2019-2020 BOARD

CVHS GUIDE TO SCIENCE FAIR

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step-by-step guide

Learn how to complete a successful project from start to finish

general tips

Read tips and advice from our own experiences

extra resources

View additional resources to get you started

A note from us

Hello! If you're reading this, you're most likely interested in competing in Science Fair at Centreville High School. The purpose of this guide is to increase the competitiveness and quality of projects from CVHS competing in the Fairfax County Regional Science and Engineering fair, and is open to ALL students competing in science fair in any manner or category! By no means is the material contained in this document the "ultimate way to win", but rather what we've learned from competing in science fairs for two years, viewing other's projects, and speaking with judges. Our qualifications to give such advice are as follows: collectively, those writing and endorsing this resource have completed 7 total projects, with 6 regionals 1st place wins, 3 regionals organization awards, 2 state top 3 category placements, 3 regionals grand prize nominations, 2 regionals grand prize alternates, and 1 regionals grand prize winner and ISEF finalist over two years, in addition to participation in numerous scientific research and outreach programs. We'll include a step-by-step guide of our recommendations on how to complete a science fair project start to finish, general tips for science fair projects and judging, much-needed resources, considerations for now-popular machine learning projects, and advice for working with students and professors alike. No matter if you're conducting your project in a lab, at home, or at school, this guide contains information that will help take your project to the next level.

Step-by-Step Guide

Step 1: Gain Perspective

It's very important to understand the environment in which you'll be competing. Start by understanding the type of projects that perform well, the trends in the categories you're looking to compete in, and the quality of projects at the Fairfax County Regional Science Fair. Our area is extremely competitive in science fair, so it's best to recognize this by viewing winning projects from past regional fairs. Almost every year, Fairfax and NoVA in general tend to produce ISEF placers in every category. To explore past projects, especially winning ones, from the past two FCPS fairs, you can do so here. If you're shooting for a grand prize nomination, you'll likely be competing against past ISEF finalists. Luckily, every ISEF project can be found in the ISEF Project Database. Here, you can view the best science fair projects from around the world for inspiration and perspective on winning projects. Keep in mind, however, that the quality of projects that qualify for ISEF depends on where the regional fair was conducted. Be aware that projects from FCPS tend to be much more complex than many ISEF projects from other areas simply because we have access to many more resources than other countries and states. You'll also find that most successful ISEF projects, although not as complex as from wealthier areas, address or solve local issues and make a large impact on the surrounding communities.

NOTE: steps 2 and 3 may be done in reverse order depending on whether you value the methodology or application of your project more.

Step 2: Identify a Topic of Study

Now that you have an idea on what you'll be up against, there are two ways to do this. Try to find an issue you'd like to solve or contribute to. Issues which relate personally to yourself or your community are typically more suited for science fair projects; not only is it more fulfilling to contribute to a passion, but the judges like it as well. Global issues and challenges, such as climate change, biomedical issues, clean water, etc, are also very popular, but only with meaningful contributions. If you try to stretch the applications of your project ("By playing music to plants as they grow, I will solve global warming"), it is quite obvious you are doing so and that was not your main goal. Being honest with how your project will affect the world is the best way to do well. You may also speak to other professionals, professors, researchers, and teachers about science issues they foresee in the future for more inspiration in tandem with looking at past science fair projects to identify what you want to address. Finally, make sure the topic interests you! You will lose passion extremely fast if the problem you want to contribute to doesn't keep you intrigued throughout your project, and it will show in your effort and final product. Also, try to find inspiration from your classes. Oftentimes, you run into areas where you can be a contributor because some research problems are not understood as well. The best research projects are those that either pertain to you on a personal level, or topics you have had an academic interest in for a long time.

Step 3: Identify how you will address the issue: the science.

If the impact of your project is Mars, the methodology is the rocket that gets you there. You'll be spending most of your time completing your project with your chosen method. By method, we mean the science behind your project. Will you use a biochemical pathway? Machine learning? Develop a new workflow to biofortify crops? Figuring out the science behind your project is the most important part of it, and it's the part that judges especially love to talk to you about (they're experts in the field). There are four ways to do this:

