joined in) were grouped roughly by age and/or grade into sessions mostly held in classrooms as described in Table 1. Gymnasium, soccer and Girl Scouts are self-explanatory, Social Emotional Learning (SEL) is a program that coaches children to improve their self-awareness, self-control, interpersonal skills and emotional intelligence (*casel.org*), Slime was a chemistry activity, and Step was a popular dance/exercise activity. Any single day there could be multiple STEM activities and groups going, usually with at least one language arts and/or math activity. There were also clubs and activities that occurred less frequently than every day like homework club (for homework help), exam coaching the week before scheduled state assessments, weekly bike club where interested students built and repaired bikes from donated used parts that they eventually took home, and presentations from visiting community cultural, issue or entertainment organizations, variety shows and other performances. Each group was supervised by one certified NYSED teacher present (for legal accountability, and teachers supervised others use of their own classroom space) who helped with student discipline management, but most sessions were planned and run by a large coterie of paid and volunteer pre-service elementary teachers, preservice teachers doing clinical course projects, education and non-education service-learning volunteer students, and uniquely on Fridays, a group of up to five physicists.

Table 1: Sample PS45 Friday after school / aftercare daily schedule. Activity ran five days/week 4:00 PM – 6:00 PM with a 15-30 min snack in cafeteria usually at midpoint.

4:00 PM Groups	**Activity**	**5:15 PM Groups**	**Activity**
PreK / Kindergarten	Gym	PreK / Kindergarten	STEM / Slime
Grade 1	SEL	Grade 1	STEM / Slime
Grade 2	Soccer	Grade 2	SEL
Grade 3	Soccer	Grade 3	Girl Scouts / Music (separated by gender)
Grade 4	Girl Scouts / Music (separated by gender)	Grade 4	Soccer
Grade 5	Fun Physics	Grade 5	Soccer
Grade 6	STEM / Slime then Step	Grade 6	Math STEM
Grades 7-8	Eat then Step	Grades 7-8	Fun Physics

Fun Physics Friday Goals

Fun Physics Friday faculty were a group of five rotating physics pedagogues: three college physics faculty and staff, a Physics Educational Research (PER) doctoral student, and a retired physics teacher. Four of the five had at some time in their lives prepared to become a teacher or actually taught public school. Thus, we had a deep bench to usually provide 2-3 physicists to cover one scheduled session per week even when some folk were ill or otherwise absent. Also, due to rotating through 2 groups of Grades 3 and above each Friday, any single group of students was seen only every third or fourth Friday, so we had to prepare any single activity once then repeated it six times over three weeks, reducing preparation time for us and providing opportunity for improving our practices with each repetition. As a result of previous experience with physics pedagogy in after school clubs (MacIsaac, Genz & Resvoll, 2021), we developed some explicit and distinctly non-traditional goals for our Fun Physics Friday sessions. See description below.

Fun Physics Friday sessions will provide a safe and fun environment for immigrant children to explore select rich and interesting physics activities and phenomena so children will:

- *feel welcome, valued, respected*
- *be encouraged to observe, explore, look for patterns, reason and take risks*
- *collaborate with others*
- *respect differing perspectives*
- *recognize science beyond the classroom*
- *share activities and insights with friends and families*
- *develop positive attitudes towards STEM*
- *eagerly anticipate future sessions*

Especially note that we were not explicitly physics-centric and did not intend to teach and assess any learning of any specific physics content, though we deliberately included many themes and ideas from the New York State Science Learning Standards (NYSSLS). We were child-centered and fun-centered, and almost entirely a-mathematical -- though geometry and patterns regularly arose and one day the students taught us how to write the modern Eastern Arabic numerals (*https://en.wikipedia.org/wiki/Eastern_Arabic_numerals*) they learned in their Koran classes. Like jazz musicians improvising while playing standard melodies, physics content and phenomena were for us a vehicle to student exploration, joy, fun and sense-making, not our destination.

Example Activities and Related NYSSLS

Some sample physics activities students carried out at PS45 included those described in Table 2. In general we were looking for rich, attractive and interesting phenomena that could be experienced and analyzed at multiple levels of complexity by different individuals, and hopefully be related to and/or enrich student's lives. Many activities were modified and homebrew activities from our prior experiences teaching physics and STEM courses and workshops to preservice teachers, or from known grade school curriculum such as taking hand-held physics white boarding group discourse and activities from *Modeling Physics*. In particular, optical and circuit activities were adapted from the award-winning *Physik für Straßenkinder* activity collection (Welzel-Breuer & Breuer, 2018), astronomical activities from the Astronomical Society of the Pacific's *Universe at Your FingerTips* (n.d.) collection, and Robert Morse's outstanding *Franklin and Electrostatics: Ben Franklin as my Lab Partner* curriculum inspired static electric explorations (*https://www.compadre.org/precollege/items/detail.cfm?ID=3427*).

