

Lessons in Navigation for Middle School Students

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BIOGRAPHIES

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ABSTRACT

The Satellite Division of the Institute of Navigation sponsored the University of Colorado's Integrated Teaching and Learning (ITL) Program to develop a set of navigation-based educational materials geared to middle

school students. The purpose of the project is to foster interest in navigation, and to encourage the development of the next generation of members of the navigation community. To that end, we developed ten standards-based navigation lessons with associated, age-appropriate hands-on activities and many other applicable tools for educators and students. The development of these navigation lessons is part of a larger K-12 engineering curriculum development initiative currently underway by the ITL outreach program. This paper describes the guiding principles of our curriculum development and summarizes the content of the navigation lessons.

INTRODUCTION

In September 2002, The Institute of Navigation (ION), Satellite Division selected the University of Colorado to develop a set of ten lessons on a variety of navigation topics targeted at the middle school level. The lessons are designed for use by middle school teachers on their own or with the assistance of an ION member volunteer. They can be used in the classroom or as part of a club or outreach program. Each lesson includes motivation for the students, background material for the teacher or mentor, hands-on activity descriptions and worksheets, and additional tips and resources. The activities are designed to have minimal cost and be completed during a class period. Suggestions for scaling the activities up or down a grade level are included. It is our hope that these K-12 navigation materials will facilitate the introduction of navigation in middle school curricula and encourage the involvement of ION members in educational outreach activities.

The navigation module development builds upon existing outreach efforts of the Integrated Teaching and Learning (ITL) Program within the College of Engineering and Applied Sciences at the University of Colorado at Boulder. The ITL Laboratory is a hands-on learning facility that fosters a "learning by doing" approach to engineering education. Popular among the engineering students who use the facility on a daily basis, the

laboratory is also home to a vast array of kinetic sculptures and exhibits, making it a highly-sought after venue for K-12 educators to bring their students to for field trips. The outreach component of ITL seeks to encourage greater numbers of those students typically underrepresented in the field of engineering — girls, students of color and first-generation college bound youth — to consider, and ultimately pursue, a career in engineering.



Figure 1. Captivated students enjoy the tectonic basin exhibit during a field trip to the ITL Laboratory.

We believe that the objectives of the ION education program are well aligned with this philosophy. Early testing of the navigation modules has shown that the activities are very popular with our college-level student testers, as well as the targeted middle school audience.

The following section describes the overall K-12 engineering curriculum initiative underway by the ITL outreach program, followed by an overview of the navigation modules.

INTEGRATED TEACHING AND LEARNING PROGRAM

The Integrated Teaching and Learning (ITL) program is committed to the integration of engineering principles and everyday life applications. Guided by the vision statement, “To create a K-16 learning community in which students, K-12 teachers and the College of Engineering and Applied Science explore, through hands-on doing, the role of engineering and innovation in everyday life. And, to appreciate and apply the art of engineering through designing and building solutions to meet the needs of society [1],” the ITL is dedicated to bringing engineering into the K-12 community. To provide elementary, middle, and high school students

with alternate career choices — and to guide them toward the engineering or technology pipeline — the ITL has developed an extensive K-12 outreach program to support classrooms and teachers in science, math and technology areas.

The ITL’s outreach program has many facets, including a popular “Engineering Fellows in the Classroom” initiative. Through a National Science Foundation (NSF)-funded project, engineering graduate and undergraduate students serve in K-12 classrooms to supplement existing science, math and technology curricula with hands-on engineering activities, serving as both engineering role models and instructors. These engineering Fellows act as “resource specialists” and work closely with classroom teachers to support what is already being taught in the classroom by applying a hands-on, engineering context to science and math activities.

In support of the classrooms project, the ITL team has developed an extensive cadre of engineering curricula for the K-12 classroom. The purpose of the curriculum is to develop concrete connections for K-12 students between science/math and their everyday life. The classroom-tested and affordable curricula help students understand that engineering is accessible and relevant to society. K-12 and engineering educators can use the curricular units as an engineering resource to promote learning and technological literacy, as well as to help expand the pool of students who come to imagine themselves pursuing a future in engineering and technology [2].

K-12 ENGINEERING CURRICULUM

To ensure that high-quality engineering curricular units are developed, the ITL outreach program has created a detailed and structured curriculum development and review process [3]. This process involves a myriad of curriculum partners and several key process steps.

