A deeper layer of enquiry: Using the Heuristic Investigation Delayed Evidence (HIDE) approach to evaluate how students select evidence

● Mason Kuhn

Abstract

It is widely emphasised in contemporary science teaching that students should engage in practices of enquiry similar to actual scientists. In an attempt to meet these expectations, many teachers have turned to 'hands-on' lessons that can be fun for students but may serve as a faux proxy to meet the expectations and rigour that the authors of reform-based standards intended. In an attempt to meet the expectations of these standards, the Heuristic Initiative Delayed Evidence (HIDE) method was created. The method starts with students using experience to learn instead of being told how things work, followed by teachers waiting to provide vocabulary and information about the science content after students explore the phenomenon. In this study in Grade 6 (age 11) in the United States, we evaluated how students selected evidence before and after they were taught using the HIDE method and compared that to students who were taught by a teacher who used a more traditional method.

Introduction

It is widely emphasised in contemporary science teaching that students should engage in practices of enquiry such as planning investigations, analysing data, and engaging in argument from evidence (Alexander, 2017; Bråten, Muis & Reznitskaya, 2017; Windschitl & Stroupe, 2017). This research has resulted in new science standards in Australia, Europe and the United States (see Australian Curriculum, Assessment and Reporting Authority [ACARA], 2009; UK Department for Children, Schools and Families [DCSF], 2009; Next Generation Science Standards [NGSS Lead States], 2013; Promoting Inquiry in Mathematics and Science Education across Europe project [PRIMAS], 2013). A common call made by science education researchers is that teachers should focus on the content and process of science (National Research Council, 2012). One practice with which professional scientists frequently engage is evaluating the strength of evidence, considering conflicting ideas, and deciding which source they should trust when they ultimately decide which claim they support (Oreskes, 2019). The urgency to teach enquiry to students is highlighted in the Association for Science Education's (2018) list of 'best practices' for science teachers, citing such benefits as '*developing problem-solving skills, working with independence, developing skills to think like a scientist, and effectively communicating their understanding of the content'* (p.2). However, there are critical aspects of enquiry that are typically left out of 'school science', including pedagogy that promotes creative thought, considering multiple solutions to a problem, and evaluating the strength of evidence.

To accomplish this goal, teachers need to adjust their role from being a 'gatekeeper of knowledge' to someone who manages student uncertainty (Manz, 2015). Recently, Chen and Benus (2019) evaluated how teachers approach this challenge and found patterns of *raising*, *maintaining*, and *reducing* uncertainty. Their work comes from the view that science is a base of knowledge built from communities of experts who pursue endeavours to understand our natural world better. In actual science, uncertainty is raised when ongoing phenomena lack a proper explanation and require further enquiry; it is maintained as scientists seek evidence and argue its merits with peers, and is reduced when a clear set of evidence is deemed satisfactory, and the community takes a position (Kuhn, 1962). With those ideas in mind, the Heuristic Investigation Delayed Evidence (HIDE) method was created to take those aspects of uncertainty management and develop a practical classroom-based approach. The term HIDE was developed from the pedagogical pathways that teachers are encouraged to take. The method starts with students using experience to learn instead of being told how things work. Delayed evidence refers to teachers waiting to provide vocabulary and information about the science content after students explore the phenomenon, and designing instruction where students continue with the enquiry process as they figure out which evidence should be trusted. In the following sections, we will describe HIDE in both general terms and an example in the context of light.

Heuristic Initiative (raising and maintaining uncertainty)

The HIDE method begins with an exploration of a phenomenon (see Figure 1) where students are not front-loaded with vocabulary but, instead, they discuss what they observed with their peers and then engage in dialogue about what they think it means. Phenomena can be anything that teachers imagine, but examples that we have seen include stations of materials related to light and sound to kick off an energy unit, videos of strange weather patterns to support thinking about climate, a nature walk to a nearby park or playground to support thinking about the symbiotic relationship of plants and animals, or any type of activity that elicits wonder about a topic and asks students to share their understanding.

Next, teachers ask students to take what they know about the phenomenon and co-create a 'Big Idea' for the unit with the teacher. The concept of the Big Idea was borrowed from the work by Hand and Keys (1999), which asks teachers to shift teaching from traditional methodology such as memorising facts to focusing on argumentation as a means to learn about concepts, or Big Ideas, at a deeper level (Cavagnetto, Hand & Norton-Meier, 2010; Martin & Hand, 2009; Yore, Bisanz & Hand, 2003).