Each day we started with a round-room introduction of all participants, introducing the instructors by name, profession/interest, and country of origin (two Canadians, one each of Nepali, South African and American) then asking students to give their names and encouraging students to contribute their family backgrounds and ethnicities. Then sometimes the instructors showed an attractive and interesting physics demonstration or phenomenon followed always by extended hands-on informal minimally-guided play with the apparatus, eventually leading to a sharing session where students reported interesting things they saw (practicing listening and articulating their thoughts). Usually a question was either seeded or emerged from the discourse and students were encouraged to go back and more rigorously test the question. For instance students might be asked about magnets or shadows, (ask what they are, where to see them, what they do) then be given magnets or apparatus to produce their own shadows and asked to play and find neat things to report back to the whole group. After students reported out their explorations, emergent questions would be explored and discussed *(e.g. Can we list found objects that magnets stick to and don't? Is there a pattern to shadow size?)*. Modeling whiteboards were often used by students to present their ideas in class. Some students only minimally engaged (some chose to read or put their heads down on a Friday afternoon and were left in peace), but most fully engaged and had fun. Usually students were given some inexpensive artifact, apparatus or souvenir to take home to show siblings and parents (e.g. magnets, LEDs and batteries, a plastic magnifying lens, paper tracings of their face profile shadow, etc.).

Table 2: Sample Physics Fun Friday Activities with Related NYS Science Learning Standards (NYSSLS)

Permanent Magnets: *What sticks to a magnet?* Use found and select items including Al can to refute "all metals are magnetic."	**2-PS1-1, 2-PS1-2, 3-PS2-3, 3-PS2-4, 5-PS1-3 G**rades 2, 3, 5 Describe, classify and test observable properties of different materials; cause-effect relationships of magnetic interaction
Shadows: *Face Shadow Tracing* (children's face profiles, varying sizes) Observe/ predict sizes and shapes, relations between distances and light source Use sketch as canvas for listing places students have lived, take home artifact	**1-PS4-2, 1-PS4-3, 4-PS4-2** Grades 1, 4 Objects can be seen only when illuminated; effect of placing objects in light beam path; light reflects from object into eye to see object
Circuits: *Light the light bulb* (explore simple circuits and conductivity; multiple days) Variety of self discovered circuits (how many, how bright, closed loop) possibly to include series and parallel and/or short circuits if topic arises Explore chains of conductors and batteries (found objects and a bag of supplied items including a piece of carbon rod; classroom furniture under supervision)	**4-PS3-2, 4-PS3-4** Grade 4 Energy is conserved during transfer/conversion from one form to another; design, test, and refine a device that converts energy from one form to another
Ray Optics: *Exploring Simple Geometric Optics (multiple days)* Ray box and set of optical elements; later including spoons for image characterization, later still magnifying lenses to confirm and extend optical properties; and explore found objects at magnification. Give away inexpensive spoons and plastic hand magnifying lenses	**1-PS4-3, 4-PS4-2, 5-PS1-3** Grades 1, 4, 5 Effect of placing objects in light beam path; light reflecting from object entering eye allows object to be seen; identify materials based on properties **4-PS3-2, 4-PS4-2, 5-PS1-3** Grades 4, 5 Energy conservation; how seeing works; identifying materials
Pop Rockets: (a.k.a. Alka-Seltzer rockets; outdoors as messy) *How can I make my rocket fly high?* Chemical reactions; gas pressure; exploring various amounts of reactants and mass; aerodynamics, experimental design, engineering design, Newton's Laws Can get very crafty if fins, nose cones etc. are also varied; rampant good fun	**3-5-ETS1-1, 3-PS2-1, 3-PS2-2, 4-PS3-4, 5-PS1-4, 5-PS2-1** Grades 3, 4, 5 Define a simple design problem with constraints; effects of balanced / unbalanced forces on object's motion; predict future motion; Design, test, refine energy transfer device; matter made of tiny particles; gravity
Sound: (tuning forks, vibration and pitch; coffee cups w/spoons) Investigating tuning forks and found objects, vibration, pitch, volume, effects of different taps and vibrating modes	**1-PS4-1, 4-PS3-2, 4-PS3-4, 4-PS4-1 Grades** 1, 4 vibrating materials can make sound; energy conservation; Design, test, and refine device that converts energy; wave model-amplitude, wavelength...
Earth Motion: Apparent sky daily motion via shadow tracing / sundials and sun clocks (outdoors if possible but indoor craft project also possible). Construct and use planisphere / star finder to see motion and learn elementary constellations.	**P-PS3-1, P-ESS1-1, 1-ESS1-1, 5-ESS1-1 Grades** P, 1, 5 Sunlight effect on Earth's surface and apparent motion of sun.
Static Electricity: Build an indicating electrophorus with Ne bulb; explore properties of static charges with balloons, tape, soda can electroscopes and other make-and-take devices etc.	**3-PS2-3, 4-PS3-2** Grade 3, 4 Cause-effect relationships of static interaction; energy is conserved during conversion from one form to another

