
International Journal of Science Education
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tsed20

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Published online: 02 Jul 2015.



To cite this article: Ibrahim Delen & Joseph Krajcik (2015) What Do Students' Explanations Look Like When They Use Second-Hand Data?, International Journal of Science Education, 37:12, 1953-1973, DOI: 10.1080/09500693.2015.1058989

To link to this article: http://dx.doi.org/10.1080/09500693.2015.1058989

*International Journal of Science Education*, 2015
Vol. 37, No. 12, 1953–1973, http://dx.doi.org/10.1080/09500693.2015.1058989

# What Do Students' Explanations Look Like When They Use Second-Hand Data?

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Explanation studies underlined the importance of using evidence in support of claims. However, few studies have focused on students' use of others' data (second-hand data) in this process. In this study, students collected data from a local water source and then took all the data back to the classroom to create scientific explanations by using claim–evidence–reasoning model on a new mobile application. A middle school science teacher from a Midwest town participated with four sixth-grade classes. After collecting their own data from a local water source, students created explanations by analyzing the data they collected (first-hand data), and by analyzing existing data set collected by another school from another river (second-hand data). By analyzing the health of these two water sources, students created two scientific explanations. Students participating in this study created stronger explanations when analyzing the data they generated (first-hand data).

Keywords: *First-hand data; Second-hand data; Explanations*

## Introduction

The Framework for K-12 Science Education (National Research Council [NRC], 2012) and the Next Generation Science Standards (Achieve, 2013) underline students creating scientific explanations as an important scientific practice. The National Research Council Framework (NRC, 2012) defined scientific explanations as the connection between scientific theory and observations. Similar to the standards in USA, Osborne and Dillon (2008) recommended an emphasis on the understanding of 'the material world that science offers and about the way science works' (p. 15) to improve the quality of science education in Europe. The NRC report (2012) stated that

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students' role in this process is to 'demonstrate their own understanding of the implications of a scientific idea by developing their own explanations of phenomena' (p. 68).

To define the scientific explanation process, McNeill, Lizotte, Krajcik, and Marx (2006) developed a framework by decomposing scientific explanations into claims, evidence, and reasoning (CER). Gotwals, Songer, and Bullard (2012) used the term 'evidence-based explanations' (p. 186) to refer to constructing explanations, while also using the CER framework for structuring this process. Common to these studies is the definition of a claim as a statement that answers a question; evidence as the data to defend the claim; and reasoning as the link between the evidence and the claim that shows why certain data can serve as evidence and other data are inappropriate (Gotwals et al., 2012; McNeill et al., 2006).

When creating explanations, the Next Generation Science Standards (Achieve, 2013) states the importance of generating data, using data to support claims, and including scientific principles to illustrate how data serve as evidence. To illustrate the role of generating evidence, Osborne and Dillon (2008) suggested elementary and middle school teachers focus on science learning by 'extended investigative work and "hands-on" experimentation and not through a stress on the acquisition of canonical concepts' (p. 19).

Consistent with the policy documents in the USA (Achieve, 2013) and Europe (Osborne & Dillon, 2008), previous studies (Duschl, Schweingruber, & Shouse, 2007; McNeill & Krajcik, 2007; McNeill et al., 2006; Novak & Treagust, 2013; Sandoval & Millwood, 2005; Simon, Erduran, & Osborne, 2006) and standard documents (NRC, 2000, 2012) stress that evidence is central to building a scientific explanation.



### *Rationale for the Study*

In addition to stressing the importance of using evidence when creating explanations, the NRC (2012) framework also promoted the importance of evaluating the evidence collected by others. For example, when students complete their explanations they are expected to 'evaluate their own and others' explanations for consistency with the evidence' (NRC, 2012, p. 69). Before creating explanations, students define the problem (NRC, 2012), and in this process they are expected to 'critique by asking questions about their own findings and those of others' (NRC, 2012, p. 74).

Evaluating data collected by others is a crucial component of science education, since engaging in this practice is a crucial skill for scientists (Duschl et al., 2007; NRC, 2012; Osborne, 2010). Because engaging students in collecting data also engages students in the content, several studies supported students to generate their own evidence (McNeill & Krajcik, 2008; McNeill et al., 2006; Novak & Treagust, 2013; Sandoval & Millwood, 2005; Simon et al., 2006; Songer, 2006) since it helps students to familiarize with the content. To distinguish the differences between data sources, we refer to data generated by students as first-hand data, and data generated by others' data as second-hand data.

In this study, our goal is to examine the quality of students' explanations when they used first-hand data to investigate the water quality of a local stream (West Park (WP)), and when they used only second-hand data to determine the water quality of a regional river (Rouge River (RR)).

Our first research question examined the quality of students' explanations when using the data they collected (first-hand data): 'What is the quality of student explanations when they use data they collected?' To answer this question, we analyzed the quality of students' explanations after visiting WP. When analyzing these explanations, we focused on how students justify their claims by using evidence (Kuhn et al., 2012; McNeill et al., 2006; Novak & Treagust, 2013; Sandoval & Millwood, 2005; Simon et al., 2006). When analyzing the health of WP, students also had access to the data collected by their peers in the same day from WP. Our goal was to provide a larger data set when creating explanations.

The second research question investigated students' explanations when using only second-hand data from a source that students did not visit: 'What is the quality of student explanations when they only use second-hand data?' Previously, Hug and McNeill (2008) found that students' use of second-hand data affected how students justified their evidence. The second research question focused on whether providing only second-hand data affects the quality of students' claims and reasoning statements.

When examining the explanations students created by analyzing only second-hand data, students' sense of ownership over the data could play an important role. Data that students collect on their own is more contextualized and learners see value in the work they are doing (Gordin, Polman, & Pea, 1994; Rivet & Krajcik, 2008; Tal, Krajcik, & Blumenfeld, 2006; Woodgate et al., 2008). When students are involved in the data collection process, this increases their involvement in the work they are doing. Hug and McNeill (2008) noted that when students analyzed different data sets, students were 'willing to accept second-hand data with little questioning about the source' (p. 1746). On the other hand, when students analyzed their own data (first-hand data), Hug and McNeill (2008) found 'an unexpected amount of ownership that students voiced with regard to their own first-hand data and their willingness to critique and discuss the limitations around it' (p. 1746). Although students participating in our study will investigate identical data sets, because of the ownership effect, we do expect students to create higher level explanations when they write explanations with the data they generated (first-hand data). Before moving forward, we will examine how previous studies supported students' use of second-hand data. Previous studies used two ways when supporting this process: (1) providing existing data sets and (2) creating data pool to combine first-hand and second-hand data.

