

COMPOSITES WORKFORCE, THE NEXT GENERATION OUTREACH THROUGH THE COMPOSITE MATERIALS MERIT BADGE

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ABSTRACT

Numerous industry reports show the need for more composite materials experts, both engineers and technicians, and recommend outreach to K-12 education. The Composite Materials Merit Badge from the Boy Scouts of America provides an opportunity to reach that future workforce. The merit badge provides an overview of composites including safety hazards, types of composites, resins and fibers, material properties, applications, a facility tour, and various careers. Two projects are required, one from the book and one that could be a neckerchief slide, hiking staff, or canoe paddle. 11-17 year old youth can use the merit badge to develop an interest leading to a career.

A major challenge to reach these youth is a lack of counselors to teach the merit badge. In 2017, composite materials was 130th out of 137 for the number of Scouts earning the merit badge. Scouting recognizes this is a barrier. However, becoming a counselor is straightforward. The merit badge provides a ready-made package to reach highly motivated students that can be recruited in the future. Scouting also provides a youth protection policy and training that companies can use to protect both the youth, the counselor and the organization.

1. INTRODUCTION

Growth in the composites industry requires new trained professionals, including engineers, scientists and technicians. Outreach to youth is recommended to encourage them to pursue a career in composites. This outreach also provides the industry with an opportunity to recruit Eagle Scouts and other highly motivated youth that will bring desirable skills to the workforce.

The Composite Materials Merit Badge from the Boy Scouts of America (BSA) provides an established curriculum and avenue to reach youth. It broadly introduces composite technologies, especially through projects and tours. Projects demonstrate various technologies to make a composite part that is interesting to a Scout. It also includes careers that are available in the industry for both engineers and technicians.

The challenge with offering the Composite Materials Merit Badge is a lack of trained counselors. It is easy to become a counselor, and BSA provides ways to reach these youth. A summary of how to become a counselor and set up a course will be discussed.

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2. THE NEED FOR MORE TRAINED COMPOSITE PROFESSIONALS

2.1 Trained Professionals

It is well known that the composites industry needs more trained professionals, both on the engineering and scientist side as well as the technician side. This not only applies to traditional composite industries like aerospace but newer markets like infrastructure.

Sheridan, et al, examined composites' future in infrastructure, and concluded that "There is an overall lack of education and familiarity with FRP [fiber-reinforced plastics] composites." [1]

Sheridan, et al, adds "On a related note, the group concurred that the infrastructure workforce needed to be trained on FRP composites-specific aspects such as handling, installation (including interfacing with tradition construction materials), storage, inspection, safety, and maintenance." [1]

Milberg notes that the composites industry needs not just new workers but also replacements for an aging workforce. He writes that the Institute for Advanced Composites Manufacturing Innovation (IACMI) "projects that more than half a million workers will need to be replaced in the next 10 years." [2]

2.2 K-12 Outreach

The Facilitating Industry by Engineering, Roadmapping and Science (FIBERS) consortium looked at industry needs and not only reached the conclusion that more professionals are needed, but also that outreach needs to be in K-12 education:

The most significant logistical barrier to growth of the US composites manufacturing industry is workforce development. The future of composites manufacturing is one in which new college graduates enter the workforce with a broad, relevant and up-to-date knowledge of composites manufacturing methods and materials. Efforts must be pursued to inform K-12 students about the role of composites in society and career opportunities. [3]

Currently, high school graduates enter the workforce or college unaware of composites manufacturing as a career. Education and training programs may not be tailored to match regional industry requirements, despite a significant fraction of workers remaining geographically local to their respective educational institution. No national standards or accreditation body exists for the industry, which hinders consistent education standards and transfer of skills between composites companies. Efforts must be pursued to inform K-12 students about the roles of composites in society, e.g. high-performance cars and architecture, and career opportunities. [3]

The FIBERS report goes on to explain that "Minimal exposure to the concept of composites leads to poor name recognition among students in subsequent education and career options" [3] and the industry needs to "Recruit high school students to composites career paths." [3]

The Composite Materials Merit Badge is ideal to address these issues. It is a national standard curriculum targeted towards 11 to 17 year old youth. It is an overview of the technology that

introduces youth to composite materials, their history, fabrication, and applications. Scouts and their parents are interested in the merit badge specifically for potential Science, Technology, Engineering, and Math (STEM) careers. The merit badge lends itself to older Scouts. These Scouts will be making career choices in a few years and could enter the workforce in 5-10 years.

