Tie-Breaking Methodology for the Assessment of Science Olympiad Events

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ABSTRACT

Science Olympiad events are annually conducted competitions that cover a variety of science disciplines spanning biology, earth science, chemistry, physics, engineering, and technology. Each event addresses the knowledge of science concepts, as well as the application of these concepts, along with the necessary process skills to participate in the National Science Olympiad Tournament at the end of May of each year. In 2019, the meteorology event was conducted in Division B (Middle Schools). Fifty questions were prepared before the events in the North Dakota state competition to cover topics ranging from the Earth's modern atmosphere to weather forecasting and temperature indices. The North Dakota Meteorology event facilitators used the Turning Technologies' student response system to automate the scoring to minimize manual grading error and to eliminate any ties in score consistently for all competitors. Breaking multiple ties by manual grading is a difficult task considering that the scores need to be turned in as soon as the tests end. Additionally, the Olympic rules do not allow any ties and ask the event facilitators to turn in the score sheets with each team awarded unique scores. In other words, the facilitators are expected to come up with their own way to resolve the ties, leading to inconsistencies in methodologies among the events. This paper focuses on breaking ties based on the difficulty level of a question in such a way that the more difficult the question is, the more points are awarded for the team in an automated fashion. The authors believe that the method described here is a simple but useful method that will save the facilitators time and provide an error-free, and most importantly a consistent grading system that is designed to eliminate the tie of scores among the competing teams. Furthermore, the tie-breaking methodology described in this paper and the publicly available score sheet, which could be adapted for use even if one does not have Turning Points technology, have the potential to lead to more consistent scoring in any of the Science Olympiad events across the country.

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1. Background on Science Olympiads

The Science Olympiad is a US non-profit organization with the goal of increasing K-12 student interest in the sciences through teamwork and by providing recognition for achievements by both students and their teachers. Otto (2010) suggests that the National Science Olympiad is an attempt to involve the students in competitive events in science to turn students onto science. Wirt (2011) analyzed the Science Olympiad survey database to show that the Science Olympiad had an impact on career choices. Based on the study, 89 students out of 635 surveyed said yes to the question asking whether the Science Olympiad led to a career. Of the 89 who said yes, one student selected meteorology as a career. Literatures cite many articles published on Science Olympiad as a whole, but there are only a few talks about the meteorology event, and none puts explicit emphasis on assessment of the meteorology event such as this paper.

The Science Olympiad competitions consist of a collection of 23 various team events presented at local, state, and national interscholastic competitions. These events cover a variety of science disciplines spanning biology, earth science, chemistry, physics, engineering, and technology. In 2018, approximately 8,000 teams of up to 15 students each participated in more than 450 competitions across all 50 states (SO, 2019).

Science Olympiad competitions are like sporting events, where teams in each division (Division B is middle schools; Division C is high schools) compete against each other for medals and trophies. Events are rotated and modified yearly to address the evolving nature of science and technology while striving to appeal to a wide selection of student and teacher interests.

North Dakota had 141 teams participate in the 2018-2019 academic year. Individual schools prepare in different ways, some through classroom activities, some through after-school training sessions, and some even set up practice competitions with neighboring schools.

The North Dakota State Tournament hosts 34 different events - - 23 in each division with some overlap. Around 720 students compete in up to five 50-minute individual events during the tournament, and the participating students in the top three teams, in each event, receive medals. Each team's performance on individual events is ranked on a 24-point scale and the top three teams with the highest accumulated number of points across all events are awarded trophies.

The top team in each division receives an invitation to participate in the National Science Olympiad Tournament at the end of May. The Science Olympiad National Tournament is held at a different university each year, and in 2019 that tournament was held at Cornell University in Ithaca, New York. The National Tournament is the culmination of nearly 300 regional tournaments from across the United States and involves 120 of the top teams from around the country. Winners at the National Tournament not only receive awards and trophies but cash scholarships, tuition awards, and prizes offered by the host universities and sponsors. For example, "In 2010, The University of Illinois at Urbana-Champaign reprised awards of four-year full-ride scholarships for all high school gold medal winners valued at more than $100,000 each. In 2012 and 2014, the University of Central Florida offered $30,000 scholarships to all gold medal winners at the National Tournament." (SO2, 2019).

