

National Eclipse Weather Experiment use and evaluation of a citizen science tool for schools outreach

Article

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National Eclipse Weather Experiment: use and evaluation of a citizen science tool for schools' outreach

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**The National Eclipse Weather Experiment: use and
evaluation of a citizen science tool for schools'
outreach**

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Keywords: citizen science, schools outreach, e-science, meteorology, astrophysics, solar eclipse

For Review Only

Summary

The National Eclipse Weather Experiment (NEWEx) was a citizen science project for atmospheric data collection from the partial solar eclipse of 20th March 2015. Its role as a tool for schools' outreach is discussed here, in seeking to bridge the gap between self-identification with the role of a scientist and engagement with science, technology, engineering and maths (STEM) subjects. (The science data generated has had other uses beyond this, explored elsewhere.) We describe the design of webforms for weather data collection, and the use of several external partners for the dissemination of the project nationwide. We estimate that up to 3500 pupils and teachers took part in this experiment, through the 127 schools' postcodes identified in the data submission. Further analysis revealed that 43.3% of the schools were primary schools and 35.4% secondary. 96.3% of participants reported themselves as "captivated" or "inspired" by NEWEx. We also found that 60% of schools who took part in the experiment lie within the highest quintiles of engagement with higher education, which emphasises the need for the scientific community to be creative when using citizen science to target minority audiences.

1. Introduction

(a) Background

On the morning of the 20th of March 2015, the moon's orbital path crossed in front of the Sun, casting a shadow over planet Earth. For this event, the United Kingdom was one of the few locations privileged to experience a significant partial eclipse. Eclipses have long stimulated the imagination of humankind, even though they are a well-understood consequence of Keplerian planetary motion. Although they have been thoroughly studied and their astronomical predictability has been known for centuries, questions remain over the consequences for the weather of the short-lived lunar shadow in the atmosphere. This astronomical event provided a novel opportunity to investigate some of these weather-related questions. Through involving schools across the UK to provide a huge source of observant young citizen scientists, we recognized that addressing the scientific questions could be combined with a strongly purposed science outreach activity. This combination of motivations provided the impetus for what became known as the National Eclipse Weather Experiment, or NEWEx.

Citizen Science (hereafter CS) projects continue to bloom across the academic community, and a considerable body of literature now exists which focuses not only on the science outcomes but also on the experiences of the participating volunteers and scientists. Unarguably, the exponential growth of modern technologies has catalysed successful CS projects such as those forming part of the Zooniverse¹ (e.g. Solar Stormwatch² [1]) or Open Air Laboratories³. These allow the use of websites or apps for data collection or analysis of large datasets, avoiding a specialised level of scientific knowledge yet still bringing tangible positive outcomes to those who get involved. For instance, the ISPEX project [2] developed and distributed a low cost add-on for smartphones, which converted them into spectropolarimetric instruments to obtain high-resolution maps of aerosol properties. Through a nationwide campaign on the 8th of July 2013, this

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www.zooniverse.org

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3 resulted in roughly 6000 measurements of aerosol concentration, when the weather forecast was
4 favourable for the experiment.
5

6 A central question remains of what motivates volunteers, especially students and teachers, to take part in
7 CS projects. The work of [3], conducted under the Galaxy Zoo project, points towards “contribution”
8 towards original scientific research, as a major motivation to engage with this particular CS project of
9 classifying the morphology of galaxies obtained from large datasets. According to these authors different
10 CS will be driven by their own set of individual motivations and more research is needed to shed light on
11 science learning outcomes, if any, gained by the contributing volunteers.
12

13 On the other hand, a study conducted amongst the astronomy scientific community gives us some insights
14 into scientists’ views on education and public outreach [4]. These authors highlighted the fact that
15 astronomers develop their scientific aptitude from a very early stage (often at primary school level) and
16 therefore they see the benefits of exposing youngsters to STEM-related activities. The authors also point
17 out that outreach is still seen by many peers as a hobby and it often lacks financial support from grants
18 and policymakers, alongside a lack of encouragement from senior staff within academic departments.
19

20 Earlier familiarisation with STEM–subjects was also a topic on a recent report commissioned by Women In
21 Science and Engineering (WISE) organization under their campaign “Not for people like me?” [5] ⁴. The
22 author explores reasons for the UK shortage of skilled workers in Science Technology Engineering and
23 Mathematics (STEM), which reinforced the idea that more needs to be done to engage with schools-based
24 audiences. This is especially so for those from under-represented backgrounds in Higher Education (HE)
25 institutions.
26

27 Changes in Higher Education landscape in England and Wales during the last decade, translated in
28 Universities cementing their commitment to engage positively with their local communities, schools and
29 colleges through outreach programmes, and, specifically, boosting the Widening Participation agenda (see
30 [6] for a chronological summary). These programmes often extend down from the University at institution
31 level to individual departments. To do so, they rely heavily on the altruistic dedication of academics and
32 post-graduate students, who see outreach and public engagement with science as vehicle of dissemination
33 of their own research, as well as a gateway to improve their communication skills.
34

35 In contextualising NEWEx within this ecosystem, we believe this CS project encouraged those who took
36 part self-identifying with the role of a scientist, as it was clearly capable of drawing in a wide profile of
37 schools nationally, who would provide feedback about data collection, science outcomes and legacy of the
38 project.
39

40 (b) Aims of the paper 41 42

43 An assessment of the performance of the CS weather observations collected by volunteers for the National
44 Eclipse Weather Experiment are discussed by [7]. In this paper, we focus on its use as a tool for schools
45 outreach and reflect on the design of the data collection activity through the use of webform platforms. We
46 consider particularly the outreach side of the project, especially where relevant for schools and colleges
47 across UK. We also discuss the dissemination of the experiment achieved by working alongside national
48 platforms such as the BBC’s *School Report*, give an analysis of who took part in the experiment and finish
49 with a summary of recommendations potentially useful in undertaking future events of similar nature.
50 Section 2 is dedicated to the description of the design and implementation of data collection from the
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perspective of usability. In Section 3 we draw a profile of schools that collected data during the experiment and in Section 4 we explore the post-experiment feedback from users who had taken part on the experiment. Finally in Section 5, we draw our conclusions, not only establishing a set of recommendations of how similar weather data collection activities might be implemented for future eclipses but also considering the impact of similar CS project on scholar audiences.

