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ABSTRACT

With the rapidly increasing demand for STEM skills, many scientists, mathematicians, engineers, and technology professionals encourage students to pursue STEM careers. However, communicating science to lay audiences is challenging due to complex scientific terminology. This qualitative research aimed to demonstrate how an exemplary scientist, Dr. Reed, used storytelling to teach science in a 7-month internship for high school students. Data sources included real-time videos, field notes, and individual student interviews. Labov's model was used to analyze 75 stories. The analysis shows that Dr. Reed's stories mainly targeted eight teaching purposes. Telling such stories allowed Dr. Reed to relate scientific practices to what the students were experiencing in the science internship. Science educators can use this study's findings to build their storytelling practice with the goal of communicating science to students more effectively.

KEYWORDS

Storytelling; scientists; high school students; internship; science communication

Introduction

With the rapidly increasing number of STEM jobs, many scientists, mathematicians, engineers, and technology professionals encourage K-12 students to pursue STEM careers (Munson et al., 2013). Working at the elbow of scientists and technicians in science laboratories has been suggested as an effective way to allow students to experience science more authentically (Barab & Hay, 2001). Through these apprenticeship-like activities, students can experience science in real-world and contextualized environments, access state-of-the-art technology, exercise their critical thinking to examine scientific evidence, and understand the relevance and importance of science to society. Importantly, the direct working relationship with scientists allows students to know scientists as real people beyond the stereotype of middle-aged white men in lab coats, or negative images such as 'monsters' or 'mad scientists' (Chambers, 1983). Students also gain opportunities to converse with scientists about professional or personal matters of interest to them. As a result, students may develop interest in science and enthusiasm about science careers (Gibson & Chase, 2002; Knox et al., 2003). However, the jargon and scientific language scientists use tends to be a communication barrier (Peters, 2013) and may be too cognitively demanding for students to comprehend (Fang, 2006). In particular, the overuse of jargon may negatively affect learners' science interest and engagement (Shulman et al., 2020). Thus, without effective training, it may be challenging for scientists to engage K-12 students. In fact, the Royal Society (2006) reported that among 3,000 scientists surveyed, 70% reported they had not been offered training opportunities to build their science communication skills. Moreover, scientists typically do not have time to develop high-quality public outreach activities due to their busy research schedules

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(Mathews et al., 2005). Thus, finding effective science communication tools that do not require much time for scientists to master becomes an important task for scientists to enhance their science communication.

Storytelling is an approachable and universal discourse that people easily comprehend (Hampton, 2004). Stories usually contain vivid descriptions of experiences that foster engagement with their audience. Storytelling is a low-threat, familiar, enjoyable activity for most people in most cultures (Hampton, 2004). For controversial topics, a story permits indirectness while delivering the key message; thus, storytelling helps avoid conflict or debates and can help people keep face and maintain conversational etiquette (Ting-Toomey & Kurogi, 1998). In science education, stories can serve as useful scaffolds. For example, stories can provide a contextualized and meaningful background for students to learn scientific concepts (Aurélio et al., 2021; Konicek-Moran, 2013) and can make science more interesting by illustrating the relationship between humans and science (Clough, 2011). Course-oriented, concrete, and memorable stories can capture students' attention and interest (Bolkan et al., 2020) and even help students understand the importance of justice, diversity, equity, and inclusion in STEM fields (Collins et al., 2023). Storytelling is also suggested as a rich tool to support culturally responsive science education (Wallace et al., 2022). Moreover, through reading or listening to stories about scientists, students can learn the different natures of scientific practices and how scientists conduct scientific experiments. Thus, well-structured stories can enhance students' views on the nature of science (Brunner & Abd-El-Khalick, 2020). However, most research about the use of stories in science education has involved young children and teachers in schools. Little research has investigated how scientists might use stories in university laboratory settings. Scientists tend to be seen as serious people who value rigor and evidence-based discourse. Studying how storytelling might support teaching in a laboratory could provide valuable insights about alternative ways of engaging students in a serious environment. Therefore, this study aims to address this research question: How does an exemplary scientist use storytelling to teach science during an internship of high school students?

Theoretical framework: Labov's model

To investigate the exemplary scientist's storytelling discourse, I drew on Labov's model as the theoretical framework for analysis. Labov's model is an analytical framework to understand narratives of personal experiences (Labov, 1972; Labov & Waletzky, 1997). In Labov's model, a narrative comprises six basic components: *abstract*, *orientation*, *complicating action*, *resolution*, *coda*, and *evaluation* (see Table 1). In the *abstract* (how does the story begin?), the storyteller summarizes what the story will be about. In the *orientation* (what does it involve?), the narrator orients the audience by describing the setting and providing information about *who*, *where*, and *when*. In the *complicating action* (what happened?), the narrator explains the main problem or issue of the story. In the *resolution* (what finally happened?), which may end in a *happy*, *unhappy*, or *open-ended* situation, the narrator describes how the issue or problem was solved or how the events concluded. In the *evaluation* (so what?), the narrator evaluates the story's events, or steps out of their storytelling role to

Table 1. Six components of Labov's model of narratives, and their definitions.