2. 2019 North Dakota Case Study

In 2019, the Science Olympiad committee decided that the Meteorology event would be conducted in division B only. Participating teams (schools) were divided into two sessions. In each session, there were 12 teams participating. Each team was represented by two students. Each team was allowed to bring two stand-alone non-programmable non-graphing calculators and four 8.5x11" sheets containing information on both sides in any form of information and from any source.

Questions

The Olympic committee determined that the 2019 Meteorology questions would come from the following topics: the modern atmosphere, solar radiation and seasons, the properties of water and its effect on weather, types and formation of hydrometeors, atmospheric pressure, air masses and fronts, local winds and precipitation, common storms and other hazardous weather, surface weather station model and maps, upper air charts, weather instrumentation and technology, weather forecasting, and temperature indices.

The corresponding author, ND state climatologist and ND meteorology event coordinator, prepared 50 questions from the topics specified by the Olympic committee. Each question was multiple choice with five options and one correct answer. The facilitators (the event coordinator and an assistant) used the Turning Technologies (Turning Technologies, 2019) QT Student response device to receive the test answers via a radio transmitter in real-time. Students were asked to mark the correct answer on the paper first, then submit the correct answers using the Turning Technologies QT response system. This back-up step was necessary in case of a technology failure, in which case the authors would have graded the tests manually. Fortunately, no tests were graded manually.

Scoring Methodology

The Olympic committee instructed event facilitators to grade the test so that the high score wins. One point is awarded for each question possible for a high score of 50. However, the rules also indicated that no teams could tie. The Olympic committee left it at each event coordinator's discretion to select a tie-breaking method to resolve ties. There are some exceptions to the tie-breaking rules. If a participating team decides to show up, sign the team name and leave without taking the exam, the team is awarded 1 point. This would be a popular choice for teams that want to put more attention into other events. Additionally, if a team does not show up or fails to appear, the team is awarded zero points. Therefore, there could be more than one team with one or zero points. These are the only exceptions to the tie-breaking rules. The team that scores the highest (plus any tie-breaker) gets 24 points, and the second highest gets 23 points and so on. This was necessary to standardize the scores based on a scale from zero to 24 with 24 being granted to the highest-scoring team.

Since the award ceremony is on the same day as the Olympic tournament, the test scores needed to be submitted as soon as the tests were taken. A lack of staff helping with the meteorology event and a large number of questions forced the meteorology facilitators to seek an automated way to speed up the facilitation process. Using the Turning Technologies' student response system eliminated the time it takes to grade the test manually. It also eradicated the error associated with graders, who usually are not necessarily in the field of meteorology, identifying and counting the correct answers while grading 50 questions manually. In case of a tie, it would have been a very difficult task to break the tie through manual grading. Moreover, when a tie is broken between two teams, the updated score would usually end up tying with another team. Then, the facilitators find themselves breaking ties in an indefinite loop while wasting both their valuable time and of those who are waiting for the final scores.

This paper focuses on breaking ties based on the difficulty level of a question in such a way that the more difficult the question is, the more points are awarded for the team in an automated fashion.

Table 1 is created by the Turning Technology Result Manager program showing the team name in the first column and the questions in the columns after that. Each cell in the question column contains points awarded for the question, with one is correct, and zero is incorrect. Team names in the first column are the names of the school the teams are coming from. However, in order to comply with the privacy issues, the original teams are replaced with Team 1, Team 2 and so forth all the way through Team 24. For simplicity, the authors decided to display only the first five questions since the format is the same all the way through the 50th question and also to fit the table on one page. The last column in Table 1, "Total Points," sums the individual points awarded to teams for each of the 50 questions. Therefore, the maximum point a team can score is 50. The last column contains multiple ties committed by 15 teams, which are highlighted in grey warning the event coordinator that these ties need to be resolved. These highlights are created automatically using the conditional formatting feature of standard spreadsheet software. Breaking these ties manually would have been extremely time consuming and prone to making human errors. In the next section, the authors explain the tie-breaking procedure.