2. Data collection for NEWEx

(a) Science considerations

The major science motivation for this project was to investigate the effects of a substantial solar eclipse on the weather. This science activity effectively began with [8], who brought together weather measurements over a wide area during the US solar eclipse of 1901. Further advances were made from the dual site work of [9] made in cloudy and clear weather during the total solar eclipse of 11th August 1999. This study used high temporal resolution meteorological data to observe the short-term eclipse related changes in temperature, wind speed, wind direction and cloud breakage from two meteorological sites in the UK, the Kehelland Met Office near Camborne, Cornwall and the University of Reading Atmospheric Observatory. The authors found an eclipse-induced decrease in surface air temperature of up to 3 °C in the clear conditions at Reading, and less than 1 °C in the cloudy conditions in Cornwall. The effects on wind speed, wind direction and cloud breakage were rather less conclusive, although widespread public interest in the weather related aspects of the topic was noted⁵.

Further analysis of the 1999 eclipse using a high-resolution weather forecasting model [10] indicated the need for a denser network of observations to advance understanding of wind speed and cloud effects. This led to the idea of using a CS approach to obtain meteorological parameters across the UK during the solar eclipse of the 20th of March 2015 – the National Eclipse Weather Experiment (NEWEx). In addition to the science motivation of acquiring a spatially widespread and dense dataset, NEWEx present a unique opportunity to obtain measurements from a national CS project and the strong associated science outreach possibilities.

The central aim behind NEWEx as a CS experiment was to encourage regular observation of simple meteorological parameters, using a webform for efficient reporting which also allowed rapid analysis. Volunteers who took part in NEWEx were asked to collect information associated with similar variables to those previously explored by [9]: temperature, wind speed, wind direction and cloud coverage. One of the main concerns was how to facilitate the simple measurement of these variables in order for the data to be of research use, whilst finding the best possible platform to collect this data on a national scale. These two factors had to be considered in the context of wide variability in the capabilities expected of the CS data collectors.

Another consideration, which is more fully explored by [7], was how to produce rapid and tangible outcomes from the data collected, to capitalise on the interest of schools and the general public. This was also expected to infuse the data collectors with a sense of ownership and positive contribution towards the project. This latter aspect was addressed by embedding analysis infrastructure from the outset, to provide plots and updated data on regular intervals of time on part of the Meteorology Department's website. On the eclipse day, these plots made the front page of national news media outlets within hours of their release.

(b) Designing of the website for data collection

The transient nature of the eclipse and the need to collect data across the entire UK argued strongly for the use of a webform, to provide a systematic, uniform and efficient collection tool. In the analysis of the total solar eclipse of 1999 [10], data values were used from the UK meteorological measurement network, which then amounted to 121 sites reporting hourly. Not all of these sites reported their data in a consistent way, which limited the analysis undertaken. Use of the webform permitted a greater density of rapid measurements. Advantages and disadvantages of collecting online data for research have previously been widely discussed [11].

The options for designing webforms lie across a spectrum, from an entirely custom design supported by a programmer to use of a standard tool supported on a wide variety of platform by a major corporation. Because of the platform compatibility issue, and indeed cost, we decided to use Google Forms⁶ to design our system, as this platform provided the necessary web infrastructure required, and ultimately, capacity for an unknown number of users which could possibly be very large. Google Forms also had an adequate level of adaptability needed for the basic data collection. For example, it allowed for different types of responses such as regular text, multiple-choice entries and, amongst others, the ability to select an item from a list. The information required from the user was location, surface air temperature, clouds, wind force and wind direction, with the meteorological observations recorded at regular intervals.

Location was entered via a postcode, as the exact measurement location was not needed, and provided some level of confidentiality. (The spatial aspects of the data are explored further by [7].) The temperature information was expected to be obtained from a simple (liquid in glass or digital) thermometer, typically able to be read to a resolution of between 0.1 °C and 0.5 °C. The wind strength was to be categorised by Beaufort force, for which the standard descriptions were given, and the wind direction by a pull down menu of eight compass directions. Cloud amount information was simplified into three categories of overcast, broken cloud and clear. In this way the only instrumentation actually needed was a thermometer to measure the air temperature. Basic instructions on measuring air temperature in the shade were given, following the usual meteorological practice [12]. Table 1 summarises the range and step size of each parameter recorded by the survey.

Table 1 – Data entries sought on NEWEx webform for data collection. We present the parameters used as well as the range of values employed and, when applicable, their step size.

Parameter	Range of Values	Step size
Time	08:00-9:00; 10:00-11:00	15 minutes
Time	9:00-10:00	5 minutes
Temperature	-10 C – 20 C	0.5 C
Wind Speed	Beaufort force 0-6	1
Wind Direction	N-NE-E-SE-S-SW-W-NW-N	n.a.
Cloudiness	Clear sky, Some cloud, Much cloud, Overcast	n.a.

The webforms matured through two major iterations. At each stage, concerns existed over how to balance the mixed abilities of the users with the accuracy required from the data for scientific purposes. In the first iteration of the forms, generated about a month before the eclipse, the user was asked to enter the time of

observation to a resolution of 1 minute and then to fill in temperature in degrees Celsius, rounded to the nearest 0.5 °C, wind speed in miles per hour and wind direction, the latter chosen from a drop-down list of compass points. This first version was released internally amongst peers. Feedback made it very clear that, for more than one observation, the webform would have to be repopulated each time. Clearly, this presented a substantial risk that the users would just give up on the data entry so an improvement was sought.

Major changes were made and a second iteration of the webform generated, designed to avoid burdening the citizen scientists with multiple webform submissions. This revised version as seen in Figure 1, was structured so that all the observations from one observer, for the entire eclipse, could be submitted at once. To do this, the observations of each meteorological variable were discretised into a matrix of radio buttons, with the columns giving the meteorological parameter values, and the rows corresponding to different observation times. This meant that numerical values were not entered individually, but instead selected from available options. This had the additional benefit of preventing entries from being mis-keyed, reducing the error checking requirement and the associated loss of data. A complete transcript of the webform is available as supplementary information.