The first step involves the development of a lesson plan and activity template. This template includes standard components used by teachers to develop an age-appropriate lesson that will be interesting and meaningful to their students. So that lesson plans would be easily integrated into the existing schema of lessons that teachers are presenting, we worked with local educators to ascertain which topics were currently being taught. National and state education standards were also used to ensure that the curricular topics are aligned with expectations at specific grade levels. Easily integrated curricula is more likely to be used in the classroom, not only by K-12 teachers but also by engineering faculty who wish to partner with their local schools through outreach programs. Curricular unit topics are selected through this process; each unit is comprised of 6-10

lesson plans that include one or more hands-on activities in each lesson.

The lesson plan and activity template includes many different components including, but not limited to: background information for teachers, introduction/motivation, anticipated student outcomes, educational standards met, lesson-related activities, lesson closure, assessment and resources. Lessons and activities may also include vocabulary, materials lists, activity attachments and worksheets, activity completion time, activity costs, troubleshooting tips, and pictures or diagrams of activity set up. Partner teachers in various school districts suggested inclusion of these components.

Engineering graduate students research and write within the constraints of the template, ultimately creating the full lesson plan and accompanying hands-on activities. Graduate students begin by researching the background information of the curricular unit topic and then fill in the components of the template using creative and imaginative ways to explain engineering content and engage the teachers and students. The engineering students also partner closely with K-12 teachers to determine age-appropriateness of the materials and to ensure that content within the lessons is readily understood by teachers. Graduate students also work within the boundary of national and state educational standards to discover age-targeted educational expectations germane to specific grade levels and topics.

Following the initial population of the lesson and activity templates, the curricular documents go through a lengthy review process that includes review of content completion, content accuracy, embedded assessment, activity comprehension, third-party activity testing, and math and literacy components. The ITL program engages engineering professors to provide critical feedback on the accuracy of the content, as well as engages assessment, math and literacy experts to review and correct those portions of the lesson. The activity is thoroughly reviewed and tested by teachers and graduate and undergraduate engineering students to determine if the activity procedure is easily understandable for students to follow the directions.

The K-12 engineering curriculum continues to evolve. All curricular units within the ITL outreach program's curriculum project are subject to suggestions resulting from in-classroom testing and teacher review. Lastly, the curriculum is reviewed for aesthetic formatting and copyright permissions necessary for distribution of the curriculum. The curricular units will eventually be distributed nationwide through another NSF-funded outreach initiative: *TeachEngineering.com* — an extensive, searchable, collection of K-12 engineering curricula available in late 2004 via the Internet through

the NSF-funded National Science Digital Library program.

NAVIGATION LESSONS

The navigation materials are designed to be useful for middle school educators and for individuals with experience in navigation interested in bringing their knowledge to students in an age-/grade-appropriate manner. Some of the lessons rely on concepts developed in earlier lessons, but generally, the lessons and activities are stand-alone — users can pick and choose lessons or individual activities that best suit their needs. For a description of the lessons and activities, see Table 1. With the exception of the *GPS on the Move* lesson, that uses hand-held GPS receivers, no specialized or expensive equipment is required. For this GPS lesson, we hope that local ION sections or manufacturers might provide technical assistance to interested educators and perhaps even provide GPS receivers on loan.

In the current climate of school accountability and standardized testing, teachers are pressed for time. Our experience is that teachers more readily adopt the engineering curricula when the materials contribute directly to identifiable math and science requirements. To that end, each Navigation lesson lists the standards met.

The lessons cover a broad range of navigation topics with several hands-on activities associated with each lesson. The basic lesson components are geared to an average 7th grade level, but suggestions for scaling to younger students and more advanced levels are included. Lesson and activity titles are designed to be fun and catch the interest of students.

Lesson 1: Where is Here?

The first lesson introduces some basic concepts of navigation, latitude, longitude, grids, maps, and the use of a compass. We ask students to think about how they navigate in both familiar and unfamiliar areas, contrasting landmark navigation with dead reckoning. A question is posed to the students: is a map all you need to navigate? (Answer: no, you also need a way to know where you are on the map.)

The hands-on activities include creating a grid in the classroom and constructing and using a magnetic compass. In the latter activity, the water-bowl compass is used to find the direction of north and to look for magnetic anomalies in the classroom (see Figure 2 below). The background material for the teacher includes an explanation of magnetic declination and an extension to the activity for more advanced students recommends that they investigate the difference between magnetic and true north.