Tie-Breaking Procedure

Tie-Breaking Procedure: The last row of Table 1 above shows the Correct Answer Percentage (CAP) by a question that is the percent of the questions answered correctly by the teams. For example, question one is correctly answered by 13 teams out of 24; therefore, 54.17% (shown as 54) of the teams answered this question correctly. The authors calculated the CAP as follows:

$$CAP = \frac{Number\ of\ Correct\ Answers}{Total\ Number\ of\ Teams} * 100$$

Then we calculated the Question Difficulty Factor (QDF) as follows

$$QDF = 1 - \frac{CAP}{100}$$

For example, the QDF for question one is 45.83% and shown as 0.46 in the second row of Table 2 below. For simplicity, the authors used only the first five questions since the format is the same through the 50th question and also to fit the table on one page.

The numbers in the table corresponding to each team for each question are the QDF if the team answered that question correctly. Zero QDFs indicate that the team did not answer that question correctly. Notice that the QDF is higher for more difficult questions, and it is lower for easier questions. These numbers are generated automatically by the preprogrammed spreadsheet that takes the numbers from Table 1.

The column labeled as "Correct Answers" in Table 2 is copied from the "Total Points" column of Table 1, which sums all the correct answers for a team. Notice that the numbers under each question in Table 2 are replaced by the Question Difficulty Factor. We will add these numbers in the column called "Question Difficulty Bonus" in Table 2 below. The Question Difficulty Bonus will later be added to the number of correct answers to make up the final points called "QDF Adjusted Total Points."

The column labeled as "QDF Adjusted Total Points" in Table 2 is the sum of the Correct Answers and the Question Difficulty Bonus in Table 2. The authors decided to divide the Question Difficulty Bonus by a factor of 100 to make sure the numbers are small enough so that the bonus is still less than one. This way the total points to the left side of the decimal point will show the number of correct answers and the numbers to the right side of the decimal point will show the bonus points due to the difficulty factor so that the more difficult the question is the more bonus is awarded to the team that answered the question correctly. For example, Team 1 (the first team row) QDF adjusted total score is 30.158. This means the team scored 30 points originally, and

Table 1. Turning Points Team Score Sheet.

Team Name	Q1	Q2	Q3	Q4	Q5	…[4]	Total Points
Maximum Points	1	1	1	1	1	…	50
Team 1	1	1	1	0	1	…	30
Team 2	1	1	1	1	1	…	16
Team 3	1	1	1	0	1	…	20
Team 4	1	1	0	0	0	…	15
Team 5	0	0	0	0	0	…	0
Team 6	1	1	1	1	1	…	35
Team 7	0	0	0	0	1	…	16
Team 8	1	0	1	1	1	…	29
Team 9	0	1	1	1	1	…	30
Team 10	0	0	0	0	0	…	0
Team 11	1	0	0	1	1	…	19
Team 12	0	1	0	1	1	…	16
Team 13	0	0	0	0	0	…	0
Team 14	0	1	1	1	1	…	29
Team 15	1	0	0	0	1	…	20
Team 16	0	1	0	1	1	…	14
Team 17	1	0	0	0	1	…	24
Team 18	0	1	0	0	1	…	18
Team 29	1	0	0	0	1	…	15
Team 20	1	1	1	1	1	…	23
Team 21	1	0	1	0	1	…	22
Team 22	0	1	1	1	1	…	23
Team 23	1	1	1	1	1	…	23
Team 24	0	1	1	1	0	…	23
Correct Answer Percentage by Question (%)	54	58	50	50	79	…	30

0.158 points are awarded for answering difficult questions correctly. If the QDF scores were too high (high enough to make the difficulty bonus greater than one for example), the bonus would have inflated the total score to a number above 30 which would make it more difficult to infer the number of questions the team answered correctly. Despite the complexity in the scoring, the authors still wanted to retain the most important information in the original data- -the number of correct answers. The SO Scores column in Table 2 is the Science Olympiad scores that are to be turned-in to the Olympic Committee administrators.

There is a text box with instructions for how to use the spreadsheet under the table titled "How to use this sheet with Turning Technology." This text box is highlighted in blue color to differentiate itself from the other text box intended for those who will use the spreadsheet in the event when no Turning Technology devices are used. That process is described in the next section.

3. Tie-Breaking Procedure without the Turning Technologies

Even though the Turning Technologies' student response system can simplify the process by automating the scoring to minimize manual grading error and can accelerate the process, the publicly-available spreadsheet (see the URL in the next section) can still be used to take advantage of the tie-breaking methods discussed in this paper. Furthermore, the spreadsheet will format the output according to the Science Olympiad official score sheet format.