Component	Definition
Abstract	Summarizes what the story is about
Orientation	Orients the listener to understand the 'who, what, when' of the story
Complicating action	Presents the issue
Resolution	Explains how the issue was resolved or the events concluded
Evaluation	Evaluates the story
Coda	Signals the story has ended and brings the listener back to the purpose of the story

provide a floor to further discuss the story's meaning and goal. During the evaluation process, the audience should be welcome to add their own thoughts on the story and its moral. This step helps convey different interpretations of the story and allows the audience to agree about what the story means and how it applies to the real-world. In the *coda* (what does it all mean?), the narrator relates the story to his or her main objective and bridges the story to the real-world (e.g. offering a moral lesson supported by the story).

The six components reflect the typical progression of a narrative, from the establishment of a setting, to a complication, a resolution, and a return to the present. A story might include all six components, but sometimes a brief account of the past can qualify as a story as long as it has the necessary component of 'complicating action' (Labov, 1997). Importantly, as narrators, we evaluate life events in terms of the cultural norms and expectations of our particular community. In this way, we affiliate with other members of society. According to Labov and Waletzky (1997), the *evaluation* highlights the point of the narrative and involves two modes of expressing that point: *external* and *internal* evaluation. External evaluation is when the narrator steps outside the recounting to state a point or offer interpretive remarks. For example, the narrator might say, 'I was young then, and it was okay for me to work like that'. Internal evaluation refers to the use of lexical, syntactic, and paralinguistic devices, such as modifiers, quantifiers, or exclamations, that are repeated or embedded in the story itself. For example, the narrator might say, 'For that whole month, I worked hard for 16 hours a day!' These six components of Labov's model provide an excellent framework for analyzing storytelling discourse systematically.

Research methods

Research context

The study is part of a 4-year research project, the Work with A Scientist Program, that supported high school students to work with scientists in a science internship at a Hispanic-serving university. This study was approved by the university's institutional review board. The internship was an intensive 7-month program that took place over 10 Saturday afternoons in spring (Jan–May) and 30 days in summer (Jun–Jul). Four university scientists, representing chemistry, neurology, biology, and immunology, were involved in the program. Each scientist, assisted by 1–3 research assistants (RAs), guided 5–9 high school students to learn scientific practices and conduct open-inquiry research, followed by cogenerative dialogs (cogens) to reflect on those practices. Cogens are conversations among different stakeholders to reflect their collective experiences, with the goal of reaching collective decisions about the rules, roles, and responsibilities that govern their shared activities (Roth et al., 2002). In the internship, cogens were used as formative assessments (Hsu & Liao, 2022) to identify issues and then generate solutions to address the issues and improve the group's scientific practice. More details about the project's cogen practice can be found in Hsu (2018, 2019a). The culminating activity was students' presentation of their scientific research to the scientists and to their families, teachers, and friends. More details about the principles and design of the internship can be found in Hsu and Espinoza (2018). To better understand scientists' narratives in the internship, our research team used video-recording to capture real-time interactions between scientists and high school students (Rogoff, 2003). After viewing these videos, I identified one exemplary scientist, Dr. Reed, as a case study to investigate how scientists might use narratives to teach science. I chose Dr. Reed as the case study because she shared more stories than other scientists in our project. Since storytelling is not a pervasive discourse in the science community, Dr. Reed's storytelling discourse represents a unique phenomenon and is worthy of further investigation. Importantly, students made numerous positive comments about Dr. Reed's teaching in the internship, such as this one: 'It was an extremely positive environment. Dr. Reed found ways to relate to us while teaching'.

Data sources and data analysis

The data sources included video-recorded internship and cogen sessions (188 and 22 hours, respectively) conducted with Dr. Reed's laboratory team. For the data analysis, I used both deductive and inductive approaches to analyze the storytelling discourse. For the deductive approach, I used Labov's model (1972) to identify stories and their narrative components (abstract, orientation, complicating action, resolution, evaluation, coda). A narrative, no matter how short, was defined as a story if Dr. Reed mentioned a 'complicating action' (Labov, 1997). However, if she related a past event but did not include a complicating action, it was not counted as a story. In sum, during the 188 internship hours and 22 cogen hours, Dr. Reed told 75 stories (49 during the internship and 26 in cogens) to help her teach science. Therefore, I applied the theoretical framework of Labov's model to analyze the data of 75 stories. For the inductive approach, I conducted *consistent comparative analysis* (Glaser & Strauss, 1967) to identify themes in the purposes of storytelling. I first reviewed videos and transcripts to identify different segments of stories shared in Dr. Reed's discourse. Second, I analyzed and compared these stories to find similarities and differences between them to generate open codes (open coding) about the stories' purposes, which could usually be identified by the story's context (e.g. Was the story told when students were about to perform a scientific practice? Was the story told to assist students in writing better scientific notes? Was the story told to address challenges students encountered?). Third, I compared these open codes, found connections, and generated categories between them (axial coding). Fourth, I compared these categories and produced core categories (selective coding). Through these analytical steps I identified eight core categories of story purposes, as reported in the following sections.

