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Introduction

The purpose of this document is to enlighten the process of science fair judging. It is meant to broadly explain the facets of judging and provide practical tips for all judges, especially new judges. This is oriented to the Pittsburgh Regional Science and Engineering Fair (PRSEF), but the concepts are applicable to any science fair. This follows the basic principles of the International Science and Engineering Fair.

PRSEF is presented by the Carnegie Science Center (CSC) and is one of the largest of the regional science fairs with around 1,000 students in grades 6-12 from Western Pennsylvania, and 2 counties in Western Maryland. It is divided into 3 divisions, Senior (9-12), Intermediate (7-8) and Junior (6), and 21 categories among the divisions.

The core of science fair is the interview with the student. The judges expend time and expertise in reviewing prepared materials, including posters, papers, abstracts, lab notebooks, etc., all this is in preparation to speak with the student to determine what they have done and what they know about their project.

The judges' job is to find which projects deserve an award, but they are also ambassadors for STEM education, individual professions and technology careers. Judges will impact each student, so the judging experience needs to be both encouraging and respectful. PRSEF is guided by the ISEF motto: "Reward the best; encourage the rest." The student interview is to find out more about the project and how it was done. It is meant to be, and usually is, a very positive experience, not one that embarrasses or intimidates the student. This sounds simple, but it can be challenging to do.

This document will explore the process from preparation to award decision.

- A. Judging Criteria
- B. Pre-Fair Preparation
- C. Fair Day
- D. Reviewing the Project Without the Student
- E. The Interview
- F. The Scoring Process
- G. Other Tips

Judging Criteria

PRSEF has developed judging rubrics based on level and category. See Judges Handbook, referenced below. There are general rubrics for Senior/Intermediate and Junior. There are also separate rubrics for Math, Computer Science and Engineering/Robotics. Science projects explain the way the world works; engineering projects solve a problem. Science projects have a hypothesis, and engineering projects have a problem statement. Categories are often well defined as either science or engineering, but some categories may contain both engineering and science projects.

Pre-Fair Preparation

It is important to begin preparing days or weeks in advance of the fair. Judges should review the following documents available on line:

Pittsburgh Regional Science & Engineering Fair GUIDE

<https://carnegiesciencecenter.org/educators/stemcenter-science-fair-registration-and-forms/>

Judges Handbook

<https://carnegiesciencecenter.org/educators/stemcenter-science-fair-judges-and-volunteers/>

Abstracts will be available on the PRSEF web site about 1 month prior to the fair. Judges should review all abstracts in their category,

Fair Day

The judging process has 3 components:

1. Review of projects without students
2. Interview students
3. Deliberate / Re-review projects without students / Select Winners

Reviewing the Project Without the Student

Judges should review the project prior to a student being present. This is the time to:

- Read the abstract
- Take a detailed look at the poster
- Read the research paper and research notebook (when available and as time permits)

Judges should avoid forming favorable or unfavorable prejudices about the project before they interview the student.

Students are encouraged to design their posters in a clear and informative manner which would then enable a meaningful in-depth discussion with the judges. In this pre-judge preparation, the job is:

1. Gather a basic understanding of the project
2. Formulate questions for the interview

The board should have five required elements:

1. Introduction/Purpose
2. Hypothesis/Engineering Problem
3. Methodology
4. Findings/Results
5. Discussion/Conclusions

To gain a general idea of what the project is about, judges can conduct a quick initial triage by comparing the hypothesis and the conclusions. Do they match? Do the findings support the conclusions? If not, consider why.

During the review (and later in the interview), judges should be looking for:

1. **Scientific Method:** Good science is not indicated by whether the project was done at home or in a lab, but by the merits of the project itself.—Did the student use the scientific method correctly?
2. **Creativity:** Is there something unique, clever or different? A creative project demonstrates imagination and inventiveness, and often offers a different perspective that can reveal new thinking. The ideal, especially in the senior division, is that a project is original research or a creative take on something previously published in the literature.
3. **Work:** The basis of science is reproducibility. Subjects, trials or sample size should be appropriate to the research. Experimental trials should be run a minimum of two times, unless this is not practical, for example, a single run of the experiment takes several months. The shorter time it takes to run a trials, the more trials should be done. If the experiment takes a few minutes, then making hundreds of trials is reasonable. If it takes one day, then 10 – 20 would be appropriate. Students should have a statistically valid sample for a survey. Judges should always be reward more work.