In this context, a Big Idea is a simple statement that connects the various aspects of phenomena exploration and serves as a starting point to pique student interest (Akkus, Gunel & Hand, 2007). The Big Idea should be considered a launchpad that gives students a foundation from which to start, but requires the students to participate in a more detailed investigation and subsequent research to understand the concepts at a deeper level.

As part of the Heuristic Initiative, the teachers we worked with in this professional development

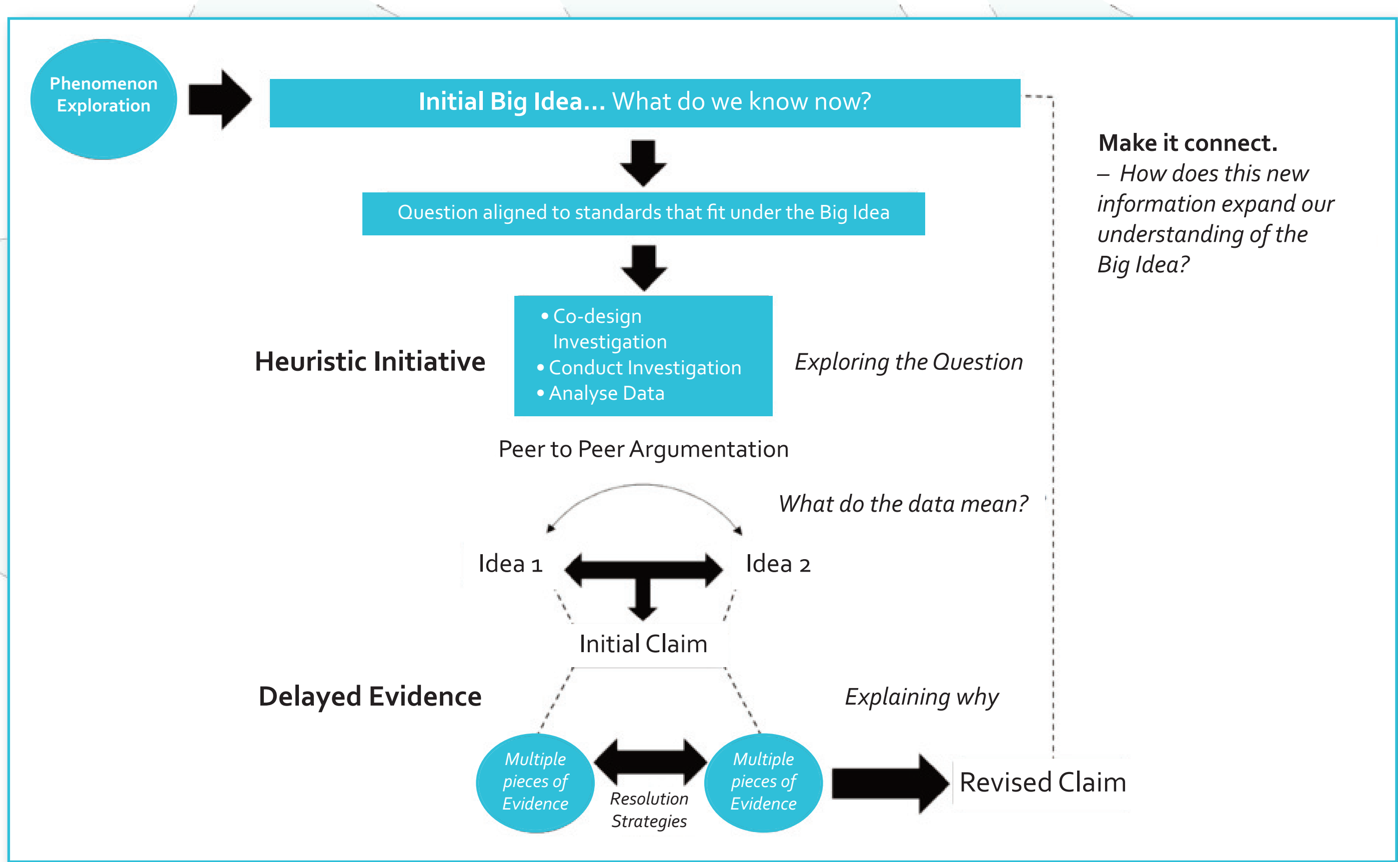


Figure 1. Flow chart of the HIDE Approach.

research project asked their students to answer the following questions:

- How do we write a testable question?
- What is the best type of investigation?
- What are the independent variables, dependent variables, and what variables do we need to attempt to control (if conducting an experimental design)?
- How are we going to collect the data?
- How will we analyse the data?
- How do these data help us answer the research question?
- How do these data help us better understand the Big Idea?