Close-up of a Sample Activity: Cereal Spoon Optics

The *Cereal Spoon Optics* activity / learning progression started with an informal playtime exploring the (Buffalo State Physics loaned) PASCO OS8516A Ray Optics Kit (components included converging and diverging lenses and mirrors, planar mirror, a liquid cell, rhomboids, prisms and cylinders; https://www.pasco.com/products/lab-apparatus/light-and-optics/ray-optics/os-8516) and OS8470 Basic Optics Light Source / Ray Box for a source of white and colored parallel rays. We showed the students the apparatus (setting the ray box for white parallel rays), and about 21 students played with seven set of apparatus, trying various components and sequences (and orders of sequences) of components in the parallel rays and discovering how to switch the source to (their much preferred) RGB color parallel rays. Imagine a nifty set of building blocks with colored lights.

After informal exploratory play, we asked students to each show-and-tell (demonstrate and describe) us their favorite or otherwise unique neat thing they did or had seen. As the students described their effect, instructors tried to sketch some of the phenomena in standard ray diagrams on the board, particularly those involving the converging lenses and mirrors, drawing attention to rays apparently converging upon and crossing and uncrossing through focal points, eventually using the formal term “focal point.”

Students were also asked if and where they saw interesting optical phenomena in everyday life and mirrors usually emerged as something of relevance. Instructors then asked if students had looked closely at breakfast cereal spoon reflections and we supplied a set of inexpensive soup spoons to students (one each) to check out their reflected images. Children easily saw that the back of the spoon produces an upright reflected image, and the inside of the bowl produces an inverted reflected image. We pressed them to also look close, and most readily discovered that getting very close to the inside of the bowl flips the image back right side up (students usually point this out to each other, then excitedly hunt to see the effect themselves). Students verified that depending upon object distance, they could see BOTH upright and inverted reflected images inside the spoon bowl (often carefully observing their finger tips moving along the principal axis towards and away from the spoon) but ONLY upright images in the back surface of the spoon. Then students were asked to explain why that might be (See Figures 1 and 2).

Figure 1. Author's daughters model (magnified) upright image reflected from back of spoon. Images from a convex mirror (spoon back) are always upright at any distance from the spoon.

Figure 2. Author's daughter models inverted image (object is farther than focal point) reflected from inside bowl of spoon. This is what we usually see at breakfast. Distant images from the bowl are always inverted and smaller than reality, related to the optical scenario where one looks through a magnifying lens at a distant object.

When the object is nearer than the focal length, one sees an upright image reflected from inside bowl of spoon. For most spoons this focal length is too close to photograph (the spoon is almost on your face) so one can move your finger along the sight line into the bowl and watch the image of the fingertip to see it turn upright. This image can be found at breakfast if one deliberately looks for it. This optical scenario is related to the commonly used image from a magnifying glass.

Explanations eventually appealed back to the ray diagrams and discussion, and then to the ray box with converging and diverging mirrors held vertically on a whiteboard at front of the classroom. Most students readily identified and embraced the idea, ***"if the rays cross over the image will be upside down***,***"*** which is a distillation of the characterization of a positive focal point. Image size (magnification) was shown by the instructors but usually not appreciated by students. Students were encouraged to check their cereal spoons at home and show their families what they learned next morning at breakfast.