Figure 1 – Second and final version of the webform released to public to allow users to record their entire observations with a single submission.

The Google form was embedded in the Department of Meteorology website. This increased traffic to the website and with it, the profile of the institution. However, there was a fear that if large numbers of volunteers participated in submitting data via the webform (and there was no basis for estimating the take-up in advance), both the webform, and the software produced to gather and analyse the data might fail. Therefore it was important that the complete data submission and analysis system was tested beforehand, with a large number of submissions. This was done by generating synthetic meteorological observations of 10,000 observers, which were then submitted via the webform automatically, over a few minutes, as further explained in [7]. This volume of data was significantly more than that expected to be received during the eclipse, and it was demonstrated that there no difficulty in the complete NEWEx submission and analysis system processing these.

After putting up the webpages of information about the forthcoming NEWEx activity, questions about how to enter the data and what was needed began to arrive. Many similar enquiries were received, which began to become onerous. This was managed by producing a list of frequently asked questions (FAQ) on the same website, as and when a particular query was made. This provided a means to manage the enquiries effectively, particularly those around the type of instruments needed. Further, the material was used to draw attention to important information about safe ways to observe a solar eclipse.

(c) Dissemination methods adopted

We marketed NEWEx through a multitude of communication vehicles with the intention of national coverage, so as to get good spatial information on the transient phenomena expected in the atmosphere. To do this we relied heavily on third parties such as learned societies with distribution lists, partnerships with other institutions and direct engagement with the media.

We also drew attention to the eclipse by publicising a special in-house event. This was on the evening prior to the partial eclipse, for which we organized a series of lectures attended by 215 members of our local community. This brought together specialists not only to talk about the science but also explore the folklore behind eclipses. This interdisciplinary approach brought together science, history and arts associated with eclipses. Further details on the depiction of eclipses in art can be found in [13].

For the eclipse morning itself, we sent out invitations to local schools to attend a solar eclipse event held on the Whiteknights campus of the University of Reading co-hosted by the Reading Astronomical Society⁷, which provided a variety of telescopes and filters. Fifty-five students from both primary and secondary local schools attended this event alongside the majority of members of staff and postgraduate students of the Department.

At the regional level we made use of our partnerships with the South East Physics network (SEPnet), The Institute of Physics (IOP) and the Royal Meteorological Society (RMetSoc) all of whom willingly disseminated the experiment amongst their contacts.

A particularly fruitful collaboration arose from engagement with BBC Education, through their *School Report*⁸. This is a news report filmed and directed by school children for school children, in the past working with over 1000 schools in developing the journalistic skills. This synergistic collaboration resulted in a special edition of the Schools Report, with some of this paper's authors being interviewed by local secondary school pupils⁹; the relationship which developed also led to contributions to the BBC Stargazing Live event held in Leicester Racecourse on the eclipse day, in which live, regular updates from NEWEx were provided.

Even though only 26% of the participants found about NEWEx through media coverage (see Section 4 for further details), we reinforce the importance of the media as vehicle of dissemination: from local radio interviews to influential national newspapers^{10,11} and television, the unexpected ability of NEWEx to raise media interest highlighted the broad interest in the topic.

7 www.readingastro.org.uk

8 www.bbc.co.uk/schoolreport

9 www.bbc.co.uk/schoolreport/31591588

10 www.theguardian.com/science/solar-eclipse
11 <http://mc.manuscriptcentral.com/issue-ptrsa>

3. Analysis of the data

(a) Summary of NEWEx data collection

Data submission for the National Eclipse Weather Experiment began on the morning of the eclipse day (20th March 2015, a Friday) at around 7:30 GMT, with the last data entry a few days after the experiment on the 27th of March 2015. During this period we received 503 web form submissions, 475 of which were submitted on the day of the eclipse, with the remaining submitted subsequently. The geographical location of each submission was determined from the participant's postcode, which was converted in software to geographic longitude and latitude. Some multiple data entries were associated with the same postcode. We now focus on entries with postcodes matching school locations across the UK.

(b) Data selection and validation

During the first inspection of the 503 NEWEx data entries, incomplete and duplicate postcodes were sought and removed. To study the schools' profiles, our approach was to keep the first entry per site and discard any subsequent duplicate entries with the same complete postcode. This reduced the sample to 271 individual full postcodes. (The accompanying publication [7], which assessed the performance of data collected by CS volunteers, presents greater numbers, as full postcodes were not needed to validate their data entries.) We discarded partial postcodes, as we could not match them with schools or non-schools postcodes as we categorize data for further analysis.

The geographical distribution of the individual postcodes can be found in Figure 2, where they are divided them into two groups of schools and non-schools, which is a distinction developed further in this paper. In Table 2 we subdivided postcodes by regions to highlight the fact the schools, which participated, were not evenly distributed across the country. We found a higher concentration of schools postcodes from the South East (68 out of 127) followed by Scotland (39 out of 127). By opposition we found fewer schools' postcodes from Northern Ireland (2 out of 127) and Wales (6 out of 127).

Figure 2 – *Left panel:* Geographical distribution of postcodes associated with NEWEx data submission online for both schools postcodes (yellow squares) and non-schools postcodes (pink dots). *Right panel:* Distribution of postcodes associated with NEWEx data submission according to their quintiles of young participation with Higher Education also know as POLAR classification. (POLAR quintile 5 relates to the highest engagement postcodes, quintile 1 with the lowest.)