EXAMPLES:

- A. **Growing Plants:** A lower level student should ideally grow between 20 - 30 plants. A high school student would ideally grow a minimum of 100 plants.
- B. **Doing Tests on Other Students:** Simple tests should include a sample size of at least 30 in lower grades, or a sample size greater than 50 in high school.
- C. **Physical Factors:** If testing some physical factor, such as rolling cars down a slope, then they should have hundreds of trials, perhaps, 25 runs for each car.
- D. **Microbiology:** If testing/growing specimens in a petri dish or well, a senior division student might have hundreds of specimens.
- E. **Simple Random Sample:** The simple, random sample is the standard for selecting a population to study. Software for performing the sample size calculation is readily available on the web. For large populations, about 370 subjects is the minimum sample size.

F. **Clinical Trials:** NIH literature suggests minimum sample size of 90, with 90 controls.

4. **Statistical Analysis:** Their numbers tell the story. 6th, 7th & 8th graders should report average (mean) values. High school students should report standard deviations and be able to do a simple significance test to determine if the experimental values are statistically different than the control values (basic p or t values). Higher level projects might have higher level statistics, including linear regression. The student should understand the significance of any statistical tests they have completed.
5. **References:** References may be on the board or in the paper or lab notebook. They should be properly written in some recognized format. They should usually include some recent literature. Wikipedia should never be used as a reference. Standalone URLs are never acceptable as references.
6. **Presentation:** Content is paramount, but good presentation may suggest an attention to detail that belies good content.
 - a. Presentation is an important criterion in judging, but don't let a showy poster take the place of a good presentation and a meaningful interaction with the judge. Substance is most critical!
 - b. Writing should be clear and professional.
 - c. Figures and tables should be clearly labeled with the appropriate units and axes indicated.
 - d. Flow of the information should be clear leading up to how the student developed their conclusion or produced their engineering apparatus?

Students applying to attend ISEF write a research paper. These are not required for PRSEF. Papers should look like they came from a peer reviewed journal. Papers that do not meet this standard cast doubt on the quality of the research. Poor references may suggest poor work.

Attention to detail is what makes a winning project stand out from the others. The research notebook, if present, should be neat and complete. The notebook, abstract, research paper and poster should all be consistent.

The initial review (without the student present) should prepare the judge for the interview, help raise questions and give an early sense of each project's quality.

The Interview

During the interview, the student answers questions and tells what they know, providing judges with the opportunity to determine the quality of their research and the work relative to other projects within the category. There are many outstanding projects in which the display (unfortunately) does not appropriately capture the knowledge and talent of the student. In the end, the interview is critical, as the display is secondary to the student's actual knowledge of the subject and explanation of the work.

There are 2 ½ hours allotted to interviewing. Judges should use the entire time, or about 10-12 minutes per interview.

The judge's approach to the interview should:

- Be friendly, courteous, and professional
- Demonstrate an interest in what the student has done
- Employ active listening
- Attempt to learn something from each project
- Differentiate nervousness/shyness from lack of knowledge

The interview should start with the student explaining their project. All students have a prepared speech. Typically, they are too long. It is the duty of the judge to take control of the interview and not allow the student to monopolize the time with their prepared speech. Judges can request either a short introduction (1-2 minutes), or instruct the student to make their prepared speech, but warn that they will interrupt with questions as they arise. The student should know the ground rules from the beginning.

Ideally, the judge should have some specific questions which were formulated during the review of the board without the student. These should project to the student that the judge has reviewed the project and is prepared to conduct the interview. These questions should focus on:

- What is new/unique about this project?
- How did the student collect data and control data quality?
- Does the student understand the effect of one variable on others?
- What work was done by the student and what was done for the student?
- Does the student know the science/engineering principles behind the project?
- Did the student design the project or was it given to the student, perhaps as part of a larger research effort?
- What might the student do differently the next time around?