- **Reading the literature.** The more you keep up with current science, the better. Always be on the lookout for new or underdeveloped science that you can expand upon in your project. Some articles may be dense, but make sure to thoroughly understand the science and the methodology behind the paper you're reading. When formulating an idea for your project, save all the papers from which you're drawing inspiration for materials, methods, results, and references once you begin your experimentation. It is also a good idea to annotate any papers that are crucial to your topic to gain a better understanding. You can always look up papers in a certain area on Google, but other great places to start are NCBI Literature, Nature Articles, ResearchGate, and Google Scholar. For math/physics papers, almost all can be found on arXiv (also some other fields use this archive often. It consists of "preprints" or papers which are not yet published in a journal, but essentially carry the same idea and will help you in your research project). If you find an abstract that you like but can't get access to the paper for some reason: email the authors! They are in most cases more than willing to share their paper if you ask nicely. You can also use a program, like Kopernio, that can search for a free copy of the article on another website. If you are dual-enrolled with GMU (Multi/Lin Alg.) you can use your GMU issued email to go onto their online database and browse hundreds of thousands of resources from textbooks to research journals. No matter how you find the science behind your project, reading the literature on it is how you'll be knowledgeable enough to execute it and produce a successful project!

- **Using your connections.** While certainly not necessary, conducting research at a laboratory or alongside professionals will undoubtedly result in a fantastic project. If you have worked with professors or researchers in the past and are interested in their work, try contacting them to conduct a new project or assist in a current one for science fair. You never know the opportunities waiting for you. If you don't know any such people or lack connections, try applying for and participating in summer research internships. Not only will you gain research experience, but you'll also get close with mentors who can sponsor science fair projects in the future, as some of us did. From experience, another option is cold-emailing professors to ask to assist them in a project or utilize their resources for your own, as long as it aligns with their research. Always be respectful and brief when cold-emailing, as they most likely have a lot of work on their plate already. Don't get discouraged if you receive a no, or even no response; just don't harass professors or email everybody you can find (don't mass email people working in the same departments; they talk to each other). Cold-emailing should be a last resort, as it doesn't work much more often than it does. Here is a great article on cold emailing from Harvard Business Review. Even if you are unable to work in a professional laboratory, you can still create an award-winning project from home or school!

- **The Silicon Valley technique.** This technique has the potential to produce some legendary projects. It's all about getting in at the right time. When you're reading literature and science articles when deciding your science fair project, analyze the trends over the past few years in scientific methods and technologies. Look for the technologies and methods that are new, relatively unknown, or emerging but contain a lot of potential in a variety of different fields. Those are what you want to use in a science fair project. For example, a few years ago, Machine Learning was a long-known but recently-emerging technology with massive potential for use in every scientific field imaginable, yet few were using it in science fairs. Now, for the past 2-3 years, machine learning projects have dominated science fairs nation-wide in many categories, particularly the FCPS fair; the technology exploded in popularity after laying dormant with potential for many years. By analyzing trends and following the news, you may stumble upon the next big scientific boom you can use to your advantage in science fair. Currently, there is a lot of buzz in the scientific community about Metal-Organic Frameworks and Exosomes (computational sciences are also gaining grounds, especially in fields like chemistry and biology, which one board member conducted research on for a grand prize); we recommend looking at those subjects to get a feel for what to look for when utilizing this method and finding the next potential trend. By finding the technology (whether it be code, a process, new chemical, experiment method, topic of study, etc) that is emerging with lots of potential, you can stake your claim early with a winning science fair project in the field and blow the judges away.

- **Combination.** While reading the literature on your subject, you may come across many technologies that would fit well together in a novel idea or system. Do not be afraid to combine two existing ideas in a novel way to produce a new result!

Step 4: Propose your project to others.

Once your idea is set, run it by peers (with whom you are not competing; make sure your ideas are not used by others), teachers, or other contacts you have. You can even email professionals about your project, as they may be willing to give you helpful feedback and advice. There may be a flaw in your idea, materials you can't obtain, and others may see ways to improve your project that you didn't think of! The more people see your project idea and provide feedback, the better your project will become.

Step 5: Identify and obtain the necessary resources to complete your project.

What do you need to execute your project and obtain the necessary result? Chemicals? Plants? Biological materials? Software? Expensive machinery or a regulated lab environment? Make sure you have access to all the resources you need for success, including the money to buy materials if you have to. If you can't access what you need to complete the project, it's time to reconsider your options. You can find what resources you need to conduct your project through the materials/methods section of research papers you're basing your work on, internet searches from approved sources, or scientific supply stores. If you're conducting a computer science project, ensure you have access to the exact datasets you need to complete it. If the data that you are trying to analyze or work with does not exist or is not found in an accessible format, you cannot complete that project! Public datasets on a variety of topics can be found here on GitHub. If you are really brave, you can make your own dataset by compiling data from multiple researchers. Even though it is possible, it is extremely time consuming. One member of the SNHS board needed to email well over 50 researchers to do this for their ML project, even after reading and searching for over one hundred papers.