An exemplary scientist's storytelling in high school students' internships

This qualitative study investigated the storytelling practices of an exemplary scientist, Dr. Reed, in high school students' internships. The analysis shows that Dr. Reed shared stories mainly to achieve eight purposes in teaching science to high school students: (1) to teach students about a particular scientific concept, practice, or equipment; (2) to teach students how to take scientific notes systematically; (3) to encourage students to ask questions or for help to clarify scientific understanding; (4) to encourage students to persist when they encounter difficulties; (5) to acknowledge the value of students' ideas and possible contribution to science; (6) to improve students' teamwork and team communication; (7) to help students present scientific findings effectively; (8) to help students understand the career of becoming/being a scientist. In the following sections, I explain each story purpose with examples and narrative analysis of Dr. Reed's storytelling.

Purpose #1: to teach students about a particular scientific concept, practice, or equipment

One of Dr. Reed's purposes for using stories in the internship was to teach students about a particular scientific concept, practice, or equipment. For example, she might share her own or her colleagues' experiences to clarify how radiation therapy advanced over her lifetime, to demonstrate how to develop project ideas or manage one's time to complete scientific experiments, or to convey the cost of specialized laboratory equipment.

A story that helped Dr. Reed teach a particular scientific concept to students is illustrated in Table 2. In this example, Dr. Reed recounted that as a graduate student, she heard about a laboratory fire caused by students' indiscretion in their experiment, which led to an *unhappy* event ('the teacher was so pissed'). Dr. Reed then made an *external* evaluation ('not nice'). To help students avoid similar laboratory mistakes, Dr. Reed used this story to convey the importance of being aware of scientific knowledge ('you guys already know every time you see a clear solution in the lab, know what it is. It's not usually water'.) and following laboratory procedures ('Any time you run a gel in the lab, it has to be buffered'.). This story helped students understand that agarose

Table 2. A story example of 'teaching students about a particular scientific concept, practice, or equipment'.

No	Labov's model	Story example
1	Abstract	*Okay, so you're going to set up an agarose gel. Any time you run a gel in the lab, it has to be buffered. And the reason why I tell you this.*
2	Orientation	*So, I went to a good graduate school, and at the graduate school, somebody saw that the buffer was clear, and they thought it was water.*
3	Complicating action	*And they ran, I don't know what they ran in there, but they set the box on fire.*
4	Resolution	*And of course, the teacher was so pissed and was running up and down the hall telling everybody about the idiot in his lab.*
5	Evaluation	*Not nice, okay.*
6	Coda	*So, we're not going to make that mistake because you guys already know every time you see a clear solution in the lab, know what it is. It's not usually water.*

gel is transparent and flammable. Instead of telling students explicitly that agarose gel is transparent and flammable, this vivid story of a fire implicitly described similar properties of agarose gel. Moreover, this story helped students understand the possible consequences when they don't fully understand or follow proper scientific procedures.

Purpose #2: to teach students how to take scientific notes systematically

Since notetaking plays a crucial role in scientific practices, Dr. Reed told several stories to emphasize the importance of taking systematic notes. For example, she told stories of experiments that failed because she or her colleagues had not taken consistent notes. She emphasized the rationale for taking systematic notes (e.g. being able to reliably replicate work in the future) and tried to illustrate all the possible problems or confusion students might encounter (e.g. forgetting steps, not being able to find the right steps to move forward) if they did not take notes accurately and consistently.

A story example that helped Dr. Reed teach students how to take systematic notes is illustrated in Table 3. In this story, Dr. Reed shared an *unhappy* incident where someone had failed to keep intact scientific notes the previous year ('we had somebody actually tear a page out') and made an *external* evaluation by explaining that if someone did not keep systematic notes as instructed by the funding agency, the person actually committed a crime and might end up in jail. This story helped Dr. Reed demonstrate how important systematic notes are when conducting scientific research.

Purpose #3: to encourage students to ask questions or for help to clarify scientific understanding

Dr. Reed used many stories to encourage students to ask questions or for help when needed to clarify their scientific understanding. These stories outlined various benefits when students take the initiative to ask questions. For example, students may not understand because the professor went too fast and skipped too many bridging concepts. Dr. Reed's stories conveyed that students

Table 3. A story example of 'teaching students how to take scientific notes systematically'.