The flow chart of the HIDE method in Figure 1 shows how uncertainty is raised and maintained by setting up a phenomenon for students to explore, developing a Big Idea to guide the investigations, and generating multiple questions and investigations related to the Big Idea.

For example, if primary students were investigating light, teachers could set up stations with mirrors, prisms, cups of water, magnifying glasses and translucent items at the stations (see Figure 2). Next, the teacher would provide students with flashlights and have them take turns rotating around the stations using their flashlights to explore the phenomenon. After the students finish making their observations, the teacher would gather them in a whole-group discussion about how the light interacted with the objects.

At the end of the discussion, the teacher would co-create a Big Idea with the students about light and how we use it to see. The Big Idea for this standard would be *'Light interacts with objects and we need it to see'.* After that, the teacher and students would make a list of questions to investigate. The teacher would allow the students to develop their own questions in which they are interested and multiple questions could be investigated at once, but the teacher would include the question *'How do we use light to see objects?'* to make sure that the enquiry covers the content in the standards.

Finally, the teacher would ask students to design an investigation where they would use the materials available to them to answer the question, followed by an informal argumentation lesson where students would make tentative claims based on the evidence collected during the investigation.

Delayed Evidence (maintaining and reducing uncertainty)

After students conduct the investigation and collect data, the teacher asks the class to explain what the data mean and how they help them to

Figure 2. Stations that the teacher used for the Heuristic Initiative.

answer the question. At this step, the teacher would still maintain the uncertainty by asking students to explain why the data came out the way they did without telling them the answer. In the HIDE method, teachers are asked to allow students to raise competing ideas of what the data mean; however, the teacher should come prepared for this lesson with at least two competing ideas if the students do not create them on their own. One of these ideas should be supported by science, and the other idea should represent a common misconception or a plausible explanation that is ultimately wrong.

For example, if primary students were investigating the phenomenon of how our eyes interact with light in order to see, the competing ideas might be:

1. We see objects when light reflects off the object and enters our eye.
2. We see objects when light enters our eye and then we shoot it out.

At this point in the investigation, the teacher should allow students to choose which idea they support and argue with each other about why one idea should be supported over the other. The teacher would ask the students to think about what reasons they have for supporting the idea and explain why they do not support the other idea. After more peer-to-peer discussion, the students would write out a formal explanation of their understanding using a Claims-Evidence-Reasoning format, where they state their claim, provide evidence to support it, and then engage in reasoning by thinking about how they will figure out if their idea is correct or incorrect (See Figure 3). Teachers should emphasise that everyone should remain open-minded at this point, and teachers should also emphasise that more research needs to be done to work out which idea should be supported (see Figure 3). An advantage of using this approach is that the teacher can see if the student has a misconception about the content. For example, in Figure 3 you can see that the student thinks that our eyes work like flashlights or headlights. This information could be helpful during the next lesson when students engage in argumentation, because the teacher could lead the discussion by asking their students: 'Do our eyes work the same as flashlights?'

Next, the teacher will attempt to reduce uncertainty by providing multiple pieces of evidence for the students to read (or watch) that is grade-appropriate and would give the students the correct answer to the question that they are investigating. With lower primary grades, we have created lessons that have students read a passage that has the correct answer. For upper primary students, we have created lessons that provide multiple pieces of strong evidence to support the correct idea and pieces of weak evidence for the incorrect ideas.

For example, if we continue with the phenomenon of how light behaves, we can have teachers creating the following pieces of evidence:

- A document explaining how light travels, written by a scientist (terminal degree in physics and conducts research with other experts).
- A second document written by another expert and providing multiple examples of how light can be reflected, refracted, or absorbed.

Next, we have worked with teachers to create weak evidence for the competing idea that light enters your eye and then shoots out. Some examples of weak evidence include:

- A video produced by a non-expert (i.e. a middle-school student) claiming that our eyes work like a laser, shooting to the spot we want to see, but only offering their opinion without providing any evidence.
- A blog post written by an anonymous author who claims that our eyes work like the headlights of a car, but only offering their opinion without providing any evidence.