3. MERIT BADGE REQUIREMENTS

Composite Materials [4] contains the information to meet the requirements for the merit badge. The information in *Composite Materials* was developed with the assistance of the American Composites Manufacturers Association (ACMA). Each Scout must complete two projects, and tour a composite facility or visit several websites.

Merit badge counselor training emphasizes that when a requirement states to describe, explain, discuss or demonstrate, the Scout must do exactly that. Therefore, working with a Scout is less about the counselor teaching the Scout and more about the Scout telling the counselor what he or she has learned. Just attending the course does not earn the merit badge. Scouts must show they have a basic understanding of the subject. Counselors also cannot add or subtract any requirements.

When offering a course at a merit badge day, for example, it is recommended that the Scouts read the merit badge book prior to the course and write down answers to the questions. The Scout will be better prepared to answer the questions when asked. A merit badge worksheet is available for this purpose: https://meritbadge.org/wiki/images/e/e5/Composite_Materials.pdf

Scouts are only expected to know the material from the merit badge book to answer these questions except where it requires, like requirement 4.b, to research outside sources and discuss what the Scout learned.

Only the requirements completed in the course can be signed off by the counselor. If additional time is needed to complete the tour, the second project, or any work the Scout did not complete, extra meetings can be scheduled at a convenient time. For example, one recent session offered tours of the NASA Marshall Space Flight Center lab and then used a conference room for the Scouts to go over their material safety data sheet (MSDS) research and complete their second project.

The remainder of this section discusses the specific requirements a Scout must complete to earn the merit badge.

3.1 Requirement #1, Safety Hazards and Precautions.

1. Do the following:

- a. Explain to your counselor the most likely hazards you may encounter while working with composite materials and what you should do to anticipate, mitigate and prevent, and respond to these hazards. Describe the appropriate safety gear and clothing that should be used when working with composite materials. [4]

- b. Explain the precautions that must be taken when handling, storing, and disposing of resins, reinforcements, and other materials used in composites. Include in your discussion the importance of health, safety, and environmental responsibility and awareness. [4]
- c. Describe what a material safety data sheet (MSDS) is and tell why it is used. [4]

Explaining hazards is a common requirement for merit badges, whether it is composite materials, cooking or backpacking. This requirement also helps the Scouts understand the hazards they might encounter in the hands-on projects, and how to mitigate them.

3.2 Requirement #2, Composite Materials Definitions and Properties

2. Do the following:

- a. Explain what composite materials are. Include a brief history of composites and how they have developed. [4]
- b. Compare the similarities and differences between composites and wood, aluminum, copper, and steel. Describe the physical, electrical, mechanical, corrosive, flammability, cost, and other such properties. For each of these raw materials, give one example of how it can be shaped and used for a specific application. [4]

Composite Materials provides an overall comparison of various composite properties compared to steel, aluminum, copper and wood. This is where the merit badge counselor's experience can provide useful examples of material properties tied to real-life applications. Properties include specific strength, weight, impact durability, corrosion resistance, conductivity, magnetism, radar transparency, thermal conductivity and others. The book provides a short history back to antiquity. Applications cover the gamut from aircraft and space to sporting goods, musical instruments, and buildings. [4]

3.3 Requirement #3, Fiber and Resin Characteristics and Applications

3. Describe how composite materials are made. Then do the following: [4]

- a. Discuss three different composite reinforcement materials, their positive and negative characteristics, and their uses. Obtain the MSDS for each one and discuss the toxicity, disposal, and safe-handling sections for these materials. [4]
- b. Discuss three different resins used in composites, their positive and negative characteristics, and their uses. Obtain the MSDS for each one and discuss the toxicity, disposal, and safe-handling sections for these materials. Include thermoset resins and thermoplastic resins in your discussion. [4]
- c. For each of the three resins you chose for requirement 3b, think of a new application that might be worth developing. [4]

Scouts need to research the MSDS for both fibers and resins before taking a class. Registration documents can specify types of material to narrow down the search for the MSDS. For example, Scouts research two fiber MSDS, for example a fiberglass and aramid, and two resin MSDS,

polyester and vinyl ester. The third set of MSDS is provided for the carbon fiber and epoxy resin used in the in-class project. Scouts are expected to answer the questions on toxicity, disposal and storage for all 3 fiber and all 3 resin MSDS.