### *Providing Data Sets for Examining Second-Hand Data*

In one of the early studies, Gordin et al. (1994) supported students to collect their own temperature data (first-hand data). Students also used *Climate Visualizer* to review the Northern Hemisphere weather data (second-hand data). The authors noted that collecting data creates a personal experience and supporting it with second-hand data provides rich experiences for students. However, the authors did not examine students' use of first-hand and second-hand data (Gordin et al., 1994).

In another study, Hug and McNeill (2008) also provided data sets to students and allowed students to collect data. In this study, the authors provided different data sets to students when exploring different topics. When studying population variation, students measured the leg length of grasshoppers (first-hand data). To investigate the role of second-hand data, the authors provided students with data sets focusing on natural and sexual selection. When using first-hand and second-hand data, students created claims and conclusions by providing sufficient justification. But this happened more frequently when students used first-hand data (Hug & McNeill, 2008).

Sandoval and Reiser (2004) used *Explanation Constructor*, which provided computer-based investigations focusing on environmental topics, including the natural selection of finches in the Galapagos Islands, or the ecology of panthers in North Africa (second-hand data). *Explanation Constructor* scaffolded students' explanations by providing prompts; and as an electronic journal, it also helped students to view the relationship between questions, explanations, and evidence. The authors provided only second-hand data and found that *Explanation Constructor* helped students create scientific explanations about natural selection by supporting claims with the data (Sandoval & Reiser, 2004). But they did not compare the quality of explanations students created using first- and second-hand data.

Some studies provided second-hand data by using existing data sets (Gordin et al., 1994; Hug & McNeill, 2008; Sandoval & Reiser, 2004). Another way to support students' use of second-hand data is to create a data pool by combining data that students collected on their own, as well as data that other students collected.

### *Creating Data Pool for Examining Second-Hand Data*

Kuhn et al. (2012) created a data organization tool to combine peers' data and the students' own data in the same data pool. Students collected data to observe traits in a natural history museum. Students then created explanations to investigate the traits animals need for surviving in their ecosystem. When creating these explanations, students could use their own and select data from their peers (second-hand data). The data students collected were similar to their peers' data, since they all collected data from the same museum. Students primarily preferred using second-hand data in their explanations, but the authors did not compare the quality of student explanations when they used second-hand data (Kuhn et al., 2012). What is interesting here is that it is data collected in the same site.

In another study, Songer (2006) enabled the use of data coming from other students. In the *BioKIDS* project, students were engaged with a question focusing on biodiversity. They collected data by observing the physical characteristics of organisms and used the data to explain the characteristics of different organisms. In this process, students analyzed the data coming from other students; and the experimental group increased their ability to build scientific explanations with respect to biodiversity (Songer, 2006).

Woodgate et al. (2008) used several sensors to measure carbon monoxide, sound, and temperature in the *Participate* project. Students collected data individually. Then the data were combined by using Google Earth to create a data trail. When analyzing the trail, some student groups first focused on finding and discussing their own data, and then they examined other parts of the trail to investigate the data collected by other students (Woodgate et al., 2008).

In summary, previous studies have noted the importance of evaluating second-hand data when creating explanations (Duschl et al., 2007; NRC, 2012; Osborne, 2010), and several studies have supported the use of second-hand data by providing existing data sets (Gordin et al., 1994; Hug & McNeill, 2008; Sandoval & Reiser, 2004) or enabling data sharing (Kuhn et al., 2012; Songer, 2006; Woodgate et al., 2008). After examining how students personalize data, Woodgate et al. (2008) underlined the importance of investigating students' use of second-hand data. Up to this date, only Hug and McNeill (2008) investigated how different sources of data influence the quality of the students' explanations by enabling students to generate data (first-hand data), and to examine various data sets as second-hand data. In this study, our goal is to investigate how using second-hand data influences the quality of students' explanations by providing similar data sets as first-hand and second-hand data.

## Research Method

Students participating in this study explored the water quality in their region by investigating the following driving question (DQ): 'How do we determine the health of the water in our community?' When examining water quality, students used a mobile application when collecting data and creating explanations.

### *Demographics*

This study was conducted in a Midwest public middle school, where 20% of the students qualified for free/reduced lunch and the majority of students were white. A middle school science teacher with 20 years of experience in teaching science participated with her four sixth-grade classes ($n = 116$). Class sizes varied from 28 to 30.

### *Description of the Mobile Application*

Students participating in this study used a mobile application called Zydeco (Figures 1 and 2), which supports middle school students in collecting various types of data—audio notes, videos, and photos—inside or outside the science classroom to answer a DQ (Quintana, 2012). Figure 1 shows a screenshot of the Zydeco iPod application. Students participating in this study used the iPod application when collecting data to answer the DQ, and then they used the Zydeco iPad application when creating explanations (Figure 2). Students participating in this study observed different parts of the water source, and they collected water samples from different sections by using the iPod application. Sharing all the data enabled them to analyze a larger data source