There are multiple ways to vary the strength and weakness of the evidence, including sourcing, claim-evidence link, and statistical significance of data. However, some of those examples are too complex for primary-age students (especially lower primary grades). In the examples in this section and the research project that we will describe in this paper, we focused on sources of evidence but, in other projects, we have helped teachers to design weak evidence examples that include mathematical errors and claims that violate logic fallacies. Since knowing which source to trust is such an important aspect of how lay people interact with science, this study includes a student task related to the trustworthiness of evidence.

Figure 3. Picture of a student explaining their initial interpretation of the phenomenon.

Question: How do we see objects?

CLAIM *Remember your claim is your answer to the question.

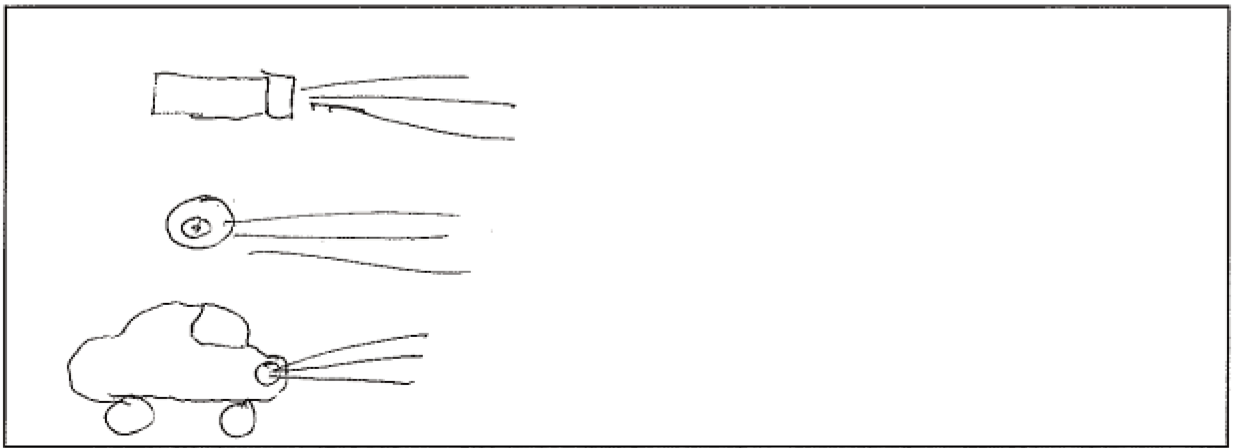
I think that….

The light goes in our eye and then we shoot it out to see

What is your **evidence**? *Remember evidence is the information that supports your claim.

Our eyes work like a flashlight or a car.