In a later activity involving plastic magnifying lenses, a bright bulb in a dark room and projected images on a file card, we returned to the theme of upright and inverted images. Students also use the hand lens to look at up close objects (upright magnified images) and distant (inverted miniature images) and to look through the hand lens while walking towards a bulletin board or sign in the classroom. Then the spoon discussions are returned to, and diagrammed if time and interest (younger students especially want to examine everything in the room with their new magnifying lens) support.

As well noted in the literature, (Galili, Bendall, & Goldberg, 1993; Galili & Hazan, 2000; Goldberg & MacDermott, 1987) especially younger students struggle to recognize discrepant events and to hold multiple discrepant events (or even sight pictures or images) in their heads at once for analysis. The cognitive overhead for such is tough (though rotatable spoons help a lot) and the phenomena are attractive and compelling and new. When everything is wonderful, unsurprisingly sense making gets overwhelmed for our students. And that's ok – learning to observe, describe and appreciate is where science begins (See Appendix A for additional photographs).

Accommodating the Pandemic

With the worldwide coronavirus pandemic that emerged in New York State in 2019, the in-person after school programs were cancelled, though the school still handed out snacks / food supplies and homework bags. In fall 2020 and spring 2021, the Friday Physics Fun group contributed to several "Buffalo Beginnings" online STEM camps for children conducted via Zoom teleconferencing. Organizers from the SUNY Buffalo State College Community Academic Center and students requested the topic of "Space STEM" so authors prepared several activities to be done at home with school delivered materials via Zoom guidance and discourse (some families received donated rebuilt used computers). Three of those activities -- the Astronomical Society of the Pacific's homemade planisphere, pocket sundial and pop rockets (n.d.) were edited into freely available YouTube videos (*https://tinyurl.com/MacIsaacOnlineSTEMplaylist*) which have links to downloadable paper templates.

Conclusion: Lessons Learned & Recommendations for Replication

We physics educators greatly enjoyed our Fun Physics Fridays with the students and it was often a great way to and cleanse our emotional palates, provide weekly closure and feel good about ourselves after a sometimes frustrating work week. This activity was great mental therapy for the physicist instructors. It was fun to interact with expert pedagogues, active physics researchers and experts in learning as a team in a different yet intellectually and emotionally rich and rewarding, low stakes, fun environment. Both the kids and our team colleagues were fun and awesome to be with, and we enjoyed one another's company and decompressed exploring cool physics phenomena together. Having fun was most important.

In particular we had a very deep bench of physicists and adult helpers every day who could "flood the zone" if safety was a worry (monitoring battery use to prolong battery life during some investigations, spotting for students who were walking about the classroom while peering closely at spoons or through lenses, keeping wires out of electrical outlets, etc.) and who could fill in for one another if physicists were sick, unavailable, or just burned out. We were also part of a deep, rich ecosystem consisting of the after school program, school, college and community and we had lots of support so we understood what was expected of us, did not have administrative or organizational expectations, and had a low amount of preparation for our activities. Students were delivered to us and taken away, behavioral intervention was readily at hand, and we could watch students at the snack time break or recharge and discuss the experiences with one another and reflect on new iterations. We could hand "activity introduction master of ceremonies" roles to one another, and our non-teachers learned from the teachers, the undergraduate students in attendance and the children in a real sharing community. The collaboration amongst different levels of participants was great for the children and the undergraduate future teachers to experience.

However, some preparation was required, and in particular we had to brainstorm on activities, regularly collect, return and sometimes order inexpensive apparatus like plastic magnifying lenses (with financial support from a physics teachers' organization), and regularly wipe down apparatus with alcohol wipes. Even before the pandemic elementary and middle school is an immunologically challenging environment, and none of the instructors were living with immunologically fragile immediate family. Two of five instructors had their own children in public school, who modeled some of the photos in this article. One of our group members is the instructional support specialist who manages labs for the college physics department, and his access and expertise were extraordinarily helpful.

Student ownership was a success; we often let students take charge of the agenda and followed their questions. We have the necessary physics expertise, and many students really enjoyed taking about physics to their own adult. Sometimes we played the “ask a physicist” game, using that opportunity to model non-authoritarian science by NOT being an encyclopedia, but rather modeling reasoning aloud from principles to “let’s see if we can reason this out together” while pointing out the existence of Google and Wikipedia. As expected, students enjoyed sharing their thoughts and stories, and white boarding. More than once, students seized the initiative and the topic of the day, which we respected. We strongly recommend the reader consider participating in after school STEM programs, and finding and supporting their refugee and immigrant communities.