Step 6: Conduct the project.

Now that you have your idea, materials, and approval, it's time to get going! Make sure to start your project early. From experience, most things will not go right the first time. Don't get discouraged; you can explain your tribulations and how you overcame them to the judges later. Always learn from your mistakes! Your project will fail if you don't adjust to unintended results (yes, they will happen and happen often). Make sure to record everything you do, not just your results. Take pictures, videos, write down other data, etc. You may need them for publication, proof, your poster, scientific notebook, or data analysis. If you are working at a regulated research institution and have any questions, don't hesitate to ask your laboratory mentor. They agreed to mentor you to provide you with their knowledge and advice. Above all, be safe, and follow the ISEF guidelines for working with chemicals, biohazards, live animals, and other potentially dangerous agents. Rather than looking for a specific destination, be endelved in the journey that is science!

Step 7: Analyze your results.

You have your results, now it's time to see what to make of them. After you complete your experiment, it's important to analyze your results with skepticism. If there are published research papers with similar methods, compare your experimental findings to theirs. If you see significant contradictions, question your methods and review your design process again.

To determine the validity of your results, you can use various statistical analysis methods, like the chi-square test or t-test, depending on your project type. Further considerations for ML analysis can be found below. You can also compare your experimental method to current processes to demonstrate its effectiveness. For example, you can calculate the percent decrease in energy consumption or the accuracy of your diagnosis method; whatever fits your project best! Your analysis methods should explain why your project works and why it is significant in the scientific community. Different tests are used for different fields, so review the literature to gauge your data.

Step 8: Write your title and abstract.

Your title and abstract are the most important parts of your project. Upon judging, the judges will only see your board once, but they will always have access to your title and abstract. Even if your work is published, the title and abstract is all that will be shown. Your title should catch the eye of readers. There is no right way to write a project title, but there are things NOT to do: do not make your title extensively long (this may seem like it would make your project stand out, but if there is no need for it to be that long, it looks like you're trying to sound fancy), do not use over-the-top scientific jargon when it is unnecessary, avoid nondescript titles, don't use the word "novel" in your title unless your work is truly novel (you are the first to do it), and most importantly, we advise you never title your project using the "The Effect of X on Y" format (this method of naming your projects can be seen in elementary and middle school projects; high school projects should not be named this way lest the project be considered to be weak or immature by judges and peers). Titles in the science fair should be bold, straightforward, and informative. Try to pick out buzzwords from your project to highlight in your title to capture the judge's attention. Your abstract, on the other hand, should explain your title in depth. Why this issue? How did you address it? What methods did you use to achieve your results? What's next? A great guide on writing an abstract can be found here.

Step 9: Design your backboard or poster.

When designing your poster, it's best to use concise explanations and demonstrate your findings through tables and graphs. You can use software, like GraphPad or Excel, to create effective diagrams. Scientific figures are also very important to represent complex methods, pathways, or techniques. You can create professional figures and flowcharts with tools like BioRender or smartdraw. Many highly competitive science fair projects have so much data that it cannot be contained within one trifold. In the FCPS fair and ISEF, it is legal to stack two standard trifold boards one on top of the other to create one tall board. Only do this if you need to explain complexities of your project, or have lots of data and graphs; blank space on your board is BAD. Further, we recommend that you design your trifold in

Powerpoint beforehand, then either print a poster to paste onto your board or use the powerpoint as a template to create your board by hand (the most competitive projects print their boards as posters, as shown here). A well-designed backboard will surely capture the attention of the judges! We cannot stress this enough: a good board and presentation is what advances you to the next level. Powerpoint templates can be found here to aid in designing your backboards.

Step 10: Present to judges.