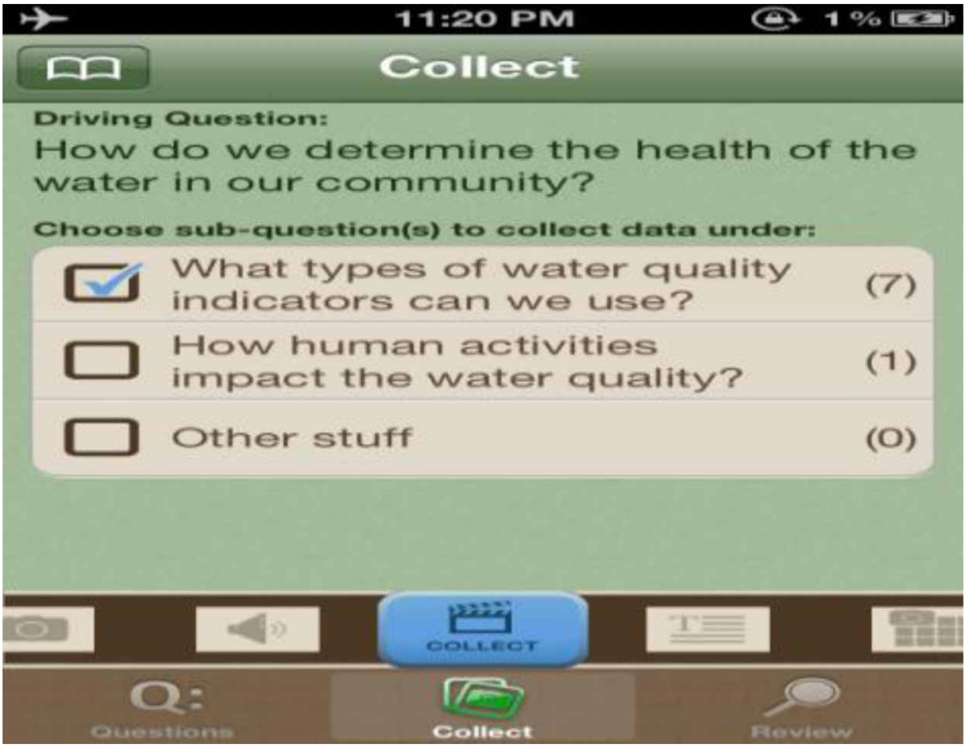


Figure 1. Data collection page

to examine the water quality of the stream when they got back to the classroom when using the iPad application.

When creating explanations, students used a CER template (Figure 2) to develop a claim about the DQ, to select observations as evidence, and to develop a reasoning statement that explains how certain observations can be used as evidence to support their claim.

*Context*

The water quality investigation took two weeks at the end of second semester. Earlier in the school year, the teacher participating in this study introduced students to writing scientific explanations using the CER framework. The teacher also organized several water quality investigations in previous school years by visiting the same local water source, which is just minutes away from school, but she never used a mobile application for data collection or to support students in writing explanations.

The first week of the investigation was devoted to the pre-activities, which focused examining key ideas in water quality to build a scientific understanding about the topic. Before collecting data, students also practiced writing explanations using the CER framework and explored the mobile application.

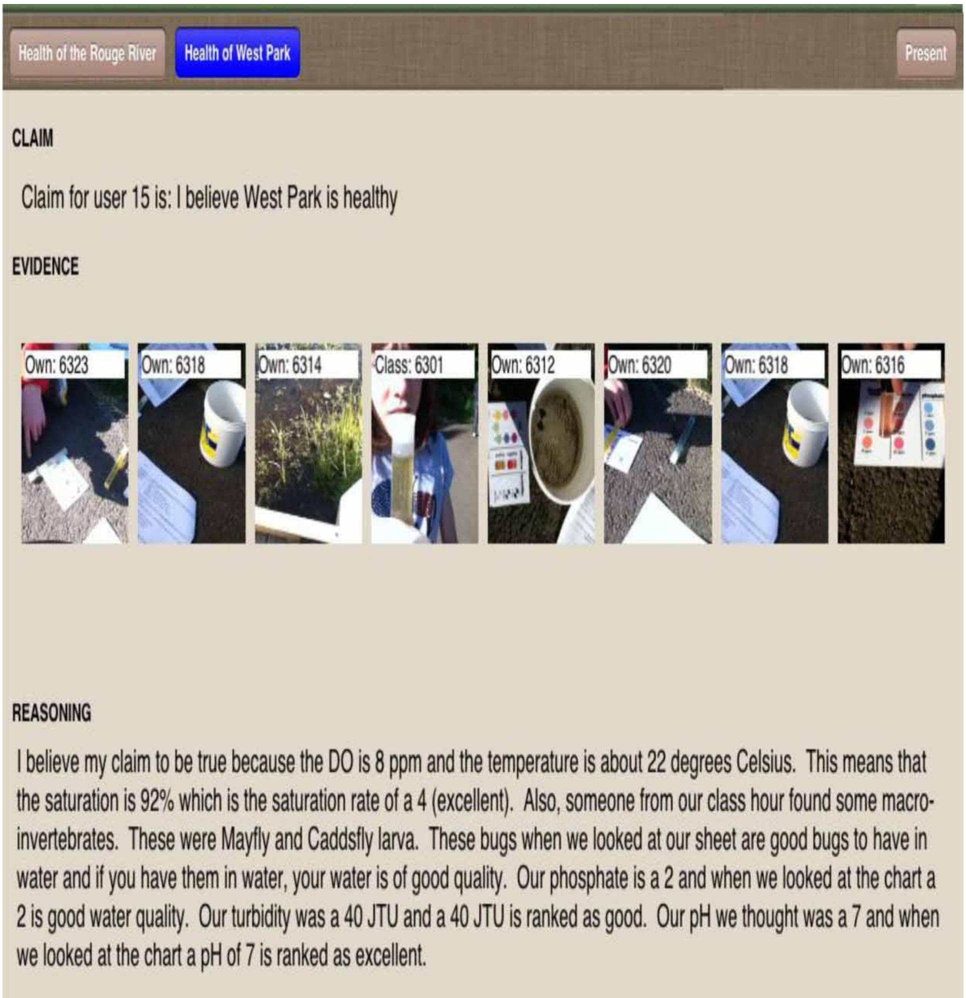


Figure 2. Group 15's explanation created after analyzing WP data



When practicing data collection and creating explanations, students tested the water quality in their school by using the indicators before the field trip, and they created sample explanations on the mobile application. Prior to the water quality investigation, students had prior experiences in relation to creating explanations. This process helped students to become familiar with data collection and to use the CER framework on the application.

At the end of the first week, students collected water samples and analyzed these samples in the field using commercial testing kits. Students collected data by focusing on the following indicators: phosphate, pH, fecal coliform, biochemical oxygen demand, turbidity, temperature, and dissolved oxygen (DO). In addition to the test kits, students made observations for macro invertebrates and human activities. During data collection, 36 student groups worked collaboratively to collect data from a local river (WP), and they observed different parts of the river by collecting water samples from different sections. Although they worked in groups, each student had an iPod. When students completed the data collection, all of the multimedia data were uploaded to the server and then transferred to the iPad application. In the classroom, the same groups continued their collaborative work to analyze the data and write scientific explanations. Each group had an iPad for accessing all the data and writing their explanations. Collecting their own data during the field experiences provided a contextualized experience for students (Krajcik & Starr, 2001; Laru, Järvelä, & Clariana, 2012; Maldonado & Pea, 2010; Novak & Treagust, 2013; Rogers et al., 2004; Songer, 2006), and students wrote explanations to examine the health of a stream in their community (Krajcik & Starr, 2001; Maldonado & Pea, 2010; Novak & Treagust, 2013).