Scouts should also be told to come up with their resin applications in registration documents. That way they come to the course ready to answer and the counselor can sign off that they completed this requirement. A common answer from Scouts is a smartphone case.

3.4 Requirement #4, Facility Tour or Web Search

4. With your parent's permission and your counselor's approval, do ONE of the following: [4]
 - a. Visit a company that manufactures or repairs products made with composites. Discuss what you learn with your counselor. [4]
 - b. Find three composites-related websites. Share and discuss what you learn with your counselor. [4]

Ideally Scouts will have an opportunity to visit a manufacturing or repair facility. It does not matter what types of composites are being manufactured. It can be a production or a research and development facility. A visit to a marina to see how fiberglass boats are repaired meets this requirement.

Figure 1 shows Scouts visiting the NASA Marshall Spaceflight Center (MSFC) Composites Technologies Center in Huntsville, AL. They saw the large fiber placement robot NASA uses to develop launch vehicles and the autoclaves used to cure large parts.



Figure 1. Scouts Visit the MSFC Composites Lab

Some Scouts may not live near a facility or do not have the time or transportation for a tour. In this case, reviewing several composites websites meets this requirement. Scouts are required to discuss with their counselor what they learned, so this may need to occur via email so the counselor has an opportunity to review the websites and ask questions.

3.5 Requirement #5, Projects

5. Do the following: [4]

3.5.1 Requirement 5.a, Project Requirements

- a. Use composite materials to complete two projects, at least one of which must come from the Composite Materials merit badge pamphlet. The second project may come from the pamphlet OR may be one you select on your own that has been approved by your counselor in advance. [4]

The two projects in the merit badge book are laminating tissue paper onto a foam glider using white school glue, and laminating fiberglass with polyester on cardboard to make a bird house. [4]

While the requirement states for the Scout to agree with the counselor on a project, that is only possible if the Scout is working independently. For group activities such as merit badge academies, the counselor must choose a project ahead of time to prepare the necessary materials.

Laminating tissue paper using glue on a glide might seem simple, but it is a very useful project. Tissue paper does not conform well to the complex contours of the glider.

The birdhouse project is a good option to illustrate the wet layup process, particularly if facilities such as autoclave or hot bonder are not available. The composite materials used (fiberglass fabric and polyester resin) are readily available.

The second project can be anything. One potential project is using the wet layup process for helicopter repair to laminate twill weave carbon fabric into a neckerchief slides. Twill weave is used at a 45 degree orientation specifically for the look, Figure 2. The process is simplified for the Scouts. For example, the Scouts do not have to do part A and part B resin calculations.

Some research was needed to develop the resin to fiber ratio of the wet layup resins, EA9396 and EA9313, and bleed schedule to make sure the slides looked nice. 25 grams of resin was applied to 1 square foot of 284 twill weave carbon fabric. Scouts cut out four two inch diameter circular plies and laid them up at [45/0]s. The bleed schedule was a layer of porous Teflon, a layer of P3 release film and a layer of 120 fiberglass. EA9396 was vacuum bagged and cured at 160 ± 10 °F for one hour. EA9313 was cured at 150 ± 10 °F for one hour. Scouts laid up their individual slides and placed them on the release film covered cure plate for vacuum bagging. A hot bonder and heater blanket were used for cure. To finish the project, the edges were sanded off and a ½ inch piece of PVC pipe was hot glued to the back. A tubular layup is feasible if an appropriate tool can be fabricated to lay up around.



Figure 2. Carbon Fiber Neckerchief Slide

Others do a group project building a canoe and paddles, Figure 3. [5] [6]



Figure 3. Composite Canoe [6]

One course laminated a braided carbon/aramid sleeve into a hiking staff, Figure 4. [7]



Figure 4. Braided Carbon Aramid Hiking Staff [7]

Another built carbon fiber bridges, Figure 5. [8]



Figure 5. Composite Bridge [8]

The key is having a project that will interest a Scout and also demonstrate key materials and processes. The neckerchief slides and hiking staffs also promote the merit badge as other Scouts see what can be made from composites and how they are used in Scouting. Other Scout projects that could be made out of composites might include a chuck box, a cooking tripod, tent poles, or a flagpole. One pair of Scouts used a fiberglass repair kit to mend their father's hard-sided suitcase that had been damaged while traveling.