In order to utilize the spreadsheet manually, the event coordinators will have to enter grades one question at a time

[4] … in Table 1 indicates more fields.

Table 2. North Dakota Science Olympiad (SO) Meteorology Event Final Scoresheet.

Team Name	Q1	Q2	Q3	Q4	Q5	Correct Answers	Question Difficulty Bonus	QDF Adjusted Total Points	SO Scores
QDF	0.46	0.42	0.5	0.5	0.21				
Team 1	0.46	0.42	0.5	0	0.21	30	0.1577	30.158	23
Team 2	0.46	0.42	0.5	0.5	0.21	16	0.0842	16.084	9
Team 3	0.46	0.42	0.5	0	0.21	20	0.0932	20.093	12
Team 4	0.46	0.42	0	0	0	15	0.0758	15.076	5
Team 5	0	0	0	0	0	0	0	0.000	0
Team 6	0.46	0.42	0.5	0.5	0.21	35	0.1852	35.185	24
Team 7	0	0	0	0	0.21	16	0.0731	16.073	7
Team 8	0.46	0	0.5	0.5	0.21	29	0.1582	29.158	21
Team 9	0	0.42	0.5	0.5	0.21	30	0.1515	30.152	22
Team 10	0	0	0	0	0	0	0	0.000	0
Team 11	0.46	0	0	0.5	0.21	19	0.0853	19.085	11
Team 12	0	0.42	0	0.5	0.21	16	0.0748	16.075	8
Team 13	0	0	0	0	0	0	0	0.000	0
Team 14	0	0.42	0.5	0.5	0.21	29	0.1569	29.157	20
Team 15	0.46	0	0	0	0.21	20	0.1095	20.110	13
Team 16	0	0.42	0	0.5	0.21	14	0.0646	14.065	4
Team 17	0.46	0	0	0	0.21	24	0.1189	24.119	19
Team 18	0	0.42	0	0	0.21	18	0.0841	18.084	10
Team 29	0.46	0	0	0	0.21	15	0.0807	15.081	6
Team 20	0.46	0.42	0.5	0.5	0.21	23	0.1259	23.126	18
Team 21	0.46	0	0.5	0	0.21	22	0.1045	22.105	14
Team 22	0	0.42	0.5	0.5	0.21	23	0.12	23.120	16
Team 23	0.46	0.42	0.5	0.5	0.21	23	0.1087	23.109	15
Team 24	0	0.42	0.5	0.5	0	23	0.1216	23.122	17
CAP (%)	**54**	**58**	**50**	**50**	**79**				

for each team. There is a text box with instructions for how to use the spreadsheet under the table titled "How to use this sheet without Turning Technology". This text box is highlighted in green color to differentiate itself from the other text box intended for those who will use the spreadsheet in the event when Turning Technology devices are used.

4. Discussion

The method the authors used was a simple but useful method that saved the facilitators time and provided an error-free grading system. It needed some minor effort in preparation at the front end of the events to make sure the process ran smoothly during the event. It took the facilitators less than 30 minutes, which was spent to copy the results from the Turning Technologies' Result Manager Module, and paste it on the pre-prepared, spreadsheet (Table 1). The spreadsheet in Table 2 was locked to eliminate accidental modification of the formulas that calculated the Question Difficulty Factor adjusted total points and SO (Science Olympiad) scores which are the ranking of the total points so that the highest-scoring team would receive a ranking of 24. A workbook containing two spreadsheets executing the above procedure with instructions is provided in the following URL: https://www.ndsu.edu/olympiad/downloads/automated_score_sheet.xlsx

The authors think that this paper, and the methodology it describes, have value for others within the field of meteorology, applied and service climatology who also lead science Olympiad events in their home regions or states.

Limitations

If questions were not answered by the teams that did not take the test, the facilitators excluded those questions from QDF calculations so that these questions would not artificially inflate the difficulty factor. However, we were not able to identify the questions that did not get answered by the teams that run out of time. In addition, we do not know how using an electronic device impacted team success. None of the teams participated in the competitions had used such a device in their classrooms before. We did not cross-check if the team electronic submission and the pencil marking on the question sheet matched. Our intention was to grade the question sheets manually only for the teams who were not able to use the Turning Technology devices.

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