No	Labov's model	Story example
1	Abstract	*Your notebooks, they belong to the government. They don't belong to me.*
2	Orientation	*Last year, we had somebody actually tear a page out of the back.*
3	Complicating action	*It is illegal to remove pages from this notebook. Okay? That's why they're bound. So, you can look at the top, each page has a number, and each page needs to be there.*
4	Resolution	*The reason why is that, if you make a discovery, if you find something that actually helps to cure cancer and we publish it, we have to be able to go back to your notebook, if anybody asks, we have to be able to go back and say, okay, John did this, this, this, this, this.*
5	Evaluation	*The pages have to be in sequential order, and I have to be able to show the people of the NIH, this is how we did it. If we can't do that, there's people who have gone to jail behind that. Okay?*
6	Coda	*So, it's important that you keep your notebook pages all together.*

should not feel ashamed to ask questions or worry about looking dumb because even the professor's colleagues with advanced knowledge may not always understand her instructions. Importantly, if students do not fully understand the professor's instructions, they are likely to make mistakes and delay their progress in completing their scientific experiments. Thus, asking questions can help students learn science faster and more effectively.

A story that helped Dr. Reed encourage students to ask questions to clarify their understanding is illustrated in Table 4. This story depicted a conversation between herself and another professor who had almost won a Nobel Prize. During this conversation, Dr. Reed was trying to explain her experiment to her colleague but was asked to 'slow down' her explanation. Dr. Reed was surprised and thought that a professional scientist like her colleague should have known all the terms she mentioned. But Dr. Reed then had the *happy* realization that every person has a different background and expertise, and she should not have assumed that her colleague had all the basic knowledge to understand what she articulated. Dr. Reed made an *external* evaluation and used this story to demonstrate that even her colleague sometimes could not understand her explanation and needed her to slow down. Therefore, students should feel confident to ask questions when needed until they fully understand Dr. Reed's instructions.

Purpose #4: to encourage students to persist when they encounter difficulties

Dr. Reed also used many stories to encourage students to keep trying when they encountered difficulties with their scientific projects. When conducting scientific research, it is normal to have all types of issues, problems, and troubles. Scientists might make mistakes in their scientific procedures, equipment might not work properly, supplies might have quality issues, and so on. Dr. Reed shared stories about many types of problems she and her colleagues had encountered. These stories demonstrate that even professionals like Dr. Reed (who has done scientific experiments for decades) frequently encounter problems. Thus, students should not feel discouraged when they encounter difficulties in conducting their scientific experiments because it is a normal aspect of doing science. Students should see difficulties as part of their scientific practice and should not give up when they encounter any.

A story that Dr. Reed used to encourage students to not give up when they encounter difficulties is illustrated in Table 5. This story described an *unhappy* situation when Dr. Reed was a PhD student; like many peers in her laboratory, she could not get her experiment to work. Thus, the atmosphere in the laboratory was depressing and negative. This collective negative emotion shows that it is normal, even for PhD students, to encounter difficulties. Dr. Reed made an *external* evaluation that students should see these ups and downs as a normal part of conducting scientific experiments. If students persist and do not give up, they will likely succeed eventually, just like scientists who won the Nobel Prize did.

Table 4. A story example of 'encouraging students to ask questions or for help to clarify scientific understanding'.

No	Labov's model	Story example
1	Abstract	*But I know it's not easy. So, you know, I wouldn't at all, ever, look at somebody and think [he is stupid].*
2	Orientation	*I met this guy, who was almost like this close to a Nobel Prize and I'm explaining to him my science.*
3	Complicating action	*And he's like, "Okay, wait. Wait, wait, wait. Okay, slow down, um, the vector is what?" And I'm thinking, "What?" I mean, you know, geez, it's your level of education, you're slowing me down?*
4	Resolution	*But it made me realize that everybody comes into this with a different background, if they're not getting it, slow me down.*
5	Evaluation	*That's okay.*
6	Coda	*And don't worry about your buddies in here 'cause they probably don't get it either, if you're asking for the fifth time. And you're going to find that out in college, you'll be asking something for the ninth time and everybody's sitting there going, "Ugh." And then you look at the exam and everybody's got F and you're like, "Nobody understood this." And you're the only one sitting there with an A because you pressed and you learned.*

Table 5. A story example of 'encouraging students to persist when they encounter difficulties'.