3.5.2 Requirement 5.b, Project Facilities

- b. With your counselor's assistance, find an appropriate site where the projects can be safely completed under your counselor's supervision and/or the supervision of an adult approved by your counselor who is knowledgeable about composites. [4]

In many cases the Scout will have little to no say in the facility used for the merit badge. It will most often be at a school or a church at a merit badge day. The merit badge book recommends doing the projects outside, which might be necessary if using polyester resins.

In the case where the facility has been chosen for the Scout, ask instead why that facility is acceptable in terms of temperature, humidity, cleanliness, and safety considerations (fresh air, away from food areas, etc.).

If the class is offered at summer camp or is done outside, ensure the temperatures are such that the resins do not gel too fast, or require the course be taught in an air conditioned room.

If using a classroom, make sure that the host facility is OK with laying up composites. Bring extra tablecloths or similar (vacuum bagging film works just fine) to cover tables and floors. Scouts might use too much glue for the glider project, so have a place where the gliders can dry.

3.5.3 Requirement 5.c, Evaluation Criteria

- c. With your counselor, determine how the finished projects will be evaluated. Using those guidelines, evaluate the completed projects with your counselor. [4]

The Scouts need to help come up with the criteria, but counselors should be prepared with some suggestions ahead of time.

For the tissue paper gliders, the book defines the first criterion as complete coverage. This evaluation is easier if the Scouts use colored tissue paper on the white glider. Additional criteria may include how smooth the finished project is, how heavy is it, how much material was used, and how long it took.

For the neckerchief slides, criteria include the number of plies, ply orientations, backing films accounted for, voids/porosity, and achieving the correct cure cycle time and temperature.

3.6 Requirement #6, Careers

6. Find out about three career opportunities in composite materials. Pick one and find out the education, training, and experience required for this profession. Discuss this with your counselor, and explain why this profession might interest you. [4]

Careers covered in the book range from the chemist and chemical technician to all varieties of engineering including materials, manufacturing, structural and certification. It also includes manufacturing and repair technicians as well.

These youth may choose colleges and pursue an engineering degree based on their experience with this merit badge. It would be advantageous for college professors and graduate students to look at offering the merit badge as a recruiting opportunity for their departments. Adults 21 or older can apply to be counselors.

In the future, the Scouts may also get certified as a technician and support manufacturing or repair activities. They may enlist in the military and become structural repairers. Community colleges offering technician certification can reach potential students by offering this merit

badge. Both Tarrant County Community College in Ft Worth TX and National Center for Aviation Training in Wichita KS offer the merit badge.

What part of the composites industry would not benefit from being able to recruit Eagle Scouts? The traits of an Eagle Scout include leadership, perseverance, discipline, and service to others. One study found that Eagle Scouts are 39% more likely than other Scouts, and 55% more likely than non-Scouts, to hold a leadership position in their workplace. [9] Many presidents, astronauts and CEOs have earned the rank of Eagle Scout.

4. BECOMING A COUNSELOR AND SETTING UP A COURSE

For Scouts to earn the merit badge, counselors must be available to offer it. Counselors with direct experience in composites make the subject matter more interesting and attractive.

BSA requires some experience in the subject and the counselor must be at least 21 years old. Engineers, scientists, technicians, professors, and graduate students all could qualify to be counselors.

4.1 The Lack of Composite Merit Badge Counselors

Figure 6 shows the number of composite materials merit badges earned over the last 5 years.

Composite materials is one of the least earned merit badges, 130th out of 137 merit badges in 2017. Only 1500 to 2000 Scouts earn it each year. Why? Most Scout troops do not have access to a composite materials merit badge counselor. [10]

In 2017, by comparison, 30,000 Scouts earned the Wood Carving merit badge, and nearly 70,000 Scouts earned the First Aid merit badge. [11]