Remember, students should be an expert on their particular research. With this in mind, judges should not be afraid to ask difficult or probing questions, but it is important to be aware of tone of voice and body posture during the questioning. The answer the student provides may cement the assessment of the quality of the student research or reveal weaknesses in their approach. Additional guidance on questions to ask, and circumstances in which to ask them, is provided in the "Other Tips" section.

There may be some difficulty in determining what the student did versus what was done for them. Students can receive appropriate help, which includes providing materials and logistical support that the student needs to do their own work. Guidance and direction are also appropriate. Anyone giving a student a "cook book" project is not. Students would not be expected to use power tools or use skills such as welding. If they do it, it's a plus, but not doing it is never a minus. Safety is critical for all students, but especially younger students. In the real world of research, lab tests are often sent to a lab, or done by others, especially where the instruments are valuable or difficult to use. If the student learns to perform lab tests, then this is a plus.

There has been significant concern about students doing projects at major labs versus those working at home or in school. For students doing projects at major labs, there should be additional scrutiny of projects to determine if the student did all the work, took the initiative to find the laboratory situation, knows the subject, and made use of what was available to use. Please see Appendix A.

A simple way to evaluate the help received is to assess the depth of the student's fundamental understanding. If they understand the underlying science, then the level of help was probably appropriate. Some example questions are:

- Ask the student to explain the fundamental science. Some examples might be: How does a semi-conductor work? How does an airplane fly? What is photosynthesis? Often a student who has been helped too much by others cannot explain the basic concepts.
- Ask the student to explain how they isolated their data to just one affected variable.
- Ask the student directly what help they received and why they felt they needed such help.
- How would their conclusion/apparatus have changed without outside help?

Team projects are those conducted by two or three students working together. Team and individual projects are usually judged together. Projects should be judged only on the basis of their quality. However, all team members should demonstrate significant contributions and an understanding of the project as a whole, as well as the underlying science/engineering principles. The judge should direct individual questions to each member of the team. Failure to have a true team approach would weigh against the final score of the project.

Sometimes a judge may have trouble finding questions for the student. In these instances, let the student go on with the canned speech a little longer than usual, or have the student explain the underlying science. Since each student should get about the same amount of time with the judge, never cut the interview short. See the "Other Tips" section for additional guidance.

Judges do not provide feedback to the student about their project during the interview. Ideally, the student should have no idea of the judge's evaluation of the project. Avoid compliments, corrections, or any other feedback. However, at the end of the interview, it is always appropriate for the judge to recognize and praise the student's accomplishment in competing at PRSEF and encourage their further work in the sciences. Comments written on the rubric are shared with the student, so that feedback is given in this way.

The Scoring Process

PRSEF does not require judges to score a project. Judges pick the best projects from among those which they have judged. Judges use the rubric as a guide and may score projects if they desire.

The goal of PRSEF is to create a rank order of projects. The process for doing this is laid out in Appendix B.

PRSEF uses a formula to calculate the number of awards so that each student has an equal chance of winning from first to fourth place. Based on the number of students in a category, there may be multiple awards at each level, although only one first place.

Ethics

All people involved with PRSEF must maintain the highest ethical standard, and conduct themselves as professionals at all times. As a general rule, any real or suspected breach of ethical conduct should be reported to a category chair/co-chair, who in turn informs the Division Chair/Chair of Judging, Science Fair Director or other designated person. The judge never adjudicates a problem. Similarly, the judge should conduct the judging process without regard to any infraction. All matters reported will be adjudicated, and instructions given to chairs/co-chairs and judges with regard to further action. While PRSEF monitors all activities closely in order to avoid potential ethical violations on the parts of students, judges, and volunteers, ethical infractions can occur.