No	Labov's model	Story example
1	Abstract	*Usually, science is all about troubleshooting … That's the whole gist of being a scientist, and then people who get the Nobel Prizes are the ones who figure out how to get the experiments done, get the answers. It's not that people don't have ideas or that they're not brilliant, it's most of the time they can't figure out how to get the science done. So that's the hard part. And like we have this idea, right? We know what we wanna do with it, but it's trying to get that science done. That's the tough one.*
2	Orientation	*So when I first started my lab, when I was doing my PhD, write our little notes, listen to a song [chuckles]. It's like this one.*
3	Complicating action	*It's horrible. It's a pretty song, but it's very depressing, and we used to play it all the time when I was in Boston, because nobody could get their experiments to work.*
4	Resolution	*It's like, nobody's stuff is working, this place is depressing, because you're so miserable here.*
5	Evaluation	*So, that was miserable.*
6	Coda	*So, you guys are normal.*

Purpose #5: to acknowledge the value of students' ideas and possible contribution to science

When students doubted their own ideas, Dr. Reed also told several stories to acknowledge the value of students' ideas and possible contribution to science. In the Work with A Scientist Program, high school students were invited to conduct open-inquiry projects that encouraged their creativity and autonomy. It was inevitable that students would feel uncertain about their ideas for conducting their own scientific experiments. To acknowledge and encourage students' ideas, Dr. Reed described several incidents when she or her colleagues doubted their own ideas or were doubted by their supervisors during their scientific practices and it turned out that these ideas were valid and valuable. Dr. Reed used these stories to assure students that they should be confident in their ideas and not underestimate their possible intellectual contributions to science.

A story that helped Dr. Reed acknowledge the value of students' ideas and possible contributions to science is illustrated in Table 6. In this story, one of Dr. Reed's colleagues had an innovative hypothesis about a possible origin of a disease (i.e. mosquitoes' eggs), but his advisor rejected this hypothesis without investigation. Instead of feeling discouraged by his advisor, Dr. Reed's colleague did not give up his idea but instead conducted further scientific investigation. It turned out that Dr. Reed's colleague was right, and he proved that the origin of this disease came from mosquitoes' eggs. As a result, Dr. Reed's colleague achieved a *happy* ending by publishing an article in a top journal. This story helped Dr. Reed make an *external* evaluation by conveying that students

Table 6. A story example of 'acknowledging the value of students' ideas and possible contribution to science'.

No	Labov's model	Story example
1	Abstract	*I like the fact that you guys are moving quickly because then you've got a little bit extra time to think about something else. So, you guys ever noticed that guy that when you walk by his office, he's got gray hair, Joe, right?*
2	Orientation	*So he was going to graduate school. And he studies vector-borne illnesses, okay?*
3	Complicating action	*And people couldn't understand why every year this disease was coming back. Like, the mosquitoes were dying off. How could this disease come every year? And he said, "I think it's in the eggs. I think they're sending it into the eggs, and then the mosquitoes are coming back." And his advisor was like, "Pfft, you're an idiot. Don't come back in here with that stupid stuff or get out of my life [chuckles]." And so, Joe ran around and collected the eggs. And he put them in a freezer. And his boss said, "I told you you're an idiot." And he put a padlock on the freezer. And he said, "You don't go in there."*
4	Resolution	*So Joe cut the lock off [chuckles], went into the thing, and found out that he was right, that the reservoir for the virus was in the eggs.*
5	Evaluation	*But his adviser told him not to do that. So he published a paper in the world's top journal; he published it in Nature, by himself as the sole author, because his adviser didn't believe in it.*
6	Coda	*And the point is that if you guys have an idea, and I appreciate the fact that you're creative, if you have an idea, think about whether or not you think it's a valid idea, and if there's gonna be data yielded from that.*

should not ignore their ideas and should be confident in their scientific thinking and possible contribution to science.

Purpose #6: to improve students' teamwork and team communication

In the Work with A Scientist Program, three students were invited to work on a scientific project as a group. During the group work, various teamwork and communication issues occurred. Dr. Reed shared stories to encourage students to confront and solve the issues as a group. She tried to help students understand that it is normal for group members to disagree, but each group member must try to solve those problems for the good of the project.

A story that helped Dr. Reed improve students' teamwork and team communication is illustrated in Table 7. First, Dr. Reed recognized the difficulty of group work. Then, she shared a story that depicted a conflict she had at home with her husband, her teammate in marriage. She described the negative emotions she felt during that conflict. But as time went by, Dr. Reed realized that she needed to solve the problem with her husband and so reached out to him to discuss their conflict. This *happy*-ending story demonstrated that people have communication issues even with family members, who are more intimate than classmates. Then, Dr. Reed made an *external* evaluation that students should take teamwork seriously and do their best to enhance group communications. This story helped Dr. Reed make the point that teamwork is not easy and requires intentional effort and time to maintain its quality and success.