Each group completed two scientific explanations (Figures 3 and 4). In their first scientific explanation, students used the evidence they collected from the local water source to explain whether or not the river in WP was healthy (first-hand data as well as data collected by other class groups).

In their second scientific explanation, students focused on the health of RR that runs through a major metropolitan area about 50 miles from their school. The students did not directly investigate the RR, but they had access to the data collected by students from a different school (second-hand data). Students investigating RR used the same indicator set and the mobile application that students from the WP study used. When students completed their first explanation, the teacher introduced data from the RR project and also reminded them that they would be investigating an

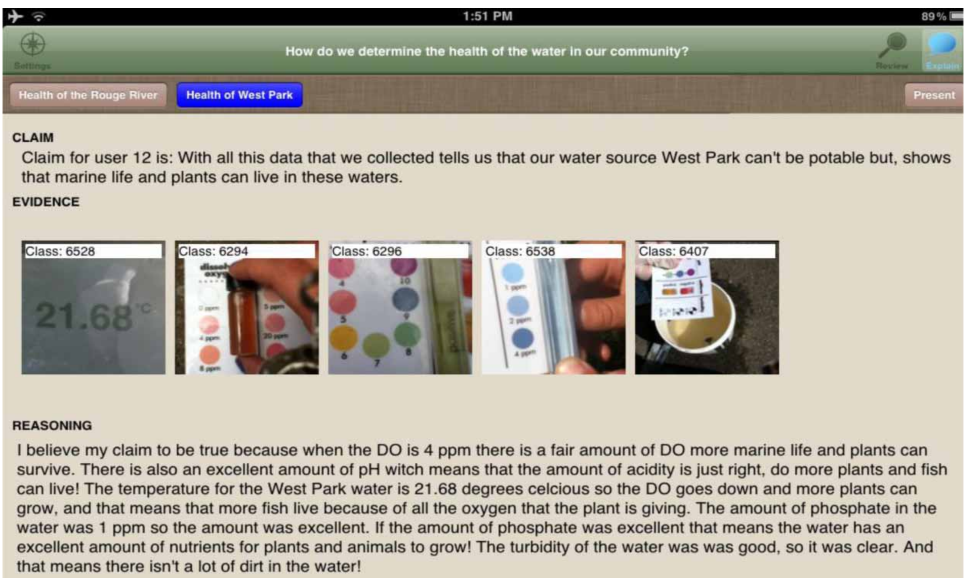


Figure 3. Group 12's explanation created after analyzing WP data

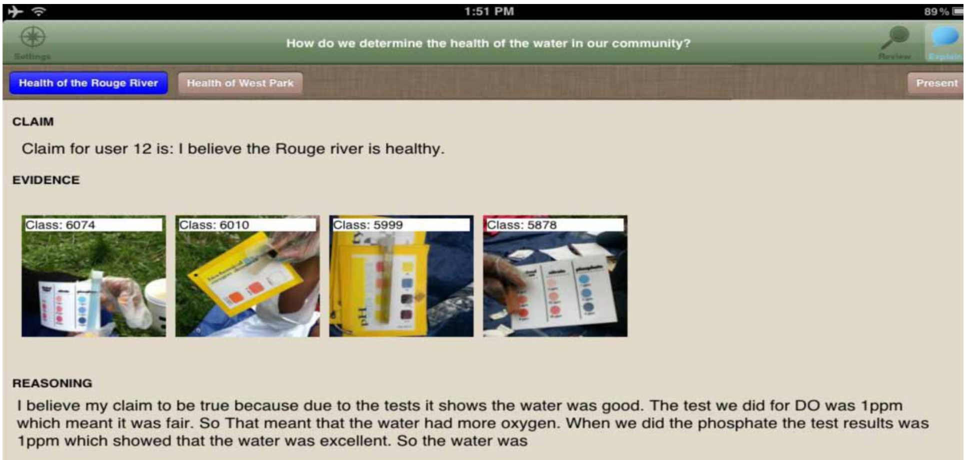


Figure 4. Group 12's explanation created after analyzing RR data

identical data set. In summary, 36 groups completed explanations for analyzing the water quality of the RR and WP by creating 72 scientific explanations in total.

### *Analysis*

We analyzed the data by scoring students' explanations separately for CER by modifying a rubric created by McNeill et al. (2006) in order to code students' explanations separately for claims (Table 1), evidence (Table 2), and reasoning (Table 3). When analyzing the data, two researchers separately coded 20% of the data, with a 91% inter-reliability score. Then the remaining responses were scored by one of the two researchers and cross-checked between the researchers. All of the differences in both stages were resolved in discussion meetings with the external evaluator of the project.

*Analysis step 1*. When coding an explanation, the first step was evaluating students' claims. As depicted in Table 1, we used the two coding labels to determine whether students had a complete claim or not. The sample explanation presented in Figure 4 includes a complete claim: 'I believe the Rouge River is healthy.'

*Analysis step 2*. The second step of coding an explanation investigated the amount of evidence students added to their explanations. When coding the evidence section, we

Table 1. Coding claims

| Code | Explanation |
|---|---|
| 0 | No claim or inappropriate claim<br>Example: 'I believe West Park is/isn't healthy.' |
| 1 | Student creates a complete claim<br>Example: 'I believe West Park is healthy.' |

Table 2. Coding evidence

| Code | Explanation |
|---|---|
| 0 | No evidence or only inappropriate evidence<br>Example: Evidence that does not support claim or reasoning. Presenting the picture of the dam, when discussing dissolved oxygen |
| 1 | Provides the evidence as text within the reasoning but does not include data values<br>Example: Group only mentions phosphate without discussing data value and including evidence from the data pool |
| 2 | Provides the evidence as text within the reasoning and includes data values<br>Example: Discussing the value of phosphate (e.g. 1 ppm) but missing evidence from the pool |
| 3 | Provides evidence by selecting data from the data pool<br>Example: If group selects photo/video of fecal coliform, phosphate, etc. |

Table 3. Coding reasoning

| | |
|---|---|
| 0 | No reasoning or inaccurate/unrelated reasoning statement<br>Example: '… 19 out of 20 averages out to more than 3.5 per test.' |
| 1 | Provides the reasoning statement without providing any supportive ideas to justify the evidence (e.g. discussing rankings, what evidence means for water quality)<br>Example: 'Fecal coliform is bad for water quality.' |
| 2 | Compares data values with the data indicator chart provided with the analysis kit to find out which values are better for water quality. Provides the reasoning by interpreting the data but does not discuss what these indicators mean for water quality<br>Example: 'I believe my claim to be true because the water tested excellent rankings for pH (7: excellent), the phosphate (3 ppm: good).' |
| 3 | Engages the reasoning with a discussion of what indicator findings mean for water quality<br>Example: 'The amount of phosphate in the water was 1 ppm, so the amount was excellent that means the water has an excellent amount of nutrients for plants and animals to grow!' |

focused on whether students included evidence from the data pool, or whether they just noted the evidence without providing any support from the data pool (Table 2). The examples presented in Figures 2 and 3 selected several pieces of evidence to support their explanations, and received '3' for their evidence score (Table 2).