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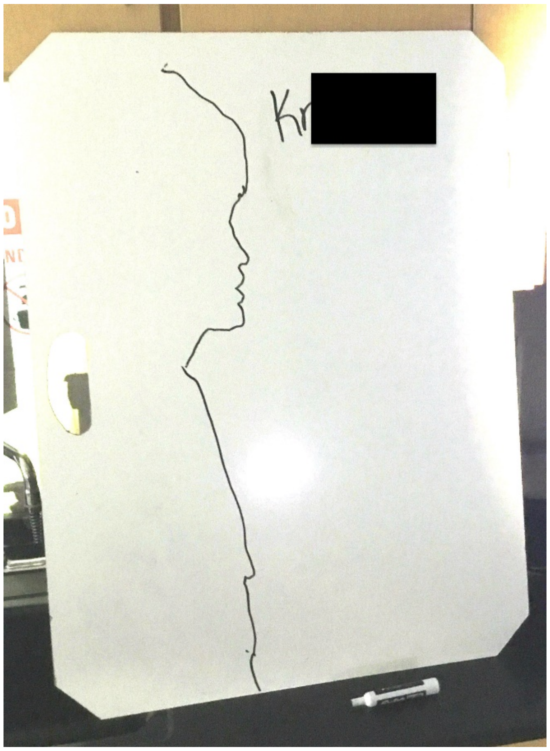
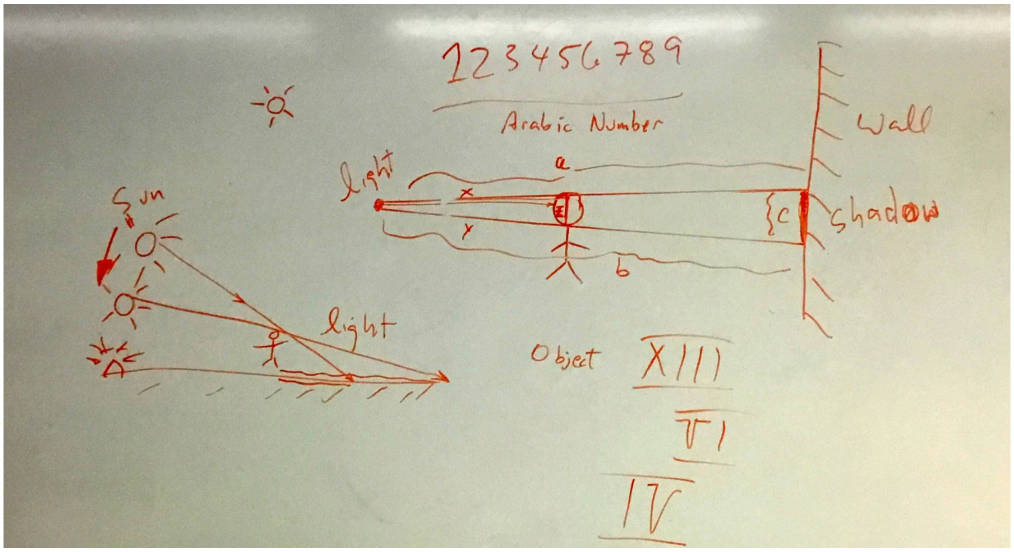
Appendix A. Sample photographs