Purpose #7: to help students to present scientific findings effectively

In the Work with A Scientist Program, students would present their scientific findings to the public. Most students were nervous about public speaking. Dr. Reed shared many stories to suggest strategies to help students prepare their presentations beforehand. For example, she shared her or her colleagues' experiences with deciding what content to include in their posters. She addressed anxiety issues and speaking effectively during presentations.

A story Dr. Reed told to help students present their scientific findings effectively is illustrated in Table 8. To emphasize the importance of practicing before the presentation, Dr. Reed described a personal experience when she first became faculty and started teaching at a university. Being new to teaching, she was very nervous. But with practice, she improved and gradually gained confidence in her teaching. This *happy*-ending story helped Dr. Reed convey that a great strategy to improve one's public speaking is to keep practicing. She made an *external* evaluation that the more one practices, the more confident they will be as public speakers.

Purpose #8: to help students understand the career of becoming/being a scientist

In the Work with A Scientist Program, high school students worked closely with university scientists for 7 months and had unique opportunities to better understand the life of a scientist. Dr. Reed

Table 7. A story example of 'improving students' teamwork and team communication'.

No	Labov's model	Story example
1	Abstract	*I think teamwork is the hardest thing in the world, honestly. Right? Like if it was easier, people would stay married.*
2	Orientation	*And even in my own house, like sometimes I get mad at my husband.*
3	Complicating action	*I move down the hall. Pack my little bag up and I'm like, "I'm done. I'm moving down the hall. When the kids move out, I'm moving outta here. I don't need this." You know.*
4	Resolution	*And like three weeks later I'm like, "Okay, let's talk [laughter]."*
5	Evaluation	*It's hard. It's really hard.*
6	Coda	*Especially the situation you guys are in, because you're a group, now let's find a way to make this work. So, so if I were you, I might think about that.*

Table 8. A story example of 'helping students to present scientific findings effectively'.

No	Labov's model	Story example
1	Abstract	*So, what you want to do is practice a little bit more, because you know what you're talking about, but then you get all flustered and you start going off on all these tangents. And, I'm just like, "Where's she going with this?" So, you want to practice, just get your stories straight, and then that way, when you present, you won't be so nervous because I'm just like you are.*
2	Orientation	*When I first taught in medical school,*
3	Complicating action	*I was so nervous and I used to get these harsh criticisms from the students: "She should never teach. She's too nervous, da, da, da."*
4	Resolution	*But now, I'm more relaxed because I practice, and I find that that's what people do.*
5	Evaluation	*That, you know, people who've taught for years, they've practiced for years because they were talking in front of classes for years …*
6	Coda	*So, the thing is that the more you practice, the more confident you'll get.*

shared several stories to depict her life as a scientist. For example, she described how she chose to become a scientist, her journey of becoming a scientist, her workload, and her passion for science. These stories helped students understand her decision-making process of becoming a scientist and the day-to-day life of a scientist.

A story that Dr. Reed used to help students understand the life of a scientist is illustrated in Table 9. In this example, she described her daily schedule as a young scientist when she was a graduate student. At that time, she had young kids who required her devoted attention. Although she had a heavy workload, she also had flexibility in deciding when to work. Thus, she could balance her family responsibilities and her scientific work. Dr. Reed appreciated this schedule flexibility in her work as a scientist. She used this *happy*-ending story to make an *internal* evaluation showing that, as a scientist, she can balance home life and work through careful use of time and energy.

Frequency patterns of story purposes, resolutions, and evaluations

Frequency patterns of story purposes

During the 7-month internship program, Dr. Reed shared 75 stories to help her teach science to high school interns. Specifically, she shared 49 stories during internship activities (188 hours) and 26 stories during cogen sessions (22 hours). Each story is further categorized by the eight story purposes. The frequencies of different story purposes among these 75 stories are illustrated in Table 10. Four major findings based on the frequency patterns are identified.

Finding 1: On average, Dr. Reed told 0.26 stories/hour in the internship (49/188 = 0.26 stories/hour) and 1.18 stories/hour (26/22 = 1.18 stories/hour) in cogens. This result shows that Dr. Reed shared five times more stories in cogen sessions than in internship activities. It is observed that cogen sessions seem to afford more story discourse than internship activities. This may be because the goal of internship activities is to formally teach students scientific practice, whereas the goal of

Table 9. A story example of 'helping students understand the life of being a scientist'.