*Analysis step 3.* After scoring students' claims and evidence, we focused on the quality of the reasoning statements created by evaluating how students justified the evidence they added to their claims (McNeill et al., 2006). In this process, we gave credit to the justification students added (Table 3) when discussing the evidence they added (e.g. how students analyzed the indicator results and what their findings mean for water quality).

In the example provided in Figure 2, the reasoning statement included an analysis of the indicators chart (noting the level found in the water is good or bad for water quality). Students ranked DO, invertebrate, turbidity, and pH findings; however, they did not discuss what the indicators mean for water quality (Reasoning Level 2).

In the other example presented in Figure 3, students discussed what indicators mean for water quality (Reasoning Level 3). For instance, they noted how different pH levels affect water quality, and then they concluded with WP's quality. Students added that phosphate is a necessary nutrient for plants and fish; they also noted that a low level of phosphate is good for water quality since higher levels of phosphate would support algae growth.

*Analysis step 4.* After coding students' explanations, the final step of the analysis focused on describing the differences between WP explanations and the RR explanations.

## Findings

This section discusses the differences in students' explanations after analyzing WP data, and RR data.



### *Comparing Quality of Claims*

Only one group did not create a claim (Claim Level 0) when analyzing WP data. They did not explicitly note whether the river is healthy or not: 'I believe West Park is/isn't healthy.' Although they did not create a claim, they added several pieces of evidence to their explanation. But they did not justify why they selected the evidence (Reasoning Level 0) under reasoning section: 'I believe my claim to be true because 19 out of 20 averages out to more than 3.5 per test.'

When groups analyzed RR data, five groups did not create a claim (Claim Level 0). Of these five, three did not provide any evidence or reasoning (Reasoning Level 0). One of them provided evidence focusing on human activities; however, they did not discuss what the evidence means for water quality (Reasoning Level 0).

The last group under this category selected five pieces of evidence focusing on temperature, DO, phosphate, turbidity, and pH findings. But they did not clearly state a claim (Claim Level 0): 'I believe Rouge River is/isn't healthy.' The absence of a claim led to an incomplete reasoning statement which did not justify the evidence by discussing the results (Reasoning Level 0): 'I believe my claim to be true because 18 out of 20 averages it to more than 3 per test.' This group also provided a similar reasoning statement when analyzing the WP data.

In summary, almost all groups included complete claims in both explanations; 35 had a claim when analyzing WP data, and 31 groups had a claim when focusing on RR data.

### *Comparing Groups' Use of Evidence and Quality of Reasoning Statements*

When students analyzed RR data, they selected 5.2 pieces of evidence in their explanations. On the other hand, this number increased to 6.4 pieces of evidence when analyzing WP data. In this process, students had access to the data collected by their classmates (marked as class data in Figure 2), and they selected evidence primarily from their own data (marked as own data in Figure 2) collection (142 pieces of data from their data collection, and 88 pieces from other students' data).

To acknowledge the role of using others' data when analyzing WP findings, we created four groups: (1) selecting only others' data when creating explanations under WP data, (2) selecting majority of the evidence from others' data when creating explanations under WP data, (3) selecting majority of the evidence from their own data when creating explanations under WP data, and (4) selecting only own data when creating explanations under WP data. After analyzing the quality of reasoning for these groups when analyzing WP data, we focused on how the quality of reasoning statements changed when these groups only had others' data (RR data).

*Selecting only others' data when creating explanations under WP data.* As presented in Figure 5, five groups used only others' data when creating explanations to explain the health of the WP, and two of these groups focused on explaining the water quality by interpreting the indicators chart. (For example, the dissolved oxygen was at 8 ppm, and with a temperature at 21.32°C, that is, a DO saturation of 88–92%, which is excellent.) When these two groups created explanations to explain the health of RR, they again focused on explaining the indicators by using the chart. (For example, the dissolved oxygen is 4 ppm, and the temperature is 20.24°C, so the saturation is 44%, which is poor water quality.)

Two of these groups included scientific principles when analyzing the WP data. When these two groups focused on RR data, both created lower level reasoning statements. As presented in Figure 3, one of these groups discussed scientific principles when analyzing WP data. (For example, there is also an excellent amount of pH which means the level of acidity is just right, do more fish and plants can live … If the amount of phosphate was excellent that means the water has an excellent amount of nutrients for plants and animals to grow.)

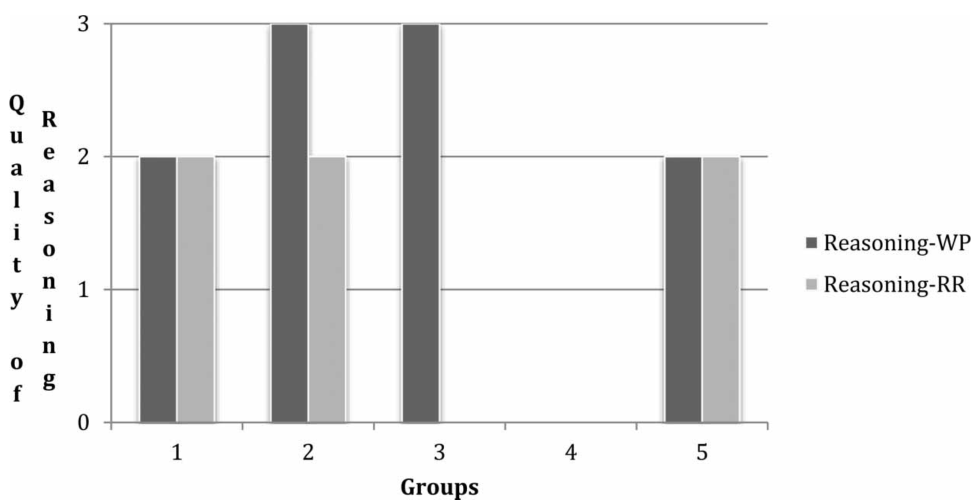


Figure 5. Comparing quality of reasoning statements for groups that selected only others' data when creating explanations under WP data

Although this group included scientific principles under WP explanation, they did not provide that information under RR data (Figure 4). For instance, they were able to explain DO under WP data (there is a fair amount of DO, more marine life and plants can survive), but they did not provide this information when analyzing RR data. They also misinterpreted DO result by noting a lower level DO means (4 ppm in WP, and 1 ppm in RR) the water had more oxygen (Figure 4).