Table 1. Summary of Middle School Navigation Lessons.

LESSON NAME	LESSON DESCRIPTION	ACTIVITY NAMES
Where is Here?	Covers the basics of Navigation, including the concepts of relative and absolute location, latitude, longitude, and cardinal directions, as well as the use and principles of a map and compass.	Nidy Gridy; Northward Ho!
How to be a Great Navigator!	Discusses the historical methods of navigation, including the concepts of dead reckoning and celestial navigation.	Vector Voyage; North Wall Star
Navigating by the Numbers	Demonstrates the importance of math in navigation by showing how ancient land and sea navigators started with the most basic navigation equations ($\text{Speed} \times \text{Time} = \text{Distance}$).	Stay in Shape; Trig River
Getting it Right!	Investigates error by introducing accuracy and precision and how computers can help in navigation.	Close Enough: Computer Accuracy; Sextant Solution
Topo Map Mania!	Focuses on how to read and use topographical maps. Students will also learn to use a compass to find bearing to an object on a map and in the classroom.	Where is Your Teacher?; The Trouble with Topos
Getting to the Point	Teaches how to determine location by triangulation and practice finding locations on a worksheet, in the classroom, and outdoors.	Classroom Triangles; Topo Triangulation; Topos, Compasses, and Triangles, Oh My!
By Land, Sea or Air	Demonstrates how navigational techniques change when people travel to different places, and explore different methods of navigation.	Nautical Navigation
Navigating at the Speed of Satellites	Investigates the basics of Global Positioning Systems (GPS), including trilateration and using the speed of light to calculate distances.	State Your Position; It's About Time
GPS on the Move	Discusses how to use a hand-held GPS receiver in a scavenger hunt to find nearby locations.	GPS Receiver Basics; GPS Art; GPS Scavenger Hunt
Not So Lost in Space	Describes the motion of planets and spacecraft in orbit about a central body and measurements made from Earth used to estimate spacecraft trajectories.	A Round-About Route to Mars Where is that Space Station?

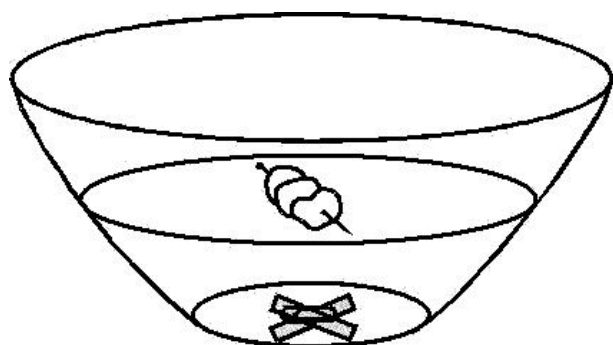


Figure 2. Lesson 1 - Making your own water bowl compass.

Lesson 2: How to be a Great Navigator!

Lesson 2 describes the process of dead reckoning and celestial navigation. The concept of dead reckoning is illustrated through an on-paper activity that traces a voyage across the ocean. Ship speed and travel time are given first and then adjustments are made for currents and winds. The second activity focuses on celestial navigation and the measurement of inclination of the North Star to determine latitude. We set up a picture in the classroom to represent the North Star and students construct a quadrant to measure its elevation. They explore how the measurements change at different places in the room.

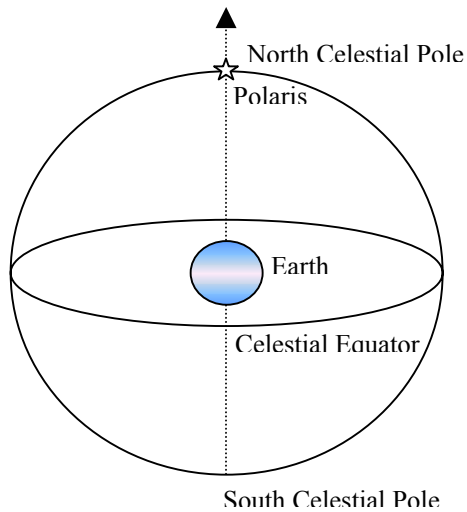


Figure 3. Lesson 2 – Concepts of Celestial Navigation.