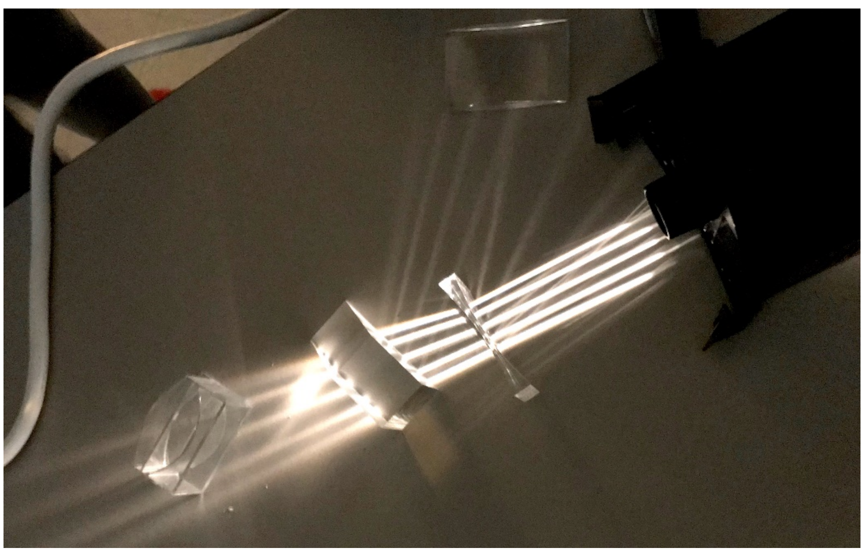


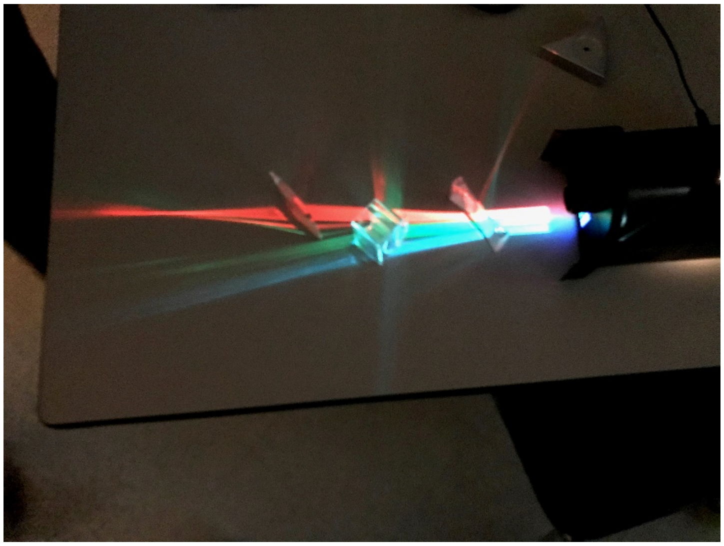
Shadow Tracing Portrait of a student profile on a *Modeling Physics* whiteboard usually used by students to report out and share their activity thoughts, observations, diagrams.


Author's daughter models informal play with circuit materials (we didn't include the genecon in our activities) figuring out how to make the bulbs light brightest and turn the motor. Later *Physik für Straßenkinder* inspired activity deliberately tries to create a circuit including found conducting materials in a large ring by testing candidates. Even metal objects and furniture can be included, under supervision.

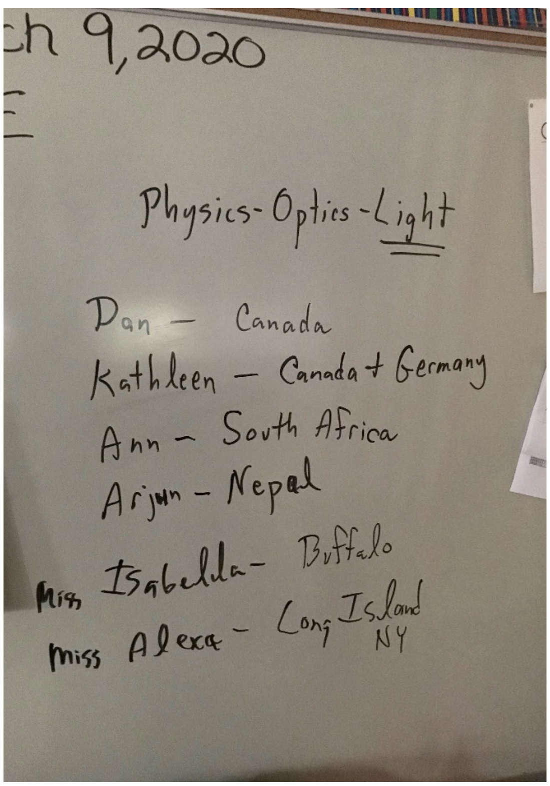


Classroom front board documentation of shadows and shadow size. The physicist was vaguely trying to lead into similar triangles and magnification, but the lesson turned into a discussion of digits and numbers, ending with a student teaching the class modern eastern Arabic numerals from her Koran class.


Student informal play with ray box and optical components.



Student informal play with ray box and components, this time resulting in an obvious focal point at the top. Physicists called student attention to this phenomenon in particular.



Instructor names and countries on classroom whiteboard at start of day. We re-introduced all participants and students every class, and encouraged, but did not require, students to describe their background and heritage.