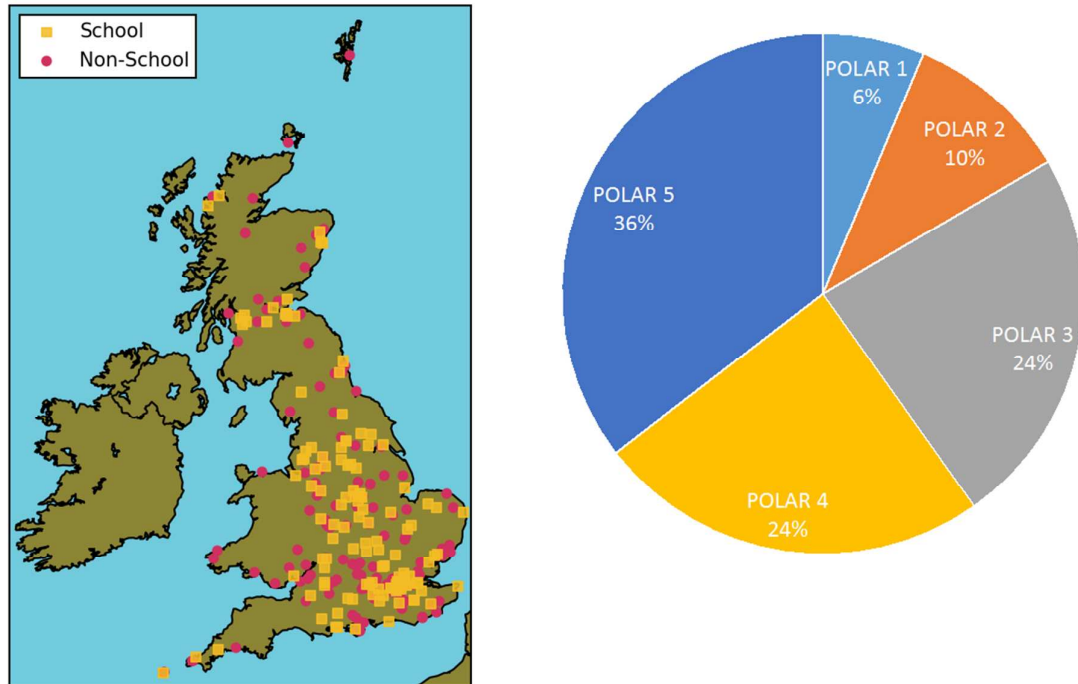


Table 2 - Distribution of complete postcodes by regions, submitted during the National Eclipse Weather Experiment. Postcodes have been categorized as originated from schools or non-schools (as explored in Section 3).

Region	schools	non-schools	both
South East	28 (22.0%)	40 (27.8%)	68 (25.1%)
Scotland	17 (13.4%)	22 (15.3%)	39 (14.4%)
London	14 (11.0%)	4 (2.8%)	18 (6.6%)
East Midlands	13 (10.2%)	10 (6.9%)	23 (8.5%)
Yorkshire and The Humber	12 (9.4%)	5 (3.5%)	17 (6.3%)
East of England	12 (9.4%)	15 (10.4%)	27 (10%)
South West	12 (9.4%)	15 (10.4%)	27 (10%)
North West	10 (7.9%)	8 (5.6%)	18 (6.6%)
West Midlands	6 (4.7%)	11(7.6%)	17 (6.3%)
North East	2 (1.6%)	6 (4.2%)	8 (3%)
Wales	1 (0.8%)	6 (4.2%)	7 (2.6%)
N Ireland	0 (0.0%)	2 (1.4%)	2 (0.7%)
Totals	127 (100%)	144 (100%)	271 (100%)

(c) Demographics of contributing schools

Postcodes from entries were checked with the Department for Education Edubase2 website¹² which holds information on educational establishments in England and Wales. When postcodes were found to be

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2
3 Scottish we made use of the Scottish Government equivalent online database¹³. We found that 127 (47.2%)
4 of the postcodes submitted were associated with schools against 144 (52.8%) of the postcodes belonging to
5 non-schools. Out of the 127 school postcodes, 55 belonged to schools identified as Primary (43.3%), 45
6 schools identified as Secondary (35.4%); for a further 27 establishments this distinction was not applicable
7 (21.3%).
8

9 Postcodes associated with schools were then analysed further, motivated by the Widening Participation
10 agenda mentioned in the introduction of this paper. As mentioned above, Higher Education Institutions
11 aim to become more diverse by seeking students from under-represented backgrounds. In the UK every
12 postcode is associated with a measurement of participation rates in Higher Education¹⁴ also known as
13 Participation of Local Areas (POLAR3) classification. This database is maintained by the Higher Education
14 Funding Council for England (hereafter HEFCE) and each individual postcode falls within one of five
15 quintiles identified by POLAR3. Areas with the least young participation rates fall within quintile 1 and
16 those with the greatest young participation rates fall within quintile 5.
17

18 Cross-referencing of the NEWEx postcodes with POLAR3 data classification is presented in Fig.3. This
19 shows that the engagement of schools with NEWEx came predominantly from those in the quintiles 3 to 5,
20 who, following the definition of this category, already have high rates of participation with higher
21 education. Quintile 4 (24%) and quintile 5 (36%) together contribute 60% of the participating postcodes.
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23

24 4. Feedback

25
26 After the eclipse data collection itself was over, a further Google Form was devised and the link sent out to
27 participants for feedback. (The questions asked are shown in the electronic supplementary material
28 supporting this article.) The feedback form was divided into two sections: a first section contains general
29 questions about the user such as their location, category and overall experience. A further section was
30 schools-related, as we wanted to unveil the impact and legacy of the project beyond the data collection and
31 quasi-live results as further explored by [7]. The information obtained by this analysis was both
32 quantitative and qualitative. A total of 31 responses were obtained between the 27th of March and the 30th
33 of March. 27 respondents identified as schools, 2 as general public, and 1 as other.
34

35 (a) Sample of survey

36
37 The 27 feedback responses, which identified themselves as schools constituted 22% of the original number
38 of NEWEx schools' postcode data. Nonetheless, only 20 of these could be matched with the postcode data
39 collected during the eclipse. This means that only 16% of the schools submitting data during the eclipse
40 responded to our post-eclipse survey. There are no doubts that such discrepancy could be easily attributed
41 to human input error or inconsistency between the locations where observations were taken (within the
42 vicinities of the school) compared with the actual postcode of school.
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44

45 The much-reduced overall response suggests that the main commitment to the science activity was an
46 important motivator in the original NEWEx participation. We can further speculate that seeking the
47 feedback nearly a week after the partial solar eclipse might also have reduced the number of returns.
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58 www.education.gov.uk/edubase/home

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59 www.educationscotland.gov.uk/parentzone/myschool/findaschool/