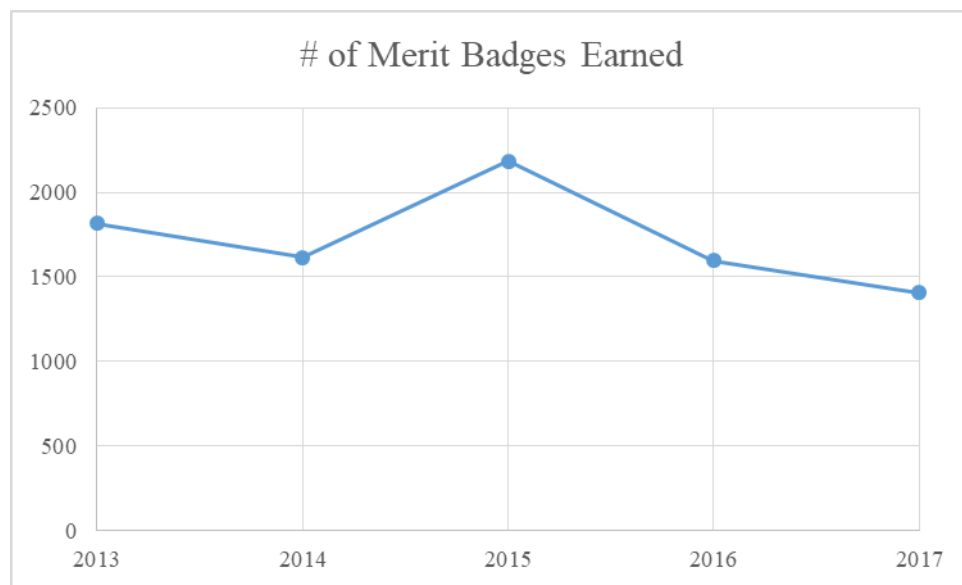


Figure 6. Number of Composite Materials Merit Badges Earned

4.2 Counselor Registration

BSA wants to attract merit badge counselors, so registration for merit badge counselors is free. You can get started by finding your local BSA council to work with, taking training, and registering as an adult leader. Your employer may have additional requirements.

4.2.1 Locate Your Local BSA Council

BSA is divided into 272 local councils that implement the merit badge program for the Scouts in that area. Registering as a merit badge counselor must be through each council. In metropolitan areas, several councils may cover the entire area. Each council is broken up into districts that are one source for finding opportunities to teach the merit badge.

To find a council in your area to register with, use the council locator function on BSA's website.

<https://www.scouting.org/discover/local-council-locator/>

4.2.2 Take Youth Protection Training

BSA will not even take your application to be a merit badge counselor unless you have completed Youth Protection Training and provide your certificate.

<https://my.scouting.org/>

<https://www.scouting.org/training/youth-protection/>

A couple of principles protect both the Scouts and the counselor working with them. Each Scout working on a merit badge must have a buddy with them. That can be either another Scout, a parent or other adult. This prevents any one on one contact that youth protection prohibits. Another layer of safety is two deep leadership, where two adults need to be present when working with the Scouts.

Youth protection training not only protects the counselor, but also the business that hosts the merit badge, by providing an established framework to protect the safety of the Scouts.

4.2.3 Take Merit Badge Counselor Training

Merit badge counselor training covers how to administer the merit badges and record work completed by the Scouts. Check with you local council or district for opportunities, or take online at my.scouting.org.

4.2.4 Register as an Adult Leader

Submit an adult application, form 524-501, with proof of Youth Protection Training. BSA will do a background check. You must also submit a Merit Badge Counselor application:

<https://www.scouting.org/programs/boy-scouts/mb-counselor-guide/>

4.2.5 Coordinate with Your Employer

Employers may have additional requirements before allowing employees to work with minor children. Company background checks, registration and reporting may all be required, especially if your employer will be providing facilities for a tour or meeting.

4.3 Organizing a Course

BSA has numerous ways to offer a course that require minimal investment by the counselor. This allows for maximum publicity. If a counselor wants to offer the merit badge to an individual unit or several Scouts, that also feasible.

It is acceptable to require the Scouts to come prepared having read the merit badge book beforehand. They also can write up answers to the questions, research fiber and resin MSDS, come up with new applications for each resin, and be ready to answer the questions. The more preparation work the Scouts do before the class, the faster the counselor can go through material and discuss with them. Merit badge counselor training will emphasize that when a requirement states to describe, discuss or explain, the Scout must do exactly that, even if it is over email.