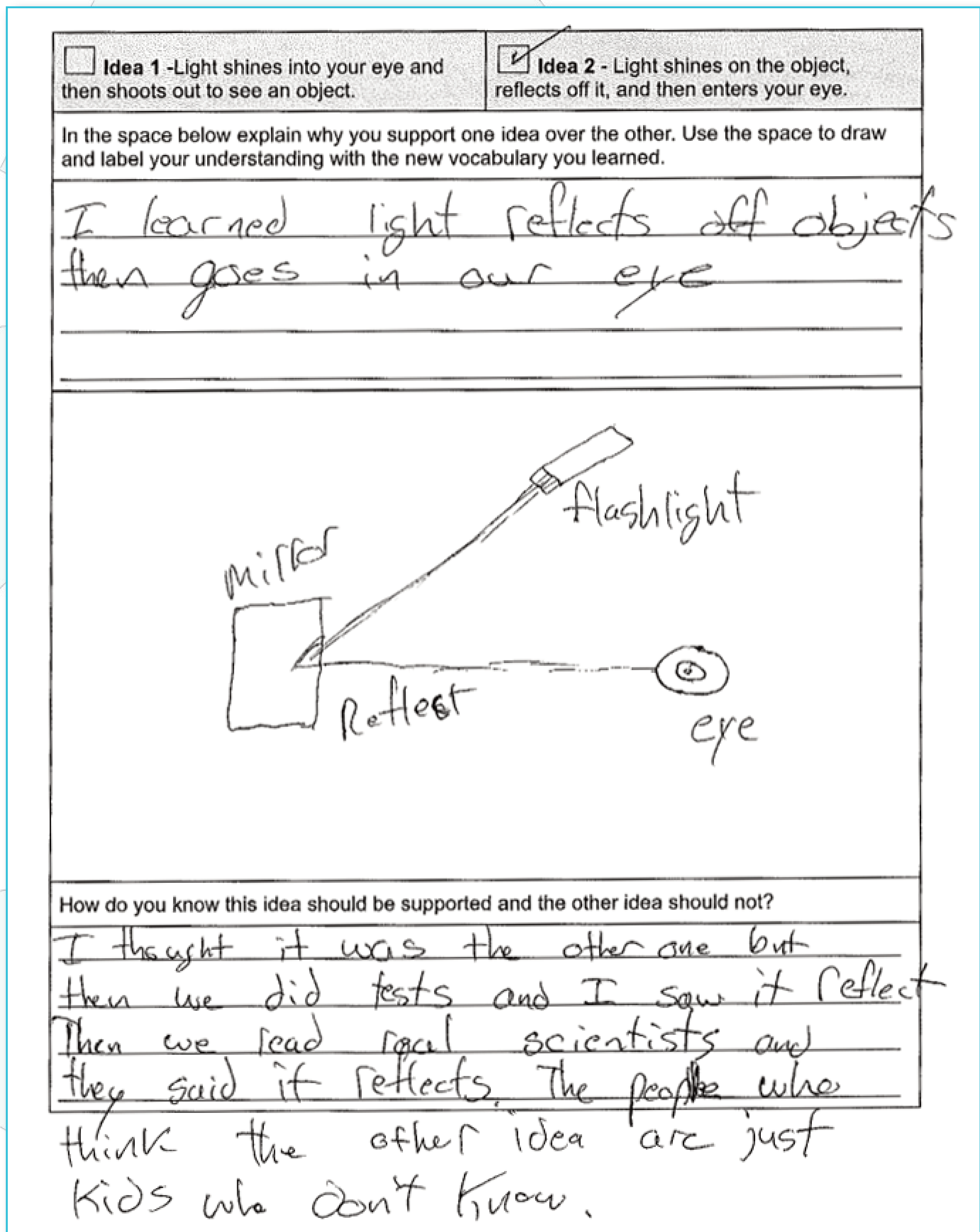
Use the space below to explain your answer through drawing



Reasoning *Remember reasoning is thinking about all the ways an idea might be right or wrong.

How will you figure out if this idea is right?	Why might this idea be wrong?
I will read about it	If light goes into our eye.

Figure 4. An example of a student's revised claim after reading the multiple sources of evidence for each idea.



☐ **Idea 1** -Light shines into your eye and then shoots out to see an object.	☑ **Idea 2** - Light shines on the object, reflects off it, and then enters your eye.

In the space below explain why you support one idea over the other. Use the space to draw and label your understanding with the new vocabulary you learned.

I learned light reflects off objects then goes in our eye

How do you know this idea should be supported and the other idea should not?

I thought it was the other one but then we did tests and I saw it reflect Then we read real scientists and they said it reflects. The people who think the other idea are just kids who don't know.

Figure 5. A summary of the HIDE method and how it helps teachers to raise, maintain and reduce uncertainty.

The Heuristic Investigation Delayed Evidence Method		
Raise Uncertainity	***Maintain Uncertainity***	***Reduce Uncertainity***
Phenomena Exploration *–Ask students to share their understanding. And develop a Big Idea based on their prior knowledge.*	**Initial Argumentation and Claim** *–Ask students to analyse the data collected and describe in their own words what they think happened.*	**Reliable Resource** *–Include a discussion about why a resource is reliable or have students search for information and vet the source they find.*
Design Investigations *– Ask students to think about how they will investigate the phenomena and how to design a fair test.*	**Competing Models of Understanding** *– Present two ideas to the students and have them engage in scientific argumentation (Claim, Evidence, and Reasoning) to present their understanding at this point in the lesson.*	**Revise Claim and Include New Vocabulary** *– Ask students to revise their claim and either explain why their initial idea was wrong or expland their understanding by including newly-learned vocubulary.*

Research question

What is the relationship between teachers' use of the HIDE method and how their students select evidence for their claims?