Infractions would include:

- **Plagiarism:** Any student applying for ISEF will submit a paper which is analyzed by iThenticate. This means that a substantial group of senior division projects are reviewed. These are the same standards that are used by ISEF. Any judge suspecting plagiarism should report this to the category co-chairs as soon as possible.
- **Violations of Research Standards:** The Scientific Review Committee reviews all projects for adherence to ethical and research standards, including but not limited to animal testing, human subjects research, and researcher safety. Again, any judge suspecting a violation of research standards should report this to the category co-chairs as soon as possible.
- **Conflict of Interest (COI):** Any direct or personal connection to a student is a COI. A parent, relative, mentor, or teacher of a student has a conflict. Being involved with another fair, or even having judged someone from that fair, would not necessarily be a conflict, unless there is some other connection. When in doubt, contact the Chair of Judging for the fair.
- **Inappropriate Behavior:** Judges should be alert for unprofessional behavior on the part of students, volunteers, or other judges. This includes inappropriate language (including slurs), sexual harassment, bullying behavior, or any other behavior that seems inappropriate or unwanted. These should be reported immediately the proper authorities, as noted above.

While all concerns will be investigated, not all concerns are founded or a cause for action.

Students and judges should not exchange personal or contact information. Judges wishing to have further contact with a student should contact the Science Fair Director who will make the appropriate connections. This can be done in person, by phone 412-237-1543, or email PRSEF@CarnegieScienceCenter.Org .

Other Tips

The tips below are from many years of science fair judging. They are useful and practical guidance to help with the judging process.

- **General Tips**
 - Be kind. It is easy to forget that the students are not graduate or undergraduate students. Especially with senior level projects, remember that the person is a child, albeit an exceptional child.
 - The judge is the adult, but the student is the expert. Respect their expertise. Allow students to succeed (or fail) in the interview on their own merits.
- **General Interview Questions:** The following may be useful in specific instances.
 - How did you come up with the idea for this project?
 - What did you learn from your background research?
 - How did you build the apparatus?
 - How much time did it take to run the experiments/collect each data point?
 - How many times did you run the experiment with each configuration?
 - How many experiment runs are represented by each data point on the chart?
 - Did you take all data/run the experiment under the same conditions, e.g., at the same temperature, time of day or lighting conditions?
 - How did you do the above?
 - How does your apparatus/equipment/instrument work?
 - What do you mean by (terminology or jargon used by the student)?
 - Do you think there is an application for this knowledge/technique?
 - Were there any books that helped you do your analysis/build your apparatus?
 - When did you start this project?
 - What is the next experiment to do in continuing this study? (or the next 2 or 3 experiments)
 - Are there any areas that we have not discussed which you feel are important?
- **Why the Student Chose the Project:** Some judges like to know why and how the student chose the project, but this is not always relevant to the science or engineering review. Two examples:
 - The student's grandma has liver cancer and that is why they chose to study liver cancer. This has no bearing on the quality of the work. It's heartwarming, but not useful.
 - The student says that they were assigned this project without their input. This is relevant/
- **Poorly Done Project:** If a project seems poorly designed and/or executed, ask questions to give the student the opportunity to dispel that notion. If true, this would be a situation in which a student is given additional time to go on with the canned speech a little longer than usual. See "General Interview Questions" above.
- **Judge Doesn't Understand Project:** Some of these projects are intimidating. A good judge who reviewed this document commented, "If you think I never interviewed

a project out of my depth, you're out of your mind.” Don't be intimidated. However, if the situation is creating stress, check with the co-chair, and have them assign another judge.