You've made it this far! The only thing standing between you and victory is a few discussions and presentations to judges. You should practice your presentation to judges. Teachers and friends you trust are good people to practice with. List down all their questions and feedback and make sure to incorporate it if you see fit. Ideally, you should have a short 15 second presentation for people who ask about your project, a 5 minute presentation for people more interested, and a presentation ~10 minutes during judging (these times may vary depending on the rules of each fair). During your presentation, you should reference graphs and figures on your board to provide context to what you are saying. Open with a short introduction on why you're conducting that project, then explain the project in general terms without getting too technical. Another way to present that is sometimes more compelling (depending on your project): describe why you did your project, explain what you got out of it (results, make them as quantitative as possible), then explain the science like you're explaining it to a middle schooler. The judges will ask about the technicality of the project on their own; if your entire presentation is the theory behind electrochemical reactions (just an example), it takes away from how YOU applied it to your project with unique methods and novel results. Try to explain the science behind your project, its results, and applications as if you were talking about your research with an adult not familiar in the field. After your presentation, the judges mainly will ask about challenges you faced, why you chose the given topic, how you researched your project, what the impact of your project is, how you can continue it in the future, and questions regarding its specific science and methodology. DO NOT LIE! The judges are all experts in their respective field, and they will see straight through any lie you tell about your project. If you don't know something, be honest; it's much better than being caught in a lie. Before the fair, write down a list of common questions you believe you will be asked and come up with an answer in your head for each. After the judging session is over (there are usually three), ask the judges how you can improve your project. You won't just gain insight for next year, but you'll impress them with your desire to improve. That's it! You've completed your science fair experience!

General Tips and Advice

Coming up with an idea.

When formulating your project, please avoid using ideas from websites, like ScienceBuddies. Judges can often spot projects taken from the internet, and you will likely see many others with the same idea. From our own experience, we've also found that deciding on an idea can be the hardest step. Don't be discouraged if you find it difficult to decide on a topic or change it multiple times. If you need to change your project idea, inform your teacher sponsor to ensure they approve of the project change before you finalize it; they will be understanding if you explain respectfully why you want to change ideas.

Working with your teacher sponsor.

Try to do as much without your teacher sponsor as possible. They are there to advise and approve your projects, not carry you through them! Most are mentoring many projects on top of their demanding schedules teaching, so don't bother them with questions you can answer yourself; they'll greatly appreciate it. This may also allow teachers to sponsor more projects than usual if they have less work for each project.

Working with students from other schools.

Before working with students with other schools, coordinate with your fair directors. They may have further insights or reservations about your collaboration. If approved, make sure you set up times to meet with them to conduct and plan your project efficiently. You'll be representing both schools, so act accordingly!

A student isn't contributing to your group?

When resolving issues with your partner, it is important to communicate the issue clearly. As a team, you can create a checklist for each member, record member contributions, and assign deadlines. If you have tried to resolve the issue with no success, it may be time to speak with your teacher sponsor.

Start early.

Developing and executing a complex project takes time and effort. Especially if your project is novel, you will experience many obstacles as you complete your research or decide to take on a different route. Mistakes and setbacks WILL happen during your research, so be sure to plan ahead! In our own experience, we've found that anything that can go wrong will go wrong. If you are creating a physical experiment, order your materials early; shipping times may be lengthy and some necessary materials may not be present in the school laboratory. Starting looking at research ideas as early as the summer.

Bandwagoning.

Don't do it! Judges don't like seeing the same project, or type of project, over and over again. If they're spending their day exploring your scientific work, they want it to be new and interesting for them, not the same information repeated by many different projects. The same goes for the subject of projects! Don't do a project on cancer or climate change or bacteria just because everybody else is and it sounds good; do it because you love the subject or have a significant contribution to the field!

Completing forms.

Complete your forms EARLY! This will save you and your science fair directors some stress. If you are working at a regulated research institution, allow plenty of time for your research mentors to fill out their required forms (there are a lot, including biological agent forms, consent forms, approval, etc); they are busy people! Most importantly, once your forms are submitted on Scienteer, don't touch them. Editing information after you submit your forms will have you redo them, potentially missing deadlines or having to resubmit your forms twice.

Working with professors and professionals.

Ensure that you are able to use your work with them in science fair. Some research can be considered a lab's own intellectual property, may be patented, or simply wanted to be kept secret. Always credit everybody who helps you in your project. An acknowledgements section should be in the bottom right corner of your poster recognizing those who helped you in any way, even if they just sent you an article once (ANY contribution to your project must be recognized).

Considerations for projects on machine learning.

Machine learning projects have been exploding in popularity for the past few years, and this year we've seen a sharp increase in the number of ML projects from CVHS students, a trend we expect to continue. While machine learning can be an extremely powerful tool in many different fields, it is NOT the key to science fair success. Machine learning is only useful if used the correct way to achieve statistically significant results, and should be verified with other tests before knowing whether or not your model was accurate or not. Here are some considerations we learned from working with ML in some of our own projects:

- **Working with small sample sizes.** Take great care when using machine learning with small datasets (<50 entries). Your model, especially if a classification/prediction model, may be inaccurate with small datasets and untrustworthy for future applications. If you are using a small sample size but also using feature ranking on top of your model, be sure to use statistical methods, such as a T-test, volcano plot, or a different ML model to verify that your results are correct. Larger datasets are ALWAYS better than small ones.