In this subsection, we summarized the reasoning statements for the groups that only used others' data in both cases (WP data and RR data). Despite the fact that students did not use any evidence from their data collection, they created better reasoning statements when analyzing the data coming from the water source they visited (WP).

*Selecting majority of the evidence from others' data when creating explanations under WP data.* As presented in Figure 6, 10 groups used mainly other students' data when explaining WP data; and 5 of these groups created a reasoning statement by explaining the indicators chart. The other five included scientific principles. When these groups only used others' data under RR explanation, only two included scientific principles, five focused on explaining the indicators chart, and three of them failed to include a reasoning statement.

Six of these groups created similar level explanations (Figure 6), but four of them created a lower level explanation when they only used others' data. For instance, one of these groups discussed invertebrates, phosphate, DO, pH, and turbidity



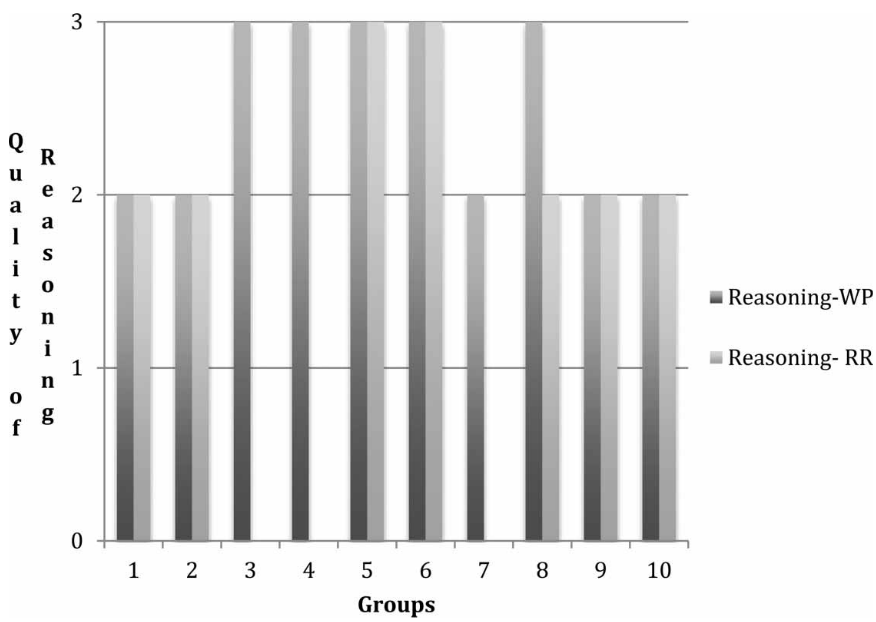


Figure 6. Comparing quality of reasoning statements for groups that selected majority of the evidence from others' data when creating explanations under WP data

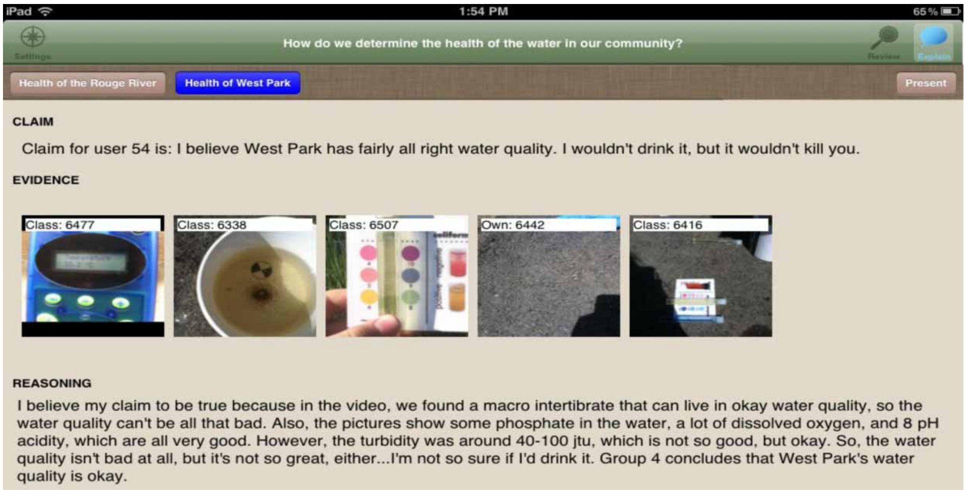


Figure 7. Group 54's explanation created after analyzing WP data

findings when explaining WP data (Figure 7). This group failed to include data focusing on these indicators when creating an explanation in relation to RR data.

*Selecting majority of the evidence from their own data when creating explanations under WP data.* As presented in Figure 8, 13 groups used mainly their own data, and all of them successfully created reasoning statements under WP data. Nine of these groups created a reasoning statement that focuses on explaining the water quality indicators, and four of them included scientific principles. For instance, the example presented in Figure 2 focused on ranking indicators. This group created a similar reasoning statement when analyzing RR data.