Lesson 3: Navigating by the Numbers

In lesson 3, important concepts in geometry and trigonometry are introduced as they relate to the earth and navigation on its surface. Examples of the different types of triangles are given and formulas for areas and lengths of a side are given. The first of the two activities provides practice in determining distances on a plane and also introduces the concept of distance on a sphere, illustrating the need to account for curvature when the distance covered is large. In the second activity, the power of trigonometry is introduced by using angle and distance measurements to estimate the width of a river without actually crossing it.

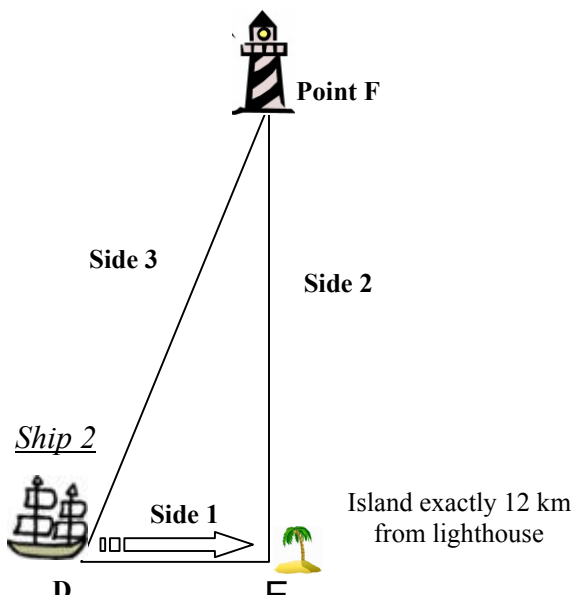


Figure 4. Lesson 3 - Stay in Shape.

Lesson 4: Getting it Right

Lesson 4 discusses sources of error in measurements and how these limit navigation accuracy and precision. The first activity, “Close Enough” focuses specifically on the contrast between precision and accuracy. Students investigate the effect of angle errors through a worksheet and a physical exercise in the gym. The other two activities are computer-based. We encourage the teacher to discuss with students the usefulness of computers and their limitations in contrast to hand calculations. The first computer activity uses an MS Excel spreadsheet with a “Find the mystery island” challenge, and “Rocket to the Moon.” The final exercise illustrates the use of sextant measurements and shows how a computer can be used to apply corrections for vehicle tilt and atmospheric refraction. On the whole, the purpose of this lesson (and many of the others) is to give students concrete examples of the importance of mathematical concepts in navigation and in everyday life.

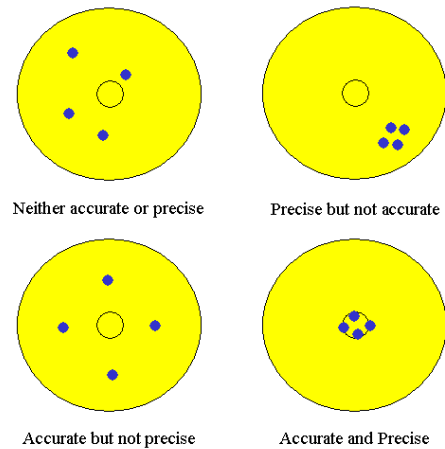


Figure 5. Lesson 4 - Comparison of Accuracy and Precision

Lesson 5: Topo Map Mania!

Lesson 5 teaches students how to read and use topographical maps and how to take a bearing with a magnetic compass. In the first activity, students practice using an orienteering compass in their classroom. They work together and in small groups to measure bearing to several objects and then work backwards to identify objects specified by the bearing measurements made by their classmates. The second activity introduces basic topographic map features such as scale, symbols, and contour lines. Several worksheets associated with this activity allow students to interpret the contour lines and match up a topo map with an associated hill or valley profile and a picture. For example, the images in Figure 6 show the topo map section and photograph of Crater

Lake. At the end of the lesson, the use of topographical features in landmark navigation is discussed.

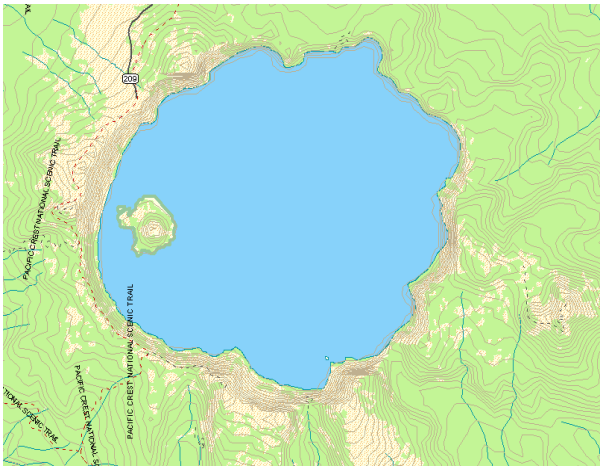


Figure 6. Lesson 5 - Contour map and photo of Crater Lake [4].