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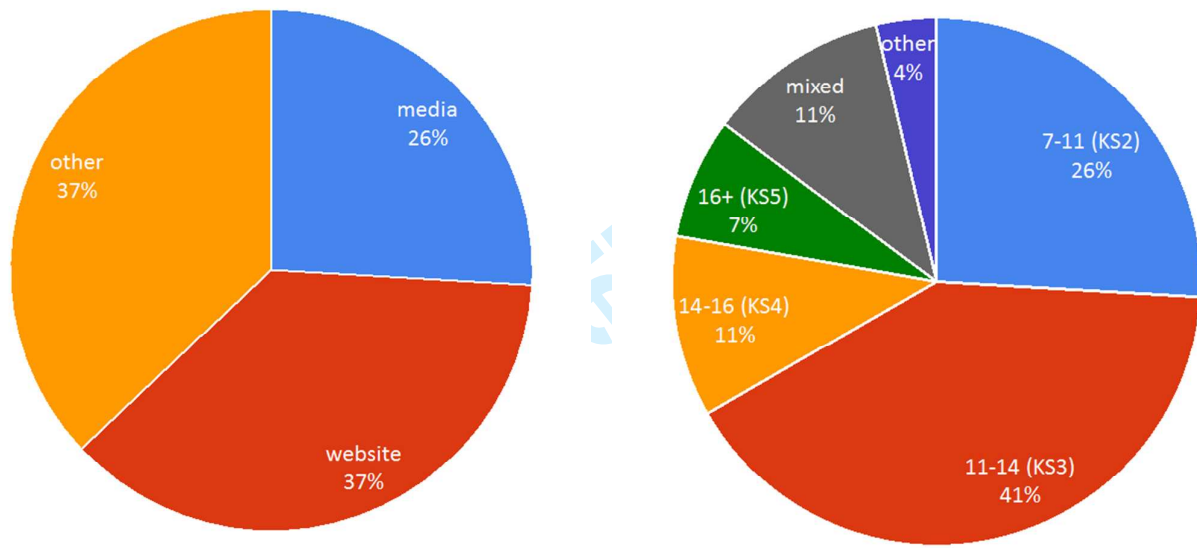
60 www.hefce.ac.uk/pubs/year/2012/201216/ <https://mc.manuscriptcentral.com/issue-ptrsa>

Nevertheless, we believe 22% to be a useful response level, and the very specific nature of the comments provided leads us to consider them further.

(b) Demographics

We found that 37% of participating schools heard about the experiment via the Department of Meteorology website, 25.7% via media coverage and a remaining 37% through other routes. As for the age groups of the pupils involved in the experiment, we found that 40.7% were 11-14 years old (corresponding to Key Stage 3), and 25.9% of pupils were between 7 and 11 (Key Stage 2). We present both quantitative results in Figure 3. When asked about the impression made on pupils by the activity, 96.3% of respondents were “captivated” or “inspired” by the National Eclipse Weather Experiment.

Figure 3 – Sources of information about the project (left) and age group of pupils who collected data for NEWEx (right panel) according to feedback survey.



It is impossible to calculate the precise number of school students involved in the experiment because only age ranges were asked for on the feedback forms. Our most conservative estimate (based on the ranges plus exact numbers provided by some schools) indicates between 577 and 775 pupils. We can only speculate about total number of students involved nationwide in NEWEx, as to do so requires the assumption that the 22% of schools providing feedback provide a good statistical representation of the groups of schools participating. Extrapolating on this basis in the remaining 78% of schools, which did not respond to our post-eclipse survey conservatively points towards the involvement of 2600 to 3500 pupils in NEWEx.

The surveys also revealed that some follow up activities using the weather eclipse data were undertaken. Overall, pupils used their own data “to draw some line graphs”. One respondent pointed to the benefits of the availability of their own data “We produced graphs of all the data we had collected every 2 minutes - temperature, pressure, humidity, wind speed - which allowed pupils to draw their own conclusions very quickly”. In another context pupils download the maps released on the departmental website and explained any trends: “We looked at our location in particular and we tried to get the children to see if it tied-in with their raw data.”

(c) Usability of webform as a tool to collect data

The feedback survey revealed that 92.6% of the respondents found data entry on the webform to be “easy” with the remainder 7.4% responding “other” which we will explore next. Only one of the respondents found it “really poor - could not see the time slots or criteria at the top of the page when I scrolled across to enter data ...” suggesting a freeze frame could be helpful to guide the user through the input table.

Another respondent commented on data entry being easy nonetheless “...we had extra info to do with pressure/humidity/data every 2 minutes so an “attach” option would have been good.” Indeed, some schools subsequently sent in their data by email to the Department of Meteorology directly in case it could be used for further analysis. In both cases the nature of the comments reflects the limitations of the generic webform platforms rather than the way the data collection was designed. As mentioned in Section 2, with the second iteration of the webforms we focussed on fixing and sampling time intervals around the peak of the eclipse in order to streamline data entry, so we regard that process (of initial trial and revision) as having been rather successful.

(d) Participation aspects of the experiment

Participants were also invited to provide feedback on participating in the experiment. Overall we found positive feedback on the engagement with the CS project.

‘We enjoyed being part of this - even if the skies were full of cloud!’, reports back one of the participant. In fact, local weather may have dictated the engagement with the project as, when skies were clear, the astronomical phenomena became the principal interest: *‘We did end up giving up on the experiment - but only because the pupils being 10 years old struggled with the excitement of the eclipse and taking readings at the same time! This is through no fault of the way the experiment had been set up by yourselves. Everything was fully explained and clear to follow.’* Obviously, for many of the participants this was probably the first eclipse they had experienced, and that this would take precedence over the weather experiment. Nevertheless, if the eclipse was not visible at a site due to cloud, the eclipse occurrence could, at some sites, only have been evident from the temperature measurements.

Interestingly [7] reports that CS volunteers collected half of the data during the peak of the eclipse and the other half prior and after the peak, which could be interpreted as symptomatic of a genuine interest in the science goals associated with NEWEx. Unfortunately we cannot further speculate about the volume and frequency of data submitted against cloudiness in situ, which could shed some light on the most prevalent motivations of CS volunteers in terms of direct participation in science versus observation of natural phenomena.