4.3.1 District Merit Badge Days

Contact your local BSA office to see when districts have merit badge days. These make it easier since advertising and registration is provided by the organizers rather than the counselors. These can take place at your facility.

The amount of material covered can be tailored to how much time is allowed at a merit badge academy. In a half day course, one of the two projects and most of the classroom work can be covered. If a full day is available, both projects can be completed. If it is at a manufacturing or repair facility, the tour can be included.

4.3.2 STEM Academies

Some councils hold a weekend campout offering STEM related merit badges. Greater Alabama Council organizes the Jedi Academy campout at a local Scout camp just to cover STEM merit badges.

4.3.3 Summer Camp

If you have time to spend part of the summer at a local BSA camp, you can offer the merit badge to a large number of Scouts. One limitation at summer camp is it is not possible to do a tour.

4.3.4 National Jamboree

If a group of counselors has the time and ability to travel to the BSA National Jamboree, an opportunity to offer the merit badge to a large number of Scouts is possible. The National Jamboree is held every four years in late July, at the Summit Bechtel Family National Scout Reserve in West Virginia.

4.3.5 Advertising a Course

If you still need an avenue to reach Scouts and their units, first talk to your friends and coworkers. They might already be involved in Scouting and can point you to units that might be interested in offering a course.

You can also reach out to the districts in your area and distribute information about your capabilities through email distribution or the monthly district roundtable meeting.

4.4 Other Considerations

4.4.1 Activity Consent Form

Working with composite resins involves using hazardous materials. BSA has an activity consent form that allows parents to permit their Scouts to participate.

<https://filestore.scouting.org/filestore/pdf/19-673.pdf>

4.4.2 Clothing

Wearing the dress “Field” uniform is typical at merit badge academies and looks great for pictures. However, since the projects use wet layup resins, Scouts should wear an “Activity” t-shirt while working on the project so they do not ruin their dress uniform shirt. Registration documents also need to detail any clothing requirements for the facility, such as closed toe shoes.

Counselors need to plan to provide safety glasses (including some that fit over glasses), gloves and aprons. A variety of glove sizes is need not only for the youth but also the adults that will be helping out. Work arounds may be necessary for a Scout that has a broken finger or hand. Remember the Scout motto is “Be Prepared.” That goes for counselors too.

4.4.3 Photographic Release Form

Counselors and their employer may want to photograph the course for promotional opportunities. BSA has a talent release form for parents to sign granting permission to use pictures of their Scouts. Double check with a facility, such as factories or laboratories, that it is permissible to photograph the class.

<https://filestore.scouting.org/filestore/marketing/doc/talent.doc>

4.4.4 Fee

It is permissible to charge a small fee, such as \$10, to cover supplies used in the course, like the foam gliders or carbon fabric for projects.

However, donations of expired or excess materials are much more desirable. A Scout is Thrifty and looks for ways to reduce the costs. However, US government employees may not be able to accept donated materials due to ethics regulations. Check with your employer on any rules for donated materials.

4.4.5 Supplies

If offering the course at a classroom at a school or religious institution, be prepared to take all supplies to complete the projects, especially curing equipment. It is advantageous if Scouts get to see standard equipment such as autoclaves and hot bonders in the course. If new curing equipment is needed for project #2, such as keeping hiking staffs vertical during cure, plan accordingly. [7]

Since time is of the essence during a class, precut as much of the materials as possible.

Limiting the number of Scouts allowed to take the class is also permissible if there are a limited number of counselors, equipment or supplies.

5. SUMMARY

The need for more composite professionals, engineers, scientists and technicians is well known. The industry is recognizing that outreach to K-12 youth is needed to generate interest in composites as a career. The BSA composite materials merit badge is one way of reaching youth that provides a standardized program to introduce the technology.

The merit badge covers health and safety considerations, including a MSDS. Scouts compare properties of composites with other materials and explore different types of composites resins and fibers. They must research MSDS and explain the toxicity, handling and disposal requirements for fibers and resins. Scouts are to tour a manufacturing or repair facility and learn about careers in the industry. Scouts also must complete two projects that demonstrate composite considerations.

To reach these Scouts, more merit badge counselors are needed. This merit badge is not earned very often due to the lack of composite professionals to teach it. The process to become a counselor, including youth protection training and registration with a council is detailed. As is how to set up a course and schedule it through opportunities like merit badge days.

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