Method

In the study, two 6th grade teachers and their students (n = 217) in a large metropolis school district in the southwest United States served as the participants. One of the teachers in the study had finished the first year of an optional multi-year professional development designed to help teachers to create a curriculum using the HIDE method. The second teacher did not attend the professional development and used a traditional approach to instruction that relied on teacher lectures and demonstrations. Both teachers agreed to record five 45-minute lessons: specifically, lessons completed after students finished an investigation and before the teacher explained the science behind the activity. To further evaluate the instructional differences between the two teachers, the author and a graduate assistant evaluated the videos using the Reformed Teaching Observation Protocol (RTOP, Sawada & Piburn, 2000) after they were formally trained in how to score the tool.

The RTOP is a commonly-used observational instrument that has been utilised frequently in research to assess the degree to which mathematics or science instruction in grades K-12 (ages 5-16) is reformed (Sawada & Piburn, 2000). Possible scores range from 0 to 100 points, with higher scores reflecting a greater degree of use of reform-based instructional practices (Sawada & Piburn, 2000). A Cohen's κ was conducted to determine if there was an agreement between the two reviewers, and a high level of agreement was found ($\kappa = .791$, $p < 0.001$).

Finally, each student in the teachers' classes was given two modified versions of the Illinois Critical Thinking Test (Finken, 1992) in the autumn of 2018 (before any science instruction) and in May 2019.

The Illinois Critical Thinking Test was chosen to measure the quality of the students' argument and the evidence used to support their argument, because the rubric for the assessment uses a claim, evidence, reasoning framework similar to Toulmin's (1958) argument framework.

Before administering the assessment, teachers provided a prompt of '*Please read the question at the top of the page, think about your answer, read the available evidence and then write the best scientifically-based answer you can that explains the reason why you support your idea over others*'.

We designed a task where students were asked to write an essay about a topic, and they were provided with eight documents of evidence (four supporting the topic and four against it; see

Table 1) written by fictitious authors. The evidence documents were designed to have varying degrees of trustworthiness by assigning the epistemic trust (ET) characteristics of expertise, integrity and benevolence to each 'author' (Hendriks, Kienhues & Bromme, 2015). In the autumn, students were asked: 'Do you think violent video games make kids act violent?' and, in the spring, students were asked: 'Should we invest more money in space exploration or focus on problems on Earth?'. The key aspects of ET mentioned earlier were considered when assigning attributes to each author (see Table 1). It is important to note that we were not concerned with which position the students took on the topic. Instead, we were more interested in how the students selected evidence to back their claims.

Results

Teacher 1 (who attended professional development and used the HIDE approach) scored significantly higher on the RTOP than Teacher 2. Specifically, Teacher 1 had a mean score of 74 for the video lessons they submitted, and Teacher 2 had a mean score of 29. Ebert-May *et al* (2015) created categories based on aggregate RTOP scores and, according to their rating, Teacher 1's instruction would be described as *'Active student involvement in open-ended enquiry resulting in alternative hypotheses, several explanations, and critical reflection'*. Using the same criteria, the videos submitted by Teacher 2 would be described as *'Lecture with some demonstration and minor student participation'* (Ebert-May *et al*, 2015, p.4). These additional data were helpful because they show

Source 1 *Peer – 6th Grade Student*	**Source 2** *Middle School Principal*	**Source 3** *Former Researcher who works for a Video Game Company*	**Source 4** *Scientist at a Major Research University*
Synopsis of Article (E1 - Pro) Explained how they play violent video games and they are not violent. (E2 - Con) Explained how they had a friend who started getting into fights after they started playing violent video games.	**Synopsis of Article** (E1 - Pro) Explains how they have observed more office referrals from students who self-reported to play violent video games. (E2 - Con) Explains how there is an after-school video game club at their school. Sometime kids play violent games at the club and they have never had issues with violent behaviour with those students.	**Synopsis of Article** (E1 - Pro) Explains that their research shows that violent video games do not cause violence and even improve academic performance. (E2 - Con) Explains that they have research that shows violent video games cause aggressive behaviour, but education video games (produced at the company he works for) improve academics.	**Synopsis of Article** (E1 - Pro) Empirical evidence suggests that violent video games might increase short-term violent behaviour. (E2 - Con) Empirical evidence (from actual peer-reviewed articles) suggests that there is no correlation between violent video games and violent behaviour.
Low Expertise/ Integrity No degree, no collaboration with experts, anecdotal evidence, and no citations or referencing professional organisations.	**Low Expertise/ Integrity** No degree, no collaboration with experts, anecdotal evidence, and no citations or referencing professional organisations.	**High Expertise/Integrity** Terminal degree in the field, recognised and publications from peer-reviewed articles.	**High Expertise/ Integrity** Terminal degree in the field, recognised international expert, and citations from peer-reviewed articles.
Low Benevolence Promotes a specific video game (either violent or non-violent) and asks readers to follow them on social media.	**High Benevolence** Explains how the aim of their article is to help students be more informed so they can be better students.	**Low Benevolence** Lost their job at the university because it was discovered they were being paid by a video game company to publish articles that promoted the type of games the company made.	**Low Benevolence** Explains how the aim of their article is to provide the most accurate information to readers so they can make informed decisions.