Revisiting the work of [3] around motivations of volunteers who took part in Galaxy Zoo, “contribution” towards original scientific research gathers 40% of responses. It was never a primary goal of our project to conduct such a thorough investigation on motivations behind participating in NEWEx. The study conducted by [3] made use of a robust Likert scale applied to a matrix of motivations, which volunteers were asked not only to rank, but also to choose the most important motivation. Our approach was qualitative allowing respondents to provide additional comments on their involvement with NEWEx. As the authors of [3] emphasises the need to compare motivations of the galaxy Zoo project and other CS projects and perhaps this could be seen as challenge for future NEWEx-like experiments.

We also revisit the idea mention on Section 1 on the need of the scientific community to expose scholar audiences to positive STEM-related activities from an early age to create a long lasting impact and combat the shortage of STEM graduates in the UK. This was supported in some of the following comments: *“Opening up the investigation to the public allowed children in our school to work on a real life situation, using equipment they were unfamiliar with, working as a team and interpreting data.”* One of the participants added that *“...the experiment was a really good way of getting students excited about science and because it was real data collection for a real project, it gave them a taste of what being a scientist is really like.”*

Even though NEWEx facilitated a short-lived window of useful skills scientists employ to conduct research, more need to be done by practitioners to combat stereotypes associated with scientists and science as discussed by [4]. As the author further explains, in order to bridge the gap with a STEM identity, younger audiences need to be exposed to a different types of scientists (as profiled in this study) all with

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3 unique skillsets beyond their academic knowledge. We like to think that NEWEx allowed volunteers to
4 identify with the “investigator”, “explorer” and the “service provider” profiles and that the work of [4]
5 will be of value when designing future CS projects as it can help engaging with hard to reach audiences.
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8 How to include hard to reach audiences, such as POLAR3 schools belonging to quintiles 1 and 2 (both
9 demographics adds to 16% of the overall schools who engaged with NEWEx), is a current and complex
10 question amongst practitioners. Producing a rigid set of guidelines of proven effectiveness seems
11 unachievable as there are so many unforeseen and unexplored factors in nature versus nurture (e.g.
12 parental engagement, schools’ infrastructure, quality of teaching). In addition an open question remains of
13 how to deal with audiences, which simply do not want to engage with STEM-related activities.
14

15 Finally we would like to point the reader to one apposite comment which summarizes the goals we set
16 ourselves when we first devised NEWEx as a CS tool to schools’ outreach: *“Our entire School participated, as
17 we have a total of 38 children from age 5-11. Each child pretended to be scientists, astronomers and
18 meteorologists! They actually were indeed ‘citizen scientists’, thanks to your outreach to the whole of the UK. This
19 participation experience combined with the actual eclipse viewing really touched each of our students. We cannot
20 thank you and the BBC enough for this incredible opportunity to learn, have fun, and see how wonderful it can be to
21 connect with nature and science. We hope our session with the kids watching the eclipse and actually collecting data
22 for your project, has planted at least one seed in the mind of a child that will inspire the next generation of eminent
23 scientists in the UK! A heartfelt thanks to you all, and with our kindest regards”.*
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27 5. Summary and recommendations

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30 In this paper we have presented NEWEx as a Citizen Science tool for schools outreach, covering the issues
31 of designing, facilitating and disseminating the collection of data through the use of online surveys or
32 webforms. We have also explored the demographics of schools taking part in the CS project together with
33 their feedback about the experience. We summarize the highlights of our findings below:
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- 36 A fundamental part of NEWEx was conveying the enthusiasm for the science opportunity in
37 getting schools across the UK involved in weather data collection for the 20th March 2015 solar
38 eclipse; [3] reports that half of the data submitted coincides with the peak of the eclipse which can
39 be seen as a genuine interest from volunteers to contribute to scientific research.
- 40 Postcode analyses mapped 47% of NEWEx submissions to schools.
- 41 Schools which participated were not evenly distributed across country with a high proportion
42 (22%) coming from the South East. 43.3% of schools were identified as primary, 35.4% as
43 secondary and for the remaining 21.3% of schools this distinction was not applicable.
- 44 60% of schools who took part in NEWEx were found to be provident from postcodes where the
45 engagement levels with Higher Education as classified by HEFCE falls within the 2 highest
46 quintiles denominated POLAR 4 and 5.
- 47 Post-experiment feedback data indicated that 2600 to 3500 pupils and their teachers took part on
48 this CS project. 96.3% of the participants responding were “captivated” or “inspired” by NEWEX.
- 49 Anecdotal feedback shows a good level of satisfaction with the usage of the webform for data
50 submission and tangible educational outcomes of the project, as teachers made the best usage of
51 the data in their classroom.
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57 The following points should be seen as general recommendations for future NEWEx-like CS projects

- 58 Webforms were found to be a reliable tool to use for national data collection. Careful webform
59 design needs to take in consideration the wide abilities of the data collectors. Simplifying the data
60 <http://mc.manuscriptcentral.com/issue-ptrsa>

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3 collection (e.g. fixing the times of the observations and minimizing the number of instruments
4 necessary) were strong themes in our webform design.

- 5
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7 Webforms associated with data gathering, should include a simple identification of the data
8 collector (e.g. school, public, other)
- 9
10 Use of partner organisation was of extreme importance in engaging with a nationwide audience.
11 The combination of local partners and national partners (particularly BBC Education's *School*
12 *Report*) catapulted NEWEx into the media and into schools.
- 13
14 In addition to questions which help draw the demographics of participating volunteers, feedback
15 forms, could include an in-depth motivation matrix survey to thoroughly understand what
16 motives volunteers to participate in CS projects.

17
18 The popularity of Citizen Science projects has been increasing over the last decade and the evidences
19 drawn from NEWEx here shows that they can play an important role in positively engaging students with
20 science. We hope that our findings will be of great help not only to improve future NEWEx-like activities
21 but also to general outreach and public engagement practitioners.

22 23 24 25 Additional Information

26 27 28 Acknowledgments

29
30 The authors would like to thank first and above all, all the anonymous data collectors who helped making
31 NEWEx a huge success. Peter Gibbs from BBC Weather and Angela Morrow and Pamela Lingham of BBC
32 education helped considerably with the national aspects. Pete Castle of the University of Reading
33 Communications Office ably coordinated the many media approaches. The authors would also like to
34 thank the anonymous referee for the constructive feedback provided.