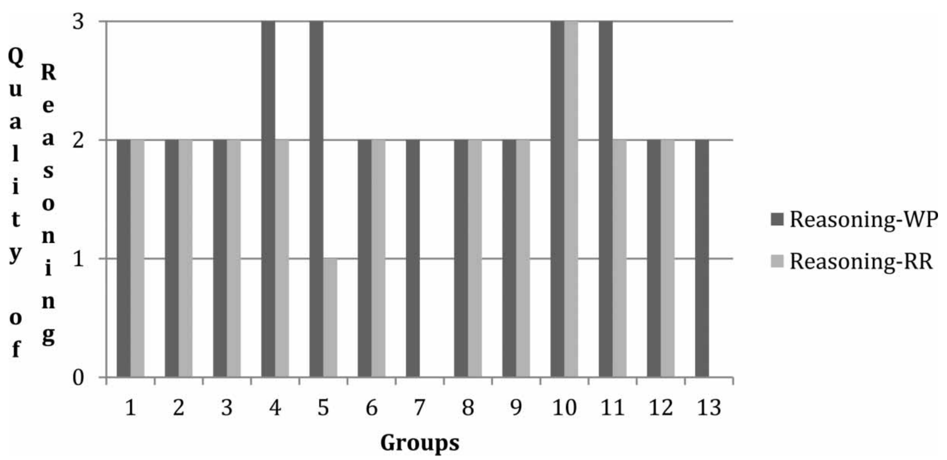


Figure 8. Comparing quality of reasoning statements for groups that selected majority of the evidence from their own data when creating explanations under WP data

When these groups were only provided others' data, only one group included scientific principles, nine of them focused on explaining the water quality indicators, one group only included their ideas without discussing their evidence, and two groups could not create a reasoning statement (Figure 8).

Under this category students primarily relied on their data collection when analyzing WP data. When these students only analyzed data coming from other students (RR data), five groups created lower level reasoning statements. For instance, one of these groups explained fecal coliform, pH, and turbidity findings when explaining WP data. But, they failed to include any data when explaining RR data.

*Selecting only own data when creating explanations under WP data.* When students used only their own data to create scientific explanations under WP data, five groups created reasoning statements by interpreting the indicators chart, and three groups included scientific principles (Figure 9). When these groups used only others' data, only one group included scientific principles, four groups focused on interpreting the indicators chart, two groups included some ideas without discussing their evidence, and one group failed to provide any reasoning statement (Figure 9).

In this category, students only used their own data collection when analyzing WP data. When these students only used data coming from other students (RR data), four groups created similar level reasoning statements when analyzing RR data, and four groups created lower level reasoning statements.



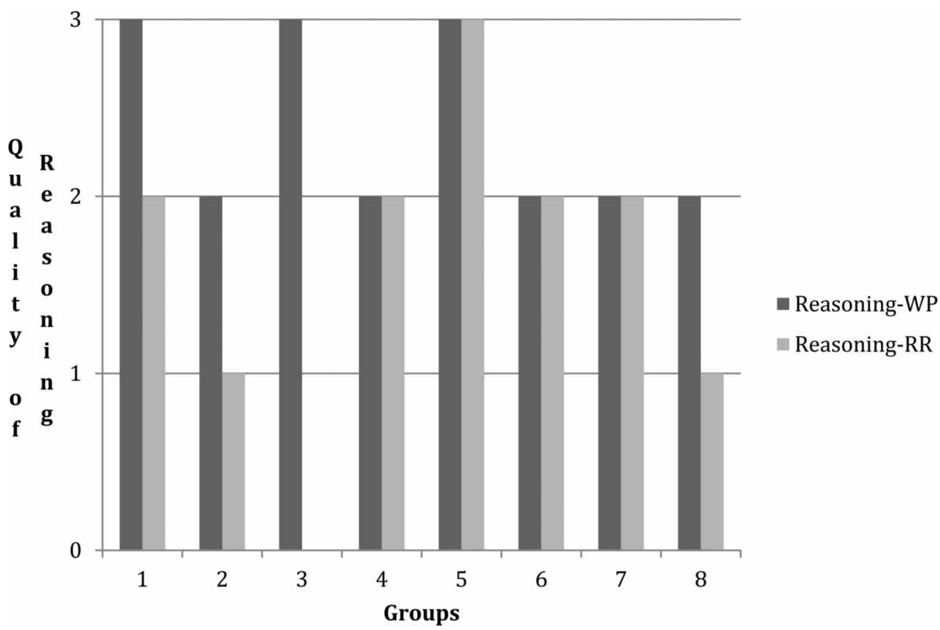


Figure 9. Comparing quality of reasoning statements for groups that selected only their own data when creating explanations under WP data

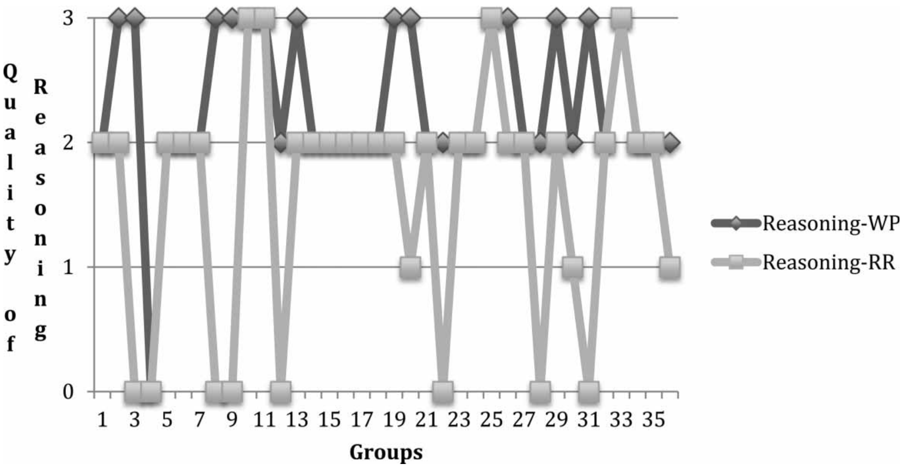


Figure 10. Comparing quality of reasoning statements for both explanations

*Summarizing the Differences*

When students had different data sources, majority of the groups included complete claims and multiple pieces of evidence in their explanations. On the other hand, when students only had second-hand data, none of the groups created a higher reasoning statement.

Figure 10 presents a combined summary of Figures 5, 6, 8, and 9. In all cases (all others' data represented by Groups 1–5 in Figure 10, majority others' data represented by Groups 6–15 in Figure 10, majority own data represented by Groups 16–28 in Figure 10, and all own data represented by Groups 29–36 in Figure 10), overall quality of the reasoning statements decreased when focusing on only second-hand data coming from a source that students did not visit (RR data). It is important to note once again that five groups used only others' data when creating WP explanations. These groups also had lower quality explanations, when analyzing RR data.

## Discussion

Supporting students to use second-hand data is an important aspect of science education because it exemplifies an important part of what scientists practice (Duschl et al., 2007; NRC, 2012; Osborne, 2010). To support students to use data collected by others (second-hand data), NRC framework (2012) noted the importance of 'communication of the results' (NRC, 2012 p. 53) as part of the scientific practices. To help students learn to communicate results, it is vital to understand how they make use of the second-hand data.