Table 1. Description of each source of evidence that students in the study could choose from.

some clear differences between the instructional practices of the two teachers and that Teacher 1 implemented the HIDE approach in a way that was commensurate with the professional development they received the previous summer.

Finally, Table 2 has the results of how the students in the study selected evidence. The results highlight a significant difference between the students taught by Teachers 1 and 2. Students taught by Teacher 1 saw a 33% increase in selecting the evidence written by the fictitious author who had high expertise/integrity and benevolence. Those same students selected the fictitious author who had low expertise/integrity and benevolence 12% less at the end of the year than they did at the beginning of the year. The students taught by Teacher 2 had almost no change in the authors they selected for their evidence. In fact, those students selected the author with high expertise/integrity and high benevolence 2% less at the end of the year when compared to their essays at the beginning of the year.

Summary

The data from the study are encouraging because there was a clear difference in how the students selected evidence. The main result was that the students who were taught by the teacher using the HIDE method selected evidence from the source that would be considered more epistemically sound. It is important to note that the results of this exploratory study need to be considered with a degree of hesitancy due to the small sample size of two teachers. However, the main finding was the shift in how their students selected evidence to support their claims after a year of two very different approaches to instruction. This study would need to be replicated with more teachers and students to increase the confidence in its findings.

In the introduction to this paper, we mentioned that science teachers had been called upon to teach both content and process of science. One aspect of the process of science that is overlooked in science education is how scientists determine if the evidence they encounter is high enough quality to be considered in the construction of their knowledge.

However, most science curricula spend little to no time discussing why the evidence that supports scientific knowledge is reliable, or how the process

Evidence Sourcing	Source 1 *Low Expertise/Integrity Low Benevolence*	Source 2 *Low Expertise/Integrity High Benevolence*	Source 3 *High Expertise/Integrity Low Benevolence*	Source 4 *High Expertise/Integrity High Benevolence*
Students for Teacher 1 Pre-Test Selection	21 (16%)	35 (27%)	31 (24%)	41 (32%)
Students for Teacher 1 Post-Test Selection	4 (4%)	19 (15%)	8 (6%)	84 (65%)
Change in Evidence Selection	△ - 17 (-12%)	△ - 16 (-12%)	△ - 23 (-18%)	△ + 43 (+33%)
Students for Teacher 2 Pre-Test Selection	18 (16%)	31 (27%)	30 (26%)	37 (32%)
Students for Teacher 2 Post-Test Selection	12 (10%)	35 (30%)	34 (29%)	35 (30%)
Change in Evidence Selection	△ - 6 (-6%)	△ + 4 (+3%)	△ + 4 (+3%)	△ - 2 (-2%)

*Note– Teacher 1 Student *n*=107; Teacher 2 Student *n*=110.
*A student's essay could receive more than one code and the aggregate score and percentages reflect how many students within that category had the same coded response.

Table 2. How the students in the study selected evidence in their essays.

of science evolves over time. This topic has become paramount in recent years, with so many people finding scientific information online and the massive amount of misinformation being spread over those formats (König & Jucks, 2019).

In this study, we were focused on the instructional practices of teachers and whether these influenced student choice of evidence. We were interested in collecting data to determine if these types of learning environments would change students' proclivity to select quality evidence for their claim. We believe that promoting evidence quality evaluation is a worthy aim of science instruction and can be accomplished by adjusting a few key pedagogical choices.

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Dr. Mason Kuhn is an Associate Professor in the Department of Curriculum and Instruction at University of Northern Iowa in Cedar Falls, Iowa in the United States.
E-mail: Mason.Kuhn@uni.edu