No	Labov's model	Story example
1	Abstract	*This job is not easy, but it's fun!*
2	Orientation	*I had my kids when I was in graduate school, and so I used to stay home with them until lunchtime. And we used to go to the library. We'd go to the park. We'd do all sorts of stuff together, and then, from lunch until 6:00, I would be in the lab. And then 6:00, I'd come home and feed the kids and get them ready for bed. And then, my husband would take the kids at that point. And then I'd go back to the lab at 7 o'clock at night, and I'd stay 'til midnight.*
3	Complicating action	*Because, like, I had all this flexibility with my time. And then, I would be back up in the morning at 6 o'clock with the kids again [chuckles]. It was great.*
4	Resolution	*Because, like, I had all this flexibility with my time.*
5	Evaluation	*And it was just like, "Ah [chuckles]." Oh, it was wonderful.*
6	Coda	*You'll see.*

Table 10. Frequencies of story purposes of 75 stories told in internship and cogen sessions.

Purposes	Internship (49, 188 hours)	Cogen (26, 22 hours)	Total (75)
1. To teach students about a particular scientific concept, practice, or equipment	33 (67%)	1 (4%)	34 (45%)
2. To teach students how to take scientific notes systematically	2 (4%)	3 (12%)	5 (7%)
3. To encourage students to ask questions or for help to clarify scientific understanding	1 (2%)	8 (31%)	9 (12%)
4. To encourage students to persist when they encounter difficulties	4 (8%)	4 (15%)	8 (11%)
5. To acknowledge the value of students' ideas and possible contribution to science	4 (8%)	2 (8%)	6 (8%)
6. To improve students' teamwork and team communication	0 (0%)	2 (8%)	2 (3%)
7. To help students to present scientific findings effectively	3 (6%)	3 (12%)	6 (8%)
8. To help students understand the career of becoming/being a scientist	2 (4%)	3 (12%)	5 (7%)
	49 (100%)	26 (100%)	75 (100%)

cogen sessions is to supplement internship activities and address any issues occurring during the internship. Thus, internship activities may be seen as a major, serious, and formal teaching space, whereas cogen sessions may be seen as a secondary, more relaxed, and informal space. Consequently, an informal discourse like storytelling would more likely happen in cogen sessions.

Finding 2: The most frequent story purpose overall was "to teach students about a particular scientific concept, practice, or equipment" (45%, 34 out of 75 stories). This story purpose was also the most frequent (67%, 33 out of 49) in the internship activity setting. This finding is consistent with the main purpose of internship activities, that is, of teaching scientific practices to students. Thus, in the internship activities, storytelling was naturally used to teach students about a particular scientific concept, practice, or equipment.

Finding 3: The second most frequent story purpose was "to encourage students to ask questions or for help to clarify scientific understanding" (12%, 9 out of 75 stories). This story purpose was also the most frequent (31%, 8 out of 26) in the cogen setting. Since cogen sessions were designed to address teamwork or communication issues, it was natural for Dr. Reed to encourage student dialogue in cogen sessions in order to understand their opinions. Thus, the stories she shared would be used mainly to encourage students to use their voices during cogen sessions.

Finding 4: The third most frequent story purpose was "to encourage students to persist when they encounter difficulties" (11%, 8 out of 75 stories). In the Work with A Scientist Program, students were invited to conduct open-inquiry projects, which rely on students' autonomy and self-direction. It is normal for students to experience uncertainty, confusion, and failures while engaging in authentic scientific inquiry. These failures and difficulties may discourage students and lead to quitting. To support students' scientific inquiry, Dr. Reed used many inspiring stories to acknowledge students' efforts and help them move forward without giving up.

Frequency patterns of story resolutions

The resolution component in a story indicates how the issue was resolved or how the events concluded. The issue may have been solved successfully, leading to a happy ending, or unsolved, leading to an unhappy ending. Of the stories Dr. Reed shared, 52% (39 of 75 stories) ended happily and 48% (36 of 75 stories) ended unhappily. That is, Dr. Reed highlighted success and failure equally in the stories she shared with high school interns about her career as a scientist.

Frequency patterns of story evaluations

The evaluation component in a story illustrates how the narrator evaluates the story told. The narrator may use *internal evaluation* by embedding his or her evaluative statement as part of the storytelling (e.g. I was so depressed in the laboratory) or *external evaluation* by making explicit comments (e.g. That was terrible!). The analysis of Dr. Reed's stories shows that 20% of the stories (15 of 75) were expressed through internal evaluation and 80% (60 of 75) were expressed through external evaluation. That is, Dr. Reed used external evaluations much more often than internal evaluations in her storytelling practices while interacting with high school students in their internships.

Discussion

This qualitative study illustrates how an exemplary scientist, Dr. Reed, used storytelling to teach science in high school students' science internships. Using Labov's model, 75 stories were identified and analyzed. The analysis shows that Dr. Reed's stories mainly targeted eight purposes: (1) to teach students about a particular scientific concept, practice, or equipment; (2) to teach students how to take scientific notes systematically; (3) to encourage students to ask questions or for help to clarify scientific understanding; (4) to encourage students to persist when they encounter difficulties; (5) to acknowledge the value of students' ideas and possible contribution to science; (6) to improve students' teamwork and team communication; (7) to help students present scientific findings effectively; and (8) to help students understand the career of becoming/being a scientist. Telling such stories allowed Dr. Reed to relate scientific practices to what the students were experiencing in the science internship. This study has four important implications.