35 36 37 Data Accessibility

38
39 The datasets supporting this article have been uploaded as part of the Supplementary Material.

40 41 42 Competing Interests

43
44 *We have no competing interests.*

45 46 47 Authors' Contributions

48
49 AP drafted and analysed the data for the paper. AP and RGH designed the NEWEx and feedback
50 webforms. LAB produced Fig 3 and contributed drafting of section 2 b and 3a. RGH revised the final
51 manuscript with contributions from all authors.

52 53 54 55 References

1. Barnard LM. et al. 2012 The Solar Stormwatch CME catalogue: results from the first space weather citizen science project. *Space Weather* **12**, 657-674. (10.1002/2014SWD00119)
2. Snik F. et al. 2014 Mapping atmospheric aerosols with a citizen science network of smartphone spectropolarimeters. *Geophys. Res. Lett.* **41**, 7351-7358. (10.1002/2014GL061462)
3. Zooniverse motivations paper
4. Dang L, Russo P. 2015 How Astronomers View Education and Public Outreach: An Exploratory Study. *Communicating Astronomy with the Public* **18**, 16-21
5. MacDonald, A. 2014 "Not for people like me?" Under-represented groups in science technology and engineering. See https://www.wisecampaign.org.uk/uploads/wise/files/not_for_people_like_me.pdf
6. Lewis, B. 2002 Widening Participation in Higher Education: The HEFCE Perspective on Policy and Progress. *Higher Education Quarterly* **56**, 204-219 (10.1111/1468-2273.00212)
7. Barnard, LM, Portas, A., Gray, S.L.Harrison, R. G. *The National Eclipse Weather Experiment: An assessment of the performance of the scientist weather observations*, [This issue]
8. Clayton HH. 1901 The Eclipse Cyclone and the Diurnal Cyclones. *AAOHC* **43**, 5-33
9. Aplin KL, Harrison RG. 2003 Meteorological effects of the eclipse of 11th August 1999 in cloudy and clear conditions. *Proc Roy Soc Lond A* **459**, 353-372. (10.1098/rspa.2002.1042)
10. Gray SL, Harrison RG. 2012 Diagnosing eclipse-induced wind changes. *Proc Roy Soc Lond A* **468**, 1839-1850. (10.1098/rspa.2012.0007)
11. Wright KB. 2005 Research Internet-based populations: Advantages and Disadvantages of Online Survey Research, Online Questionnaire Authoring Software Packages, and Web Survey Services. *J Comput-Mediat Comm* **10**, 00-00. (10.1111/j.1083-6101.2005.tb00259.x)
12. Harrison RG. 2014 *Meteorological Measurements and Instrumentation*, 1st edn. Wiley-Blackwell
13. Blatchford, I. 2016 Symbolism and Discovery: Eclipses in Art [*Phil Trans* This issue]

Supplementary material

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NEWEx - National Eclipse V x

https://docs.google.com/forms/d/1QsaWU5DZZ7_6S6YCrXlx7m4y2Na-65-UyAGomNlgGwU/viewform

Location

Please give us your full postcode e.g. "RG6 7BE"