Lesson 6: Getting to the Point

In lesson 6, students learn the basics of positioning by triangulation through three hands-on activities. The details of drawing bearing lines on a map and making adjustments for magnetic declination are presented. The first of three activities, “Classroom Triangles,” has students practice using a compass to make bearing measurements in the classroom. Instructions are given on drawing a bearing line on a grid of the classroom and using intersecting bearing lines to locate an object.

The second activity is a written exercise in which students use a topo map and navigational clues to solve a mystery. The final activity for the lesson provides guidance for outdoor triangulation using a compass and topo map.

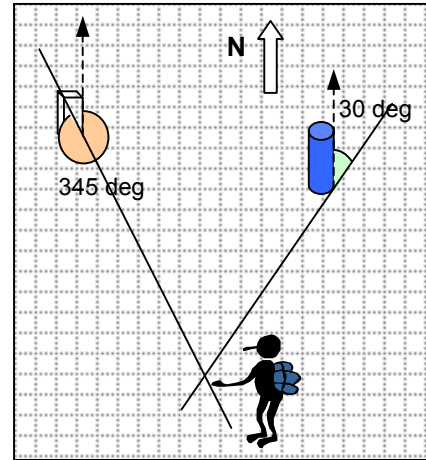


Figure 7. Lesson 6 - Illustration of triangulation.

Lesson 7: By Land, Sea, or Air

Lesson 7 contrasts the types of maps and navigation methods used for land, sea, and air navigation. Examples of nautical and aeronautical charts are shown with explanations of the markings such as shorelines, beacons, depth markers, and routes. The hands-on activity involves reading a nautical chart to plan a harbor approach and creating your own chart to guide ships to a new island.

Lesson 8: Navigating at the Speed of Satellites

Lesson 8 describes the history and basic principles of operation of the Global Positioning System. The two activities center on the most fundamental concepts of positioning by trilateration and range determination by signal timing. To illustrate positioning by trilateration, we use the explanation shown in Figure 8. In the first activity, students complete a 2-D example by graphically solving for position with several range measurements given. The second activity explores how range to a satellite is measured by timing signal travel time. This is in fact a very ACTIVE activity, in which students run to simulate the signal traveling from the transmitter to receiver. Multiplying the travel time by the calibrated student speed, the distance is computed. The lesson also provides links to excellent online resources for GPS information.

Lesson 9: GPS on the Move

In lesson 9, students learn how to navigate using a hand-held GPS receiver. It builds upon the understanding of GPS principles developed in Lesson 8 and extends them to practical navigation with a hand-held device. This lesson deviates a bit from the general K-12 curriculum philosophy because it requires the students to have access to hand-held GPS receivers. Much of the technology may also be somewhat intimidating to teachers, so we see this