First, this study provides empirical evidence to showcase how an exemplary scientist used storytelling to communicate science to high school students. The analysis suggests that the main purpose of Dr. Reed's storytelling was to teach scientific concepts to students (purpose #1, 45%). Most of Dr. Reed's stories were about incidents that occurred in a laboratory, during research, and when she was faculty. This finding shows that scientific concepts can be enhanced through storytelling based on professional or daily life, not necessarily just by using scientific jargon and terminology (e.g. Dr. Reed's story about setting a fire while running an agarose gel helped students understand that agarose gel is 'transparent' and 'flammable'). Story narratives provide vivid details and are easily understood and remembered due to their contextualized nature. As a result of this study's findings, other scientists may learn from Dr. Reed's storytelling practices and incorporate these practices into their own interactions and communications with their students, which may reduce the intimidation issues of scientific language identified in previous studies (e.g. Shulman et al., 2020). Science educators can also use these findings to build their storytelling practices in order to communicate science more effectively in various educational settings.

Second, this study suggests that educators should provide a variety of interactional structures allowing different social interactions and discourse in student–scientist partnerships. The analysis suggests that Dr. Reed shared more stories (1.18 stories/hour) in cogen practice than in internship practice (0.26 stories/hour). That is, cogens provided a friendlier space and served as a 'story incubator' allowing Dr. Reed to naturally share more stories with students, including professional and personal ones. As sociologist Pierre Bourdieu (1990) suggested, different *fields* are composited with different social interactions and can afford different social discourse and social practice. In the Work with A Scientist Program, cogens served as a space for metacognitive dialogs aimed at improving internship teaching and learning. Given that the main practice in cogens is respectful dialogs that aim to solve any issues or address any concerns participants may encounter in their internship practice, it was natural that Dr. Reed would spend more time listening to students' voices and engaging in dialogs with students in cogen practice, as compared with internship activities that involve conducting scientific practices. Sharing more stories in cogen practice (compared to internship practice) is a natural result of social interactions in cogen. Therefore, to relate to students and teach science more effectively, educators might want to set up diverse communication forums and social interactions that can afford a variety of discourse in their programs. In addition to conventional scientific practices, a different, socially structured space such as cogens may produce different forms of discourse (e.g. storytelling) that may enhance the effectiveness of science communications. In particular, research has suggested that what may have been deemed as casual chat by mentors was actually viewed as meaningful exchanges for students (Bennett et al., 1998; Young & Perrewe, 2000). Thus, it is important to design a variety of activities and structures in a program to allow for different types of social interactions, including formal and informal ones.

Third, this study demonstrates that Dr. Reed shared both happy and unhappy stories of conducting scientific practices equally. In this study, the analysis indicates that among the 75 stories Dr. Reed shared, stories with both happy resolutions (52%) and unhappy (48%) resolutions were told. The unhappy stories often illustrated the frustrations scientists experience or the consequences of unsuccessful scientific practices. Research shows that students often do not choose STEM careers even though they know that everyone has the potential to become a scientist. However, when students learn about scientists' challenges and struggles in conducting scientific practices, they can relate more to scientists, and these stories even help students form science identities (Lin-Siegler et al., 2016). Dr. Reed's stories with unhappy resolutions demonstrate how scientists' challenges and struggles can be communicated through stories and at the same time achieve specific teaching purposes (e.g. teaching scientific concepts, teaching students how to take scientific notes and collaborate with each other).

Fourth, this study suggests that using external evaluation in storytelling practices can help deliver the story message explicitly. The analysis indicates that Dr. Reed used many more external evaluations (80%) than internal evaluations (20%) in the 75 stories she told. External evaluation means that the narrator speaks outside of the storyline and makes explicit comments about the story just told, whereas internal evaluation is when the narrator embeds his or her evaluation as part of the storyline. External evaluation allows the narrator to express their evaluation of the story clearly to the audience and help the audience understand the narrator's rationale for sharing that particular story. In the case of Dr. Reed, who often used external evaluation (80%) in her storytelling practices, she tended to make explicit her evaluation of the story she had just shared with students (e.g. 'Not nice, okay!') and apply that evaluation to inform students' practices (e.g. so we're not going to make that mistake!). Doing so likely helped students understand the main story messages and learn lessons from these stories to improve their scientific practices.

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Ethics statement

This study was approved by the Institutional Review Board at the University of Texas at El Paso (approval number: 496306-16). All participants were voluntary and provided written assents or consents for participating in this research. All names in this study are pseudonyms.

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