Tell us where you are *

Air Temperature

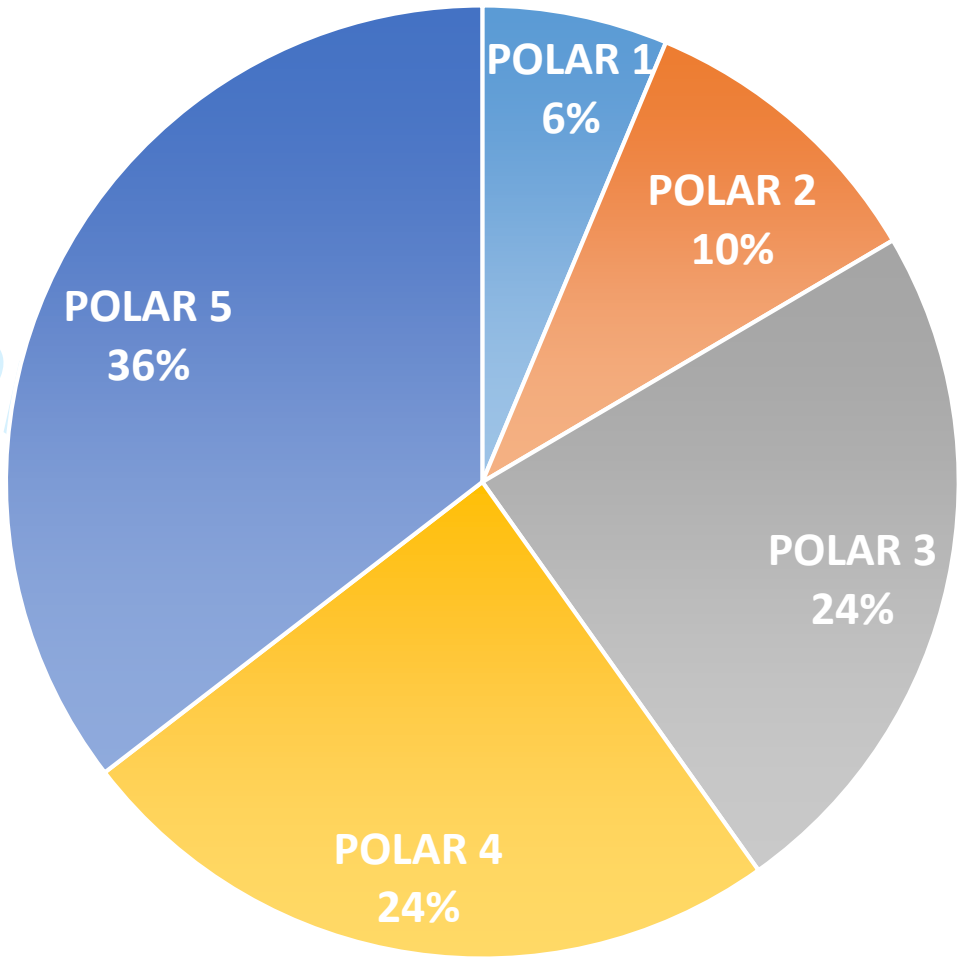
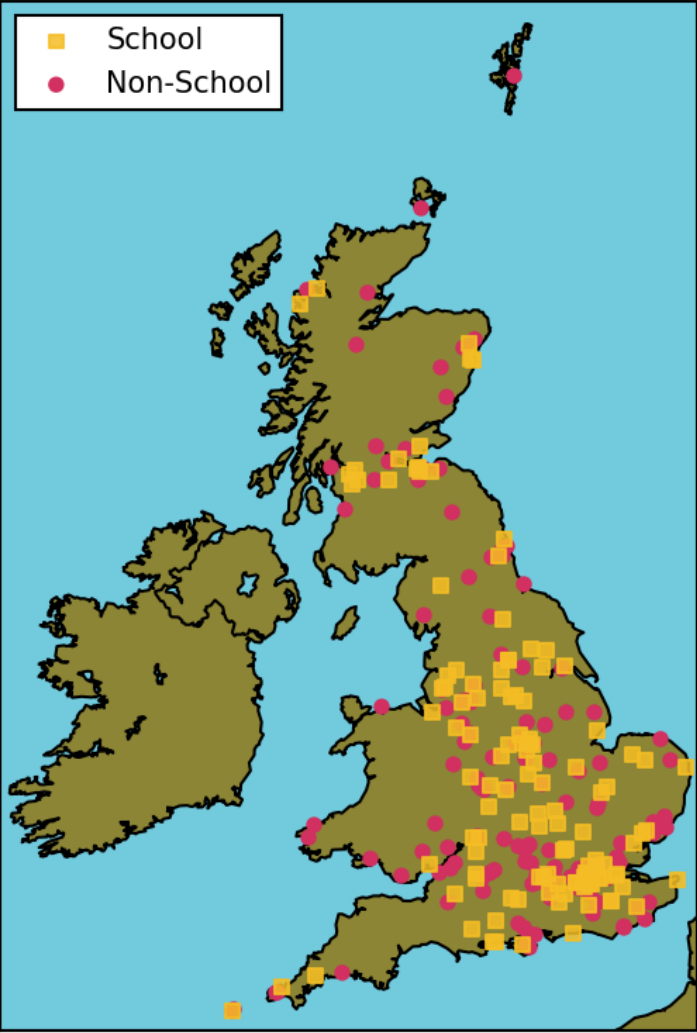
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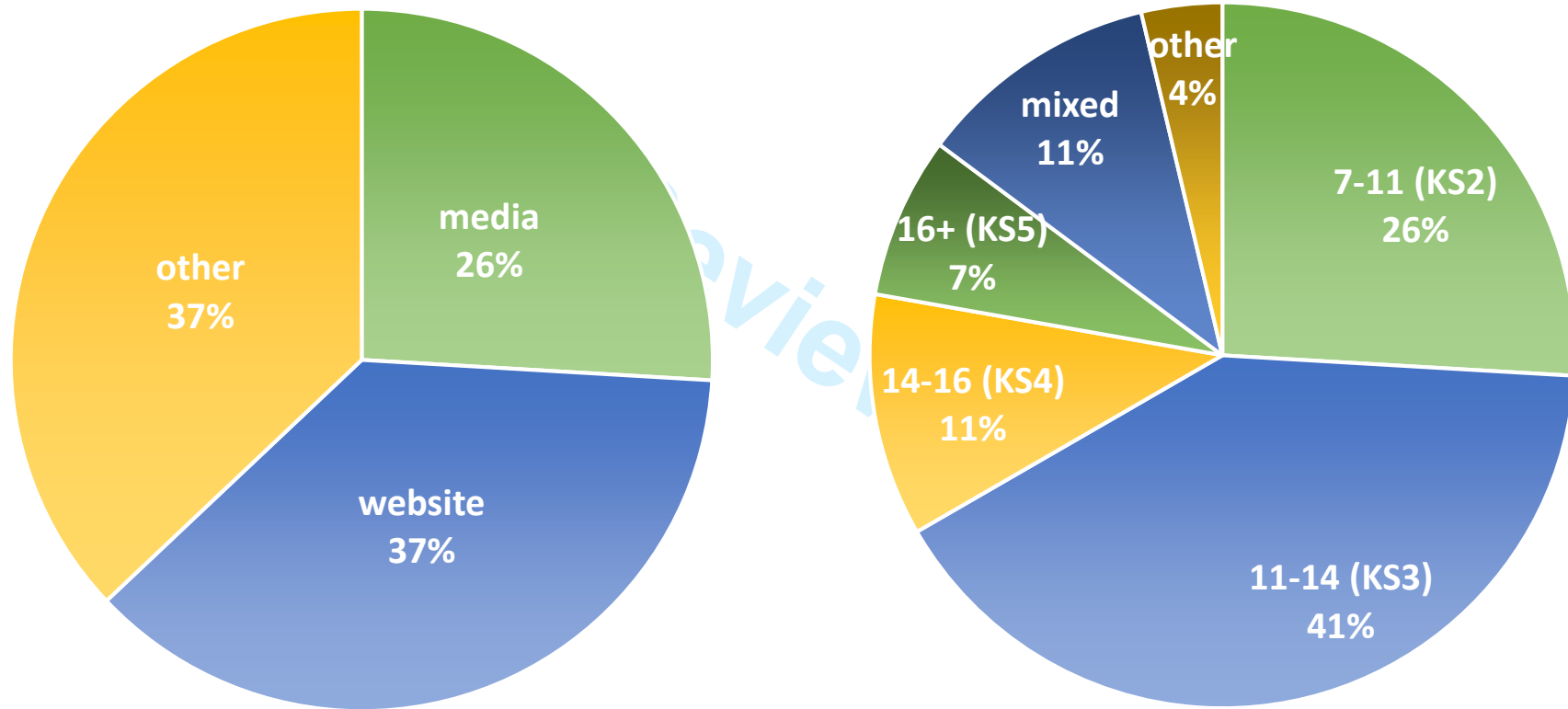
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