- **Unresolved Questions After the Interview:** If something is not completely clear, bring it up in the judge caucus meeting. Other judges, who may have more familiarity with the applicable science, can help sort it out. In the case of a serious issue which remains unresolved after the caucus, the category co-chair will contact the division chair or chair of judging to facilitate resolving the issue.
- **Student Doesn't Understand Project:** Students sometimes don't understand their project. If his might be the case, ask for explanations of words that the student uses; don't assume the student knows what the technical terms mean. Ask what a particular piece of equipment does, how it works, or why it was used. Ask the student to explain the fundamental science underlying their hypothesis. If a student has difficulty answering these questions, they may not have conducted the research independently. However, it is inappropriate to openly charge that the student falsified information or did not do their own project. These discussions should be reserved for the deliberation process. If you have misgivings about a particular project, it is likely that other judges will have similar reservations.
- **Statistical Analysis:** Students can do statistical analysis blindly without knowing what they are doing. Students may refer to ANOVA, without knowing what it means. ANOVA refers to analysis of variance, the determination of the level of statistical difference and significance in data populations. Doing significance testing is trivially easy today. Students should be able to explain the significance of their statistical analysis, how the analysis is performed (past putting it into a statistics program which tells them the answer), and why they chose a specific statistical method.
- **Shy Students:** It is common to have students who don't seem to want to talk very much. Try to help them get started with more personal questions such as why they became interested in this subject. You may also want to be prepared to ask students to expand on answers if they give cursory responses.
- **Talkative Students:** It is equally common to have students who talk too much, especially in team projects. Feel free to interrupt students with questions or ask for clarification on previous points if a student moves on too quickly. For team projects, address the other student or students in the team specifically so that one team member doesn't dominate the conversation.
- **Problem with a Student:** The job of a judge is to only consider the merit of a student's project. Any problem with the student (e.g. inappropriate dress, insulting comments, or plagiarism) should not affect the scoring of the work. Such issues should be taken to a higher authority, such as a category or division chair, or fair director. Their job is to adjudicate infractions. Do not communicate problems to the student or to the other judges.
- **Research Facility:** If the project was done at a research or industrial facility, the judge should determine the degree of independence of the student in conducting the project.

While a student may have a significant advantage from working in a research facility, you should expect to require a higher degree of knowledge to demonstrate they have ownership of their project.

- **Multi-Year Projects:** If the project is a multi-year effort, the interview should focus ONLY on the current year's work. It may be necessary to specifically ask a student what was done in the current year versus what was done in previous years.
- **When the Judge is an Expert:** Sometimes students who do projects in technical areas with which a judge is intimately familiar will make incorrect assumptions, miss a key indicator in the data, come up with a false conclusion, or overlook some common principles. It can be tempting to share knowledge about the topic, but this should not be done. However, if it is necessary to ask a pointed question (why a technique was not used, etc.) in order to evaluate the work, it should be done carefully so as not to give away excess information or prejudice the response. Judges wishing to work with or help a student after the judging process is concluded should go to the Fair Director for contact information.
- **Giving Information to Students:** Students should never be given answers to questions by a judge, as they could give these answers to other judges and distort the judging process.
- **Judge discussions:** Judges should refrain from discussing projects with other judges prior to an interview. These discussions are best left for the deliberations following student interviews.
- **Feedback to Students:** Students sometimes take a judge's reaction to determine what is good or not good about their project. Any information that a student infers will be used with other judges. There's a saying that students get smarter as the day progresses. It's true.
- **Team Projects:** A good team project requires a partnership where all parties contribute to the development of the project and understand the end result in its entirety. Any one member of the team should be able to present the entire project on their own with no input from other team members. However, team projects run the gamut from twins who finish each other's sentences to projects where one person contributed the vast majority of the work while the other contributed very little.

Conclusion

Participating in a science fair can be a rewarding experience for the student and the judge. It is a lot of work, yet also a lot of fun. The students have worked hard to be judged. Some will get awards and prizes. Others will just get to show their stuff. Judges universally find talking to these great and inspiring young folks to be rewarding, so make sure that all students feel treated fairly and that their hard work is appreciated. Be nice to the students. Have fun.

Appendix A: Judging Criteria for Lab Projects

[Note: Appendix A and B are taken directly from the PRSEF Judge Handbook]

Some students who compete at PRSEF have had opportunities to work in industrial research or teaching hospital labs. Students, parents and judges have expressed concern about equity in judging these projects in competition with those done in more traditional places, i.e., home or school labs. We have considered how best to maintain a level playing field and that discussion has caused us to generate these guidelines.

