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Pre-College Students Learn Cross-Cutting STEM Concepts by Building an Optical Imaging Projector

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Abstract: A \$2 table-top experiment was devised to introduce optical imaging principles to pre-college students. Using off-the-shelf parts, this project-based learning activity was implemented in many summer camps and schools to teach math and engineering concepts.

1. Discussion

Research in optics and photonics has advanced greatly with the advent of micro and nanofabrication. Devices like optical projectors and lens assemblies have been highly miniaturized to work in cell-phones. Students can learn about these technologies by using table-top equivalents. These hands on project based learning activities allow students to learn about the fundamental principles involved. The experiment we designed has two main parts: the conceptual section and the hands-on section. In the conceptual section, students are introduced to graphing and drawing ray diagrams. They also derive lens equations by applying the concept of similar triangles. The worksheet for this activity is shown in Fig. 1. To apply these concepts, we go on to the hands-on section. Here, each student builds their own optical projector using an educational lens, a cardstock paper printout (kirigami), an LED flashlight, and a transparency (see Fig. 2). The total cost is \$2/student. After assembly, students measure the height of an object and its image and verify the lens equations they previously derived. This activity brings several unique learning opportunities. First, students understand the intricacies of how imaging occurs and get to adjust various parameters and see their effect. Second, by matching experimental results to theoretical results, students get exposure to the basics of data analysis and interpretation. Additionally, helping students see the applicability of math in real-life problems makes math less abstract. The low-cost and portable nature of this entire experiment has enabled us to conduct this activity at electrical engineering summer camps with over 700 participants since 2014. We have also disseminated it to school teachers, who have then gone on to do it at their schools' STEM clubs, even remotely.

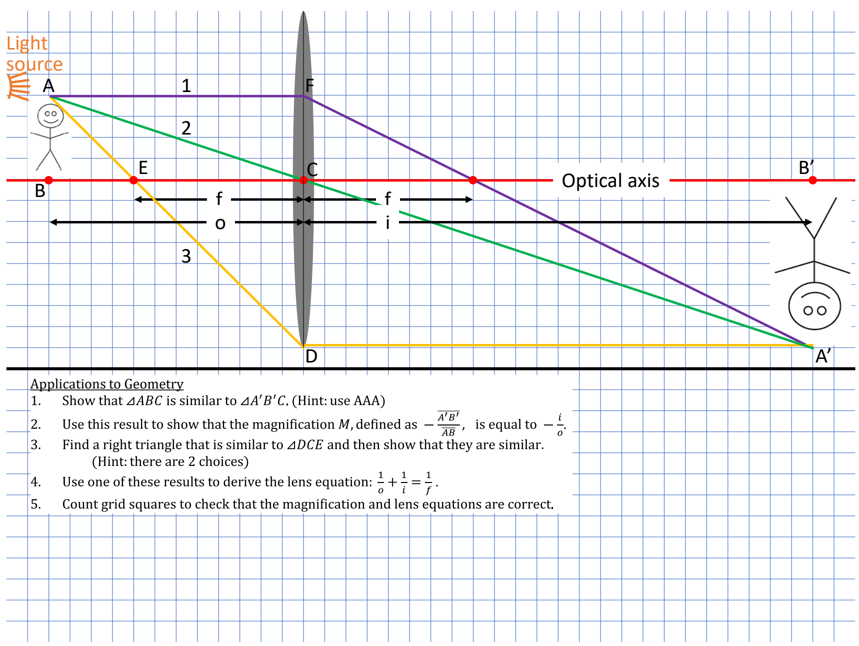

Fig. 1: Worksheet for students to visualize and learn about vertical angles, similar triangles, and optical ray tracing, and to use algebra to derive the magnification equation and the lens equation. Adapted with permission from [1].