Almost two decades ago Gordin et al. (1994) supported students investigating first-hand and second-hand data without examining how students' made use of these different data sources. In another study, Woodgate et al. (2008) underlined the need to understand how students' use second-hand data; however, only Hug and McNeill

(2008) actually examined different data sources as first-hand and second-hand data. (The leg length of grasshoppers as first-hand data, and data sets focusing on natural and sexual selection as second-hand data.)

This current study adds to the literature on students' use of second-hand data by analyzing students' investigation of similar data sets as first-hand and second-hand data. In our study, the quality of students' claims and reasoning statements changed when students analyzed the first-hand data. Although the two data sets used in this study were similar, focusing on water quality, students included less pieces of evidence (5.2 pieces when analyzing RR data, and 6.4 pieces of evidence when analyzing WP data), and less supportive details (e.g. rankings, explaining what indicator means for water quality) in their reasoning statements when they analyzed second-hand data collected by other students. This result is consistent with findings from Hug and McNeill's (2008) study, which found that students added accurate justifications more frequently when students used the data they generated. To illustrate the importance of first-hand data, previous studies focused on the importance of generating data when creating explanations (Achieve, 2013; Duschl et al., 2007; Maldonado & Pea, 2010; McNeill & Krajcik, 2008; NRC, 2012; Songer, 2006). Songer (2006) promoted data collection focusing on biodiversity; McNeill and Krajcik (2008) supported students collecting data in relation to chemical reactions; and Maldonado and Pea (2010) enabled students to observe water quality before creating explanations. In this study, students generated data by focusing on water quality, and when they analyzed the data they generated (first-hand data), students created stronger claims and reasoning statements.

Besides the role of generating data, another possible reason that explains this difference in quality of explanations might be students' involvement in the data collection process. Several scholars supported students collecting data when exploring different content areas (Fraser et al., 2005; Krajcik & Starr, 2001; Laru et al., 2012; Maldonado & Pea, 2010; Novak & Treagust, 2013; Rogers et al., 2004; Songer, 2006). Connected with this idea, some studies discussed the importance of place-based learning experiences, which help students to make sense of the learning environment (Lim & Barton, 2006; Semken et al., 2009; Tan, Barton, & Lim, 2010). More specifically, Lim and Barton (2006) noted that placed-based learning experiences connect students to the learning environment: 'When students' senses of place are leveraged in a science class, it seems to bring out opportunities to learn "connected science" and also to nurture a dynamic learning environment' (p. 137). In our study, five groups used only others' data after visiting a local water source. When these students used others' data to create explanations in relation to the health of a water source that they did not visit, students created lower quality explanations.

Students participating in this study visited WP to collect data from a local water source; however, they did not observe RR. Despite enabling students to analyze more data (more than 800 pieces of data) to explore the DQ, the absence of involvement in the data collection might have had a negative impact on ownership. Absence of involvement might have also hindered student ability to make sense of the data collection environment when creating explanations. Previously, Hug and McNeill (2008) found that students' ownership changed when students analyzed second-hand data. Authors described this difference by focusing on how students approached different data sources, and they found 'an unexpected amount of ownership that students voiced with regard to their own first-hand data and their willingness to critique and discuss the limitations around it' (Hug & McNeill, 2008, p. 1746).

To elaborate this idea, Woodgate et al. (2008) noted that students' involvement would differ when they analyze data they collect compared to using second-hand data: 'When pupils collect their own data, they are motivated to take much greater effort to grasp its meaning than they would in the case, for example, of similar material shown in a textbook' (p. 103). Some student groups showed this ownership in their reasoning statements when discussing the evidence. For instance, one of the groups noted the following statement when analyzing the DO result of WP: 'We had 88% of dissolved oxygen saturation.' On the other hand, when reporting the DO level in RR, they added: 'They have 43.04 percent of DO.' This is an example of the difference of student involvement in this study, when discussing DO data they generated versus DO data provided to them.

## Implications

Policy documents in the USA (Achieve, 2013) and Europe (Osborne & Dillon, 2008) are making the push for engaging students in generating data. To highlight the importance of this idea, our findings suggest that almost in all cases students created a similar or lower quality reasoning statement when they were provided a data coming from a source that they did not visit. Previously, Hug and McNeill (2008) compared different data sources as first-hand and second-hand data. We reached a similar conclusion by providing similar data sets as first-hand and second-hand data. This conclusion may also have implications on assessment since standardized tests only provide second-hand data to students.

Finally, we recommend teachers to provide opportunities for investigations rather than presenting evidence that do not belong to students. As noted by Osborne and Dillon (2008), there is a need to increase these opportunities especially in elementary and middle school years. Given the fact that, creating explanations also present challenges for teachers (Delen, 2014; Erduran, Simon, & Osborne, 2004; McNeill & Knight, 2013; McNeill & Krajcik, 2008; Simon et al., 2006; Zembal-Saul, 2009), providing professional development for teachers (Delen, 2014; McNeill & Knight, 2013; Simon et al., 2006) and supporting in-service teachers (Zembal-Saul, 2009) play a huge role in this process.

## Limitations

This study was small, and we only worked with one teacher and four sixth-grade classrooms. Students participating in this study created explanations with their group members by sharing devices. As such, the claims we can make are limited, and no causations were intended. In this study, students only investigated water quality, and there was no comparison group. All groups followed the same order when writing their explanations. First they created an explanation in relation to their data collection (first-hand data), and then they examined the data collected by another school (second-hand data). In addition, students had access to other students' data collection when analyzing WP findings. Finally, water quality was also the last unit, and creating these explanations was one of the last tasks of the school year, which may have affected students' motivation to analyze data collected by another school after analyzing their own data.

To understand fully the role of second-hand data, a future design might focus on collecting data from different grade levels as well as working with multiple teachers investigating different topics. When creating explanations, future research should support students to create their individual explanations, and should design counter-balanced studies to control the ownership of data (half of the students examine their own data first, and the other half investigate second-hand data before investigating their own data collection).



## Acknowledgements

We thank Dr Steven McGee and Jennifer Duck for their support during the data analysis.

## Disclosure statement

No potential conflict of interest was reported by the authors.

## Funding

This work was supported by NSF [grant number DRL 1020027].

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