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Work in Progress - Tailoring Optics Resources for K-5 Pre-college Outreach

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Abstract – **Pre-college instruction in science, technology, engineering, and mathematics (STEM) is critical to preparing a workforce and citizens for a technology-based society. The K-5 years are especially important to creating interest and instilling basic concepts. Engineering-based pre-college outreach can provide useful resources in the K-5 education classroom. However, interaction among K-5 teachers and STEM professionals is more effective if outreach is tailored to the K-5 environment. In particular, resources and outreach should accommodate K-5 assessment standards, level-appropriate concept definition, and grade continuity. This work uses a set of optics resources as an example of tailored outreach. Example lessons and activities illustrate pedagogy appropriate for the unique K-5 education environment, e.g. auditory, visual, and "kinesthetic" components, concept definition, terminology, and grade continuity. Optical engineering topics are related to Missouri science standards, STEM relevance and inquiry, and measurement activities.**

Index Terms – K-5 Education, Engineering Outreach, Optics.

INTRODUCTION

Science, technology, engineering, and mathematics (STEM) are essential parts of pre-college curriculum. Students need a basic technical understanding to function as informed citizens and to evaluate STEM-based careers. Outreach resources and activities are sponsored by STEM professionals and technical societies. However, the target audience is often upper-level students. If a technical foundation and interest are lacking for STEM subjects in the early years, student achievement and career paths are affected permanently. K-5 instruction is different from upper-level instruction [1]. Consequently, outreach must be adjusted if the desired results are achieved.

An effective approach to K-5 outreach involves a partnership among K-5 teachers and STEM professionals [1]. Outreach support should have more than an entertainment or "gee whiz" value and should reinforce and enrich curriculum. Example lessons and activities can model effective outreach, especially if explicit efforts to tailor content are described [2].

This work-in-progress presents a model set of lessons and activities that are suited for K-5 education. Optical concepts from the required science standards in Missouri are the topics. The K-5 education environment and the relevant science guidelines are described. The optics resources are tailored for pre-college outreach and optical engineering content is related to early STEM instruction. Ongoing project implementation drives improvement and provides related insights.

RESOURCES FOR EDUCATION IN GRADES K-5

I. K-5 Education Environment

Elementary education must create a foundation of knowledge and must develop skills for applying that knowledge. Young students do not have the ability to focus for long periods or the maturity to adapt their learning preferences. The classroom instruction must closely accommodate their needs. Consistent instruction and reinforcement from one grade to the next are needed for effective learning. This environment is further complicated by the requirements associated with assessments and standards and by wide-ranging teaching responsibilities for K-5 teachers, i.e. they generally teach a variety of subjects from reading and language arts to science and mathematics.

STEM-related instruction, especially in physical sciences, is often challenging for in-service K-5 teachers [1]. Scientific relevance and scientific inquiry are among the most difficult concepts. (Note that these concepts along with measurement activities have high engineering content.) STEM background resources are sometimes lacking for teachers and curricula.

II. Tailoring Resources to K-5 Outreach

Resources for outreach must address the K-5 environment. Hence, guidelines for tailoring the example lessons include:

- Aligning to state and local curriculum standards,
- Incorporating multiple pedagogical styles,
- Defining level-appropriate concepts, and
- Providing grade continuity in which progressively complex content is presented for increasing grade levels.

If outreach content supports the normal curriculum, it is welcome in the local school and will benefit the eventual student testing. If lesson components accommodate auditory, visual, and kinesthetic ("doing") learners, no student is left behind. The Madeline Hunter multi-step organization [2,3] provides such components and meets teacher expectations for lesson plans. The steps include a "hook" to create interest, explicit objectives, modeling demonstrations, comprehension questions, guided and independent practice, and a reinforcing closure. If the lessons are modified for each grade level and the instruction is consistent across grade levels, learning is progressively reinforced and expanded. Note that standards across grade-levels are similarly progressive.

OPTICAL ENGINEERING TOPICS IN K-5 EDUCATION

Optical technology is identified as one of the most significant developments of the twentieth century [4]. Optical topics are included in national and state curricula standards for science. Local school districts define curriculum per grade level by outlining what students "should know" and "should be able to do." Engineering concepts are implicitly part of the science categories, e.g. the "doing" aspects, and may overlap other categories, e.g. applied problems in mathematics and STEM developments in social studies. Optical engineering problems are suited for experiences in reasoning and in measurements.