- **Beware of overfitting**. If you're seeing extremely good results or very high accuracy for your model early in your experimentation, chances are you overfit with your model. Overfitting occurs when a machine learning model is either trained for too long or uses too complex of a model and learns to just copy the dataset in its entirety. Upon testing, an overfit model will simply spew out the information from your dataset rather than making novel predictions based on the dataset. A good analogy is a student performing well on a multiple choice test by memorizing the sequence of correct answer choices rather than studying and applying the content of the test. If this happens, try training your model for less time, using a less complex ML algorithm, or using a different dataset to test your model than you did to train it.
- **Don't initially trust your results.** From experience, it is very exciting when you see high accuracies after you tested your model for the first time. Don't let it get to you! It's a great accomplishment that your algorithm compiled and ran, but did it actually work? Check your results with literature in your field, consult with mentors, professors, and teachers, and perform statistical tests to ensure that your results truly are as accurate as they claim.
- **Analyze your results with statistical tests.** After your ML model has been trained, make sure to take the necessary steps to ensure that it is in reality as accurate as it claims. Utilize methods during training and testing such as K-fold cross validation, dataset splitting and partitioning, T-tests, imputation, and a variety of graphical methods such as the volcano plot. Such tests are vital in establishing whether your model is truly predicting the correct results, requires improvement, or is overfitting your dataset. Some significant yet sometimes overlooked metrics are Matthews correlation coefficient and Cohen's kappa coefficient.

Working in your school laboratory.

When researching at your school, you will be faced with obstacles that are less apparent in professional settings. Scientific instruments may be faulty, materials may be limited, and after school hours can get hectic. Here is some advice on common problems we've encountered:

- **Setbacks.** As you complete your project, you WILL face setbacks. Your teacher sponsor might not be able to stay after, solutions could spoil, or your results may contradict existing research. To counter these setbacks, you need to work closely with your teacher sponsor. Create a plan for your project with the expectation that it will not go as planned. You should plan to complete your research early, leaving a week or two before the deadline as a buffer. This can help you avoid a situation in which you cannot complete your project. If time is still an issue for you, ask your teacher sponsor about providing students with service hours for assisting you in the clean-up process.
- **Inaccurate measurements.** Using equipment in your school laboratory can lead to additional sources of error. To avoid erroneous results, it's critical that you gather data points from many trials. In general, the more data points you have to support your conclusion, the better; some laboratory-based ISEF projects have used hundreds of

data points! You can also evaluate the accuracy of your experimental results using statistical tests found here.

- **Limitations.** You can create a novel project without professional guidance; don't feel limited by the boundaries of your school's resources. Although some projects may not be possible due to the materials available, you'll be surprised what you can accomplish in your school laboratory if you are creative in your approach. You will likely need to spend an extensive amount of time reading scientific literature to determine a project suitable for your experimental environment. Once you settle on a topic, it might seem too difficult or outlandish for a school setting; don't let this discourage you, and you'll be surprised what you can accomplish. As always, prioritize safety when devising your research project and get your teacher sponsor's permission before you begin.

Extra Resources

Here's a list of resources to get you started!

- GitHub Public Datasets (datasets on ANY scientific subject you can imagine)
- NCBI Literature (biomedical articles)
- Nature Articles (general science articles)
- Google Scholar (search for any published article/paper)
- MilliporeSigma | United States (materials)
- Carolina Biological Supplies (materials)
- Google Patents (search for patents of technology and scientific processes)
- ISEF Rules (what you can and cannot do in science fair)
- ISEF Project Database (all ISEF abstracts)
- FCPS Science Fair Entries (FCPS science fair entrants and winners from past two years)
- NCBI Abstract Instructions (how to write a good abstract)
- GraphPad (create professional graphs from input data)
- BioRender (create scientific figures easily)
- Smartdraw (create flowcharts to describe a workflow or method)
- ResearchGate (find research papers, resources, questions, and answers)
- arXiv (math/physics research paper archives)
- Backboard Templates (science fair board templates; not necessary to use)
- Kopernio (free access to limited research papers)

Final message

We sincerely hope this guide helped you in any way during this year's science fair. Help make Centreville science thrive! Good luck!

Sincerely,

SNHS 2019-2020 Board

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