Research is usually an activity that proceeds faster when ideas are exchanged and techniques are shared. This is especially true whenever the ideas shared are in some part generated by a specialist or scientist working actively in the field in question. A student stands to gain considerable knowledge by association with these professionals and also usually has access to the latest research equipment. ***To this point, however, it is essential that the judge determine how the student earned their position with the lab and what role they had in completing the project. A student who chose the project and pursued the lab situation will be more highly rated than one who was led to those choices by someone of influence like a parent. The judge is evaluating the creativity of the student, not the mentor.***

The student researcher shall convince the judges of the following:

- **The student did all of the work.** All of the work reported must be done by the student. It is unacceptable to present other's work; any project doing that will be disqualified. It is understood that in some situations a high school student will not be allowed to use expensive or complex testing equipment and another member of the lab may assist them.
- **A higher level of science is expected.** When work is done in these labs it is expected to be more complex and advanced. In and of itself, this shall not influence a judge's evaluation. More complex science is usually presented in these cases; this is as expected and should not influence the rating.
- **The student has a complete understanding of the work reported.** Each judge shall thoroughly test the student's knowledge of the subject. If a judge is not familiar with the science of the project a Category Chair shall be notified and other judges assigned. Here especially, judges shall not be satisfied with "canned" presentations.
- **The student made use of the tools available.** The judge shall determine how effectively the student used resources available in the lab.

When deciding which of these projects to advance for Category awards, judges shall consider the judges' rubric attributes (See Appendix 3 Judging Rubrics) and reward projects that have scored well against those criteria. Just as judges are not unduly influenced by a flashy poster, they should not automatically assume that these are better science projects.

Appendix B Category Award Selection Procedure

Although there are many ways to reach a decision on category award winners, the following two procedures are simple and avoid the issue of disparity in judges' numerical scoring.

1. Judges review abstracts and view project submissions online.
2. Judges interview students in their virtual conference room.
3. After interviews are completed, each judge group should select the best 1 or 2 projects they reviewed. If the judges feel that none of the projects in their group are worthy of an award, they should discuss this with their category chair(s). Likewise, the judges may feel that there are more than 2 projects in their group which deserve further consideration, this too should be discussed with the category chair(s).
4. The top 1 or 2 projects from each judge group are then presented to the whole group of judges for that category for final award judging. The total number of projects advanced to be judged by the whole group will depend on the number of projects and awards in the category.
5. Each judge records the selected project numbers on the Award Selection Form. See Appendix 7 Award Selection Form.
6. As a group, all of the judges for the category review the top projects. At this time, one of the judges shall present each project to the panel for discussion. Judges may also listen to the student's interview if it was recorded or view the project submission files. **Not all projects advanced will be recognized with an award.**
7. When the group review is completed, each judge ranks the projects, giving their first choice 1 point, the second 2 points and so on. Discussion is encouraged.
8. The ranking scores from each judge are added and the award winners are determined based on the composite scores. The first-place winner is the project with the lowest score, and so on.
9. Judges caucus to discuss the results and confirm that the project with the lowest score is the one which the group agrees is the best project. They repeat that procedure for the other award winners. Category chair judges shall resolve ties if the selection appears to be at an impasse.
10. Based on the number of entries in each category, multiple second, third and fourth place awards may be awarded. **Only one first place will be awarded in each category.** Judges will follow the Final Category Ranking form to determine how many awards to select.

Alternate Procedure

7. After the projects have all been presented to the group, the best of the category shall be chosen by a vote. The group discusses each of the projects and, via a virtual show of hands, asks who among the judges feels that this particular project is worthy of 1st place. The project receiving the most votes is the 1st place selection for the category.
8. The group discusses each of the remaining projects and, via a virtual show of hands, asks who among the judges feels that what projects are worthy of 2nd place, 3rd place and 4th place. Based on the number of entries in each category, multiple second, third and fourth place awards may be awarded. **Only one first place will be awarded in each category.** Judges will follow the Final Category Ranking form to determine how many awards to select.