I. Optics – Science and Engineering

Missouri science standards includes topics in optics [5]. The category "Matter and Energy" identifies key concepts: light is a form of energy, light travels in straight lines, light can be refracted or reflected, and light can be transmitted or absorbed. "Scientific Inquiry" lists tools including magnifiers and periscopes. Engineering applications fit well in this latter category as well as in the category "Scientific Relevance."

II. Model Lessons and Measurement Activities in Optics

Three lesson plans in optics were developed with progressive content: (a) Transmission, Reflection, Refraction, and Absorption, (b) Mirrors Directing Light, and (c) Shadows. This content is aligned with standards and is organized using Madeline Hunter steps. Progressive content is illustrated in the first lesson. In addition to accommodating a shorter attention span for lower grades, the first lesson is limited to transmission and absorption for first grade and expands with reflection and then refraction for higher grades. Appropriate terminology can also be considered. The word transmission may not be introduced until a specific grade. Beforehand, the concept may be described as light "going through" an object.

The associated activities allow students to handle optical elements like mirrors, lenses, and polarizers and to work on an applied puzzle or measurement. Interesting puzzles start with a variety of letters and numbers (such as the school abbreviation) written backwards, in reverse order, upside down, etc. The students have to decide how they will look in a single mirror, a single lens, and/or multiple lenses and then they experimentally see the results. A measurement exercise can involve the teacher. A laser pointer mounted to a right triangle is projected to a cap on the teacher (back of the cap for safety). The distance from the laser to the teacher's feet is the teacher's height. The technique is then related to triangles in geometry and to measuring the height of a tree or building.

PRELIMINARY IMPLEMENTATION AND SUMMARY

Selected aspects of these resources have been tested for two years in a local elementary school. "Lasers and Optics" events were given to first, second, and fifth-grade classes during Engineers Week 2007 and 2006. Feedback from the students and the teachers provide insights into the effectiveness of the tailored content and into how first or second-grade students differ from the fifth-grade students. Popular aspects of the events are evident from the student thank-you letters. Interest is created by linking optical applications to student experience and study, e.g. lasers in grocery-store scanners, rear-view mirrors for viewing ambulance signs, and deck prisms in old sailing ships. Direct examinations of optical fiber, telescopes, lenses, solar cells, etc. are frequently mentioned by the students. However, the most popular aspects are hands-on activities in which the students perform a measurement or solve a puzzle. The main differences among the grades seem to be the attention span and the type of activity. The younger students particularly enjoy the activity with the mirrors and using a periscope, while the older students enjoy measuring the height of their teacher and a demonstration of polarizers and lens combinations. Also, a prior discussion with the teachers and review of the relevant science textbooks helps choose the appropriate terminology for specific grade levels.

The project purposes are to investigate the characteristics of effective outreach resources and to develop specific content for the authors' personal outreach. Enhancements of the lessons and activities are planned for this Work-in-Progress. Better linkage to everyday experience through optics devices and media and a greater range of measurement and puzzle activities are desired. Post-outreach worksheets and activities can reinforce the applied content, but these items must be coordinated with the K-5 teacher to be consistent with local curricula and texts. Note that these enhancements emphasize the engineering aspects of the optical concepts. Assessment of new features, especially with regard to more global questions of effectiveness, is needed for a comprehensive treatment.

These example lessons and activities illustrate effective outreach techniques. Optics is the interest of the authors, but the approach can be applied to other technical topics. Lessons learned include the importance of partnership between the K-5 teacher and the outreach engineer. The teachers are experts in K-5 learning and in the classroom curriculum needs. STEM professionals provide valuable resources and assistance. Also, labeling the engineering content in the "sciences" promotes the profession. Tailoring outreach to the K-5 environment promotes student learning. Effective outreach results in student excitement about and interest in STEM areas.

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REFERENCES

[1] Swift, T. M., Watkins, S. E., Swenson, K., Lasater, E. and Mitchell, O. R., "Involving Engineering with In-Service K-4 Teachers," *Proceedings of the 2003 ASEE Annual Conference,* 20-23 June 2003, Nashville, TN.

[2] Swift, T. M. and Watkins, S. E., "An Engineering Primer for Outreach to K-4 Education," *Journal of STEM Education: Innovations and Research*, **5**(3/4), 67-76, (2004). WWW: http://www.jstem.org/.

[3] Hunter, R., *Madeline Hunter's Mastery Teaching*, (Corwin Press, 2004).

[4] Constable, G. and Somerville, B., *A Century of Innovation*, (John Henry Press, National Academies Press, Washington, D.C., 2003).

[5] Missouri Department of Elementary and Secondary Education, (2007). WWW: http://dese.mo.gov/.