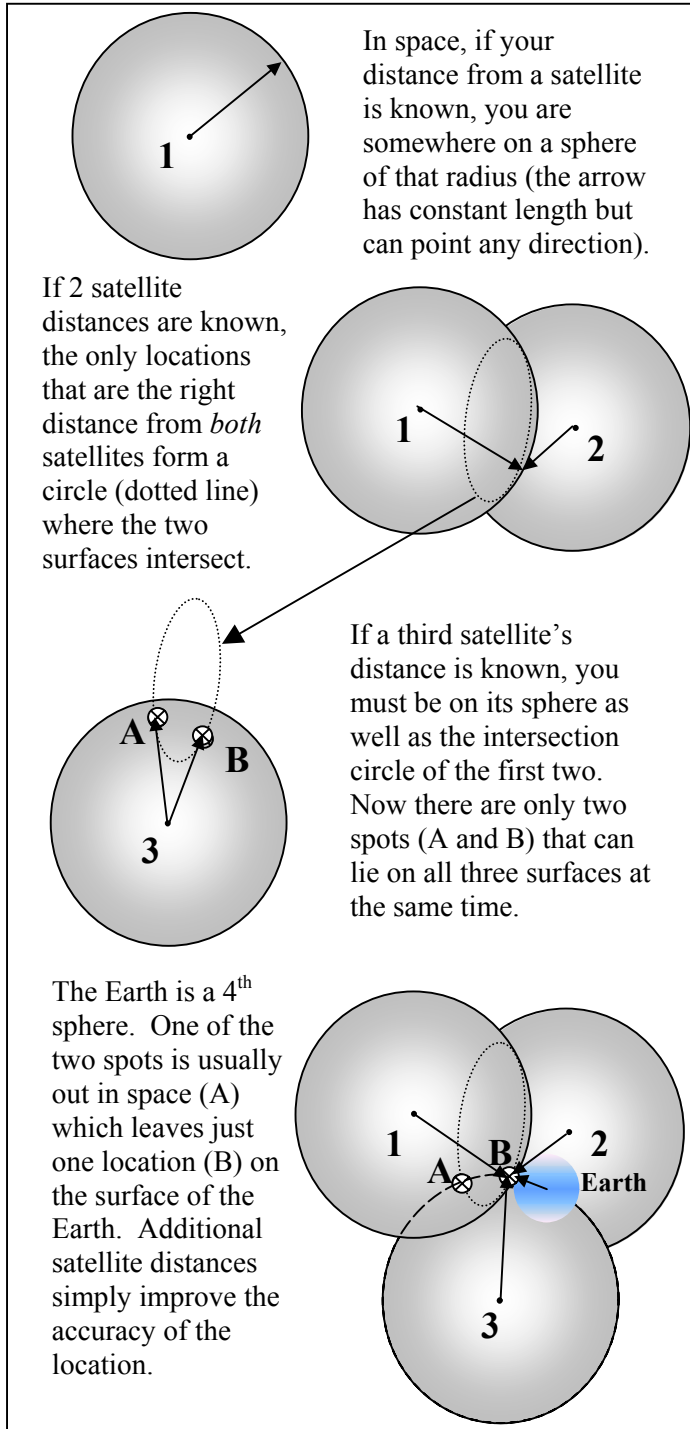


Figure 8. Lesson 8 - Illustration of trilateration.

activity as one that is particularly conducive to ION membership involvement. ION local sections, companies, or individuals could work with schools and teachers in their area to obtain a set of equipment together

and work with the teachers and students to become familiar with the equipment.

The lesson provides some general guidelines on the use of a hand-held receiver to supplement the instructions that come with any such device. There are three activities designed to explore the capabilities and limitations of GPS and to encourage the students' creativity and interest. "GPS Receiver Basics" shows how to enter and travel to waypoints, and to perform other basic navigation functions with GPS. "GPS Art" asks the students to use the tracking function to map out a picture or message, and the final activity requires a teacher or other advisor to construct a scavenger hunt or geocaching goal for students to find using their GPS expertise.



Figure 9. Lesson 9 – CU Graduate student working with middle school student on GPS activity.

Lesson 10: Not So Lost in Space

The final lesson explores navigation and positioning beyond earth. Specifically, we concentrate on describing orbital motions including transfer orbits, and take a real look at the currently orbiting international space station. The first activity uses manipulatives — tacks and string in a piece of cardboard — to illustrate motion in an ellipse and show how an elliptical transfer orbit connects two low and high circular planetary orbits. The second activity relies on the Internet to provide information on visibility of the International Space Station. Based on the data they collect online, students construct a model of the station motion overhead. They are also encouraged to use the information to schedule a night outing to view the station.

FUTURE PLANS

We are grateful to the ION Satellite Division for the funding to support the initial development of the navigation curricula. We believe that they will add an exciting component to science and engineering education for middle school students, and we hope that their use will become widespread. We also hope that the materials developed will provide ION members with the tools necessary to become more involved in education in their local communities, by connecting with young people and helping them become acquainted with a truly fascinating field.

The materials will be hosted on the ION website for easy access and will be readily downloadable by ION members and the general public. We expect to hear from educators and members with comments, suggestions, and reports from the field. Hopefully, the ION will continue to expand the resources that it supplies to the community. In addition, we expect to include the navigation modules in the NSF-funded *TeachEngineering* digital library under development at CU in collaboration with Worcester Polytechnic Institute, Colorado School of Mines, Duke University, Oregon State University and the American Society of Engineering Education.

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Crater Lake image source:
<http://tapestry.usgs.gov/features/30craterlake.html>