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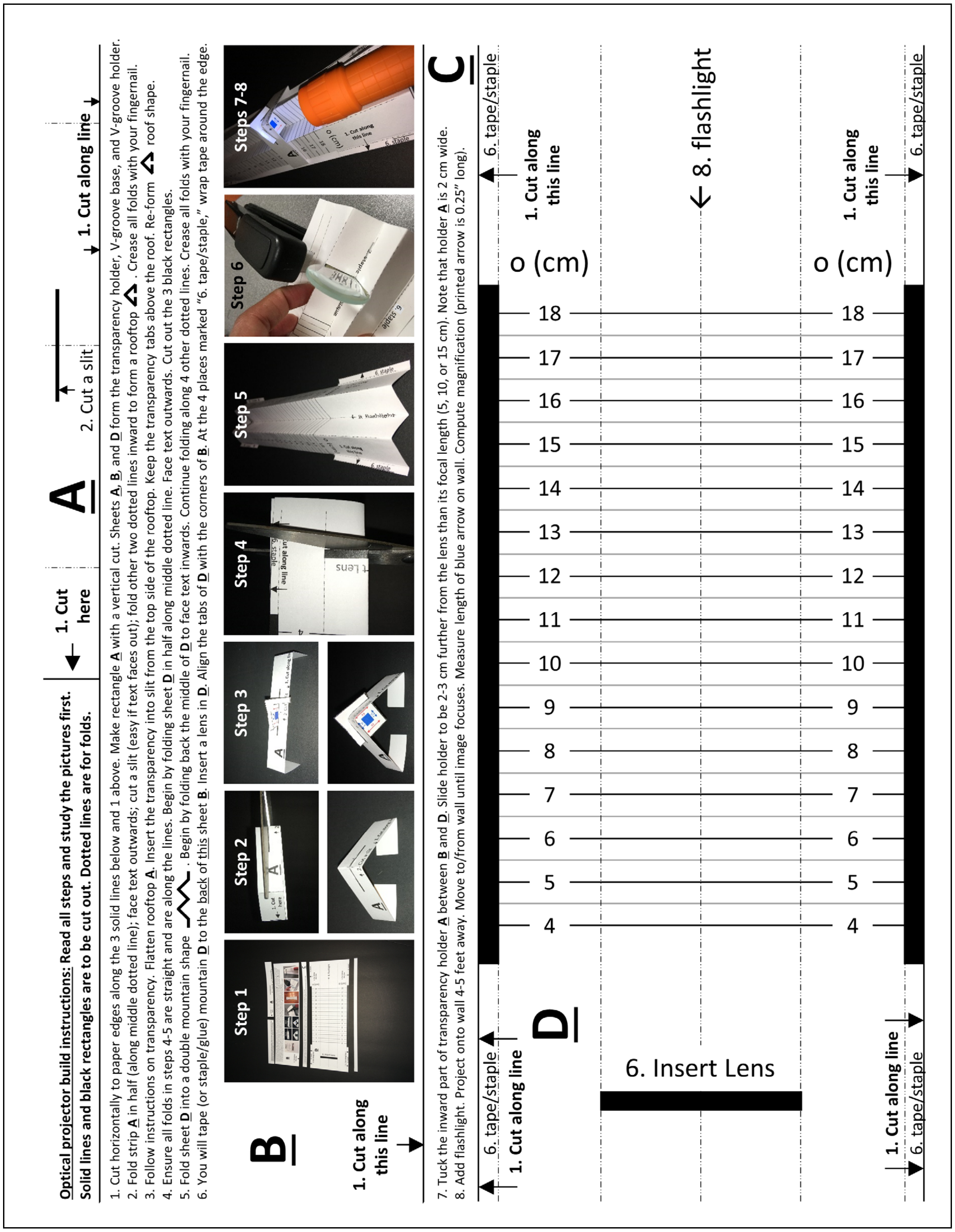

Fig. 2. Cardstock printout for building the optical projector. It must be printed to scale for 8.5" x 11".

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2. References

[1] L. L. Goddard, Y.-M. Kang, S. J. McKeown, A. Haser, C. C. Johnson, and M. N. Wilson, A Project-Based Exploration of Electrical and Computer Engineering. Amazon KDP, ISBN-13: 978-1979381468 (original publication date Nov 2017, current version Sep 2020).

[2] http://psl.mntl.illinois.edu/pbe/