Chapter 5
Identity, Materials, and Pedagogy: Girls in Primary Science Classrooms in Wales

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Abstract Girls' achievement in science has caught up with boys' in the UK and the USA, yet girls do not choose careers in science at the same rate as boys. Understanding more about the multiple and sometimes contradictory ways that girls experience science in a classroom context will help shed light on the larger problem of girls' retention in science.

Keywords Children voices • Teachers' voices • Science pedagogy • Gender equity • Identity • Inquiry • Sociocultural • Strategies • Girls and science • Primary science classroom

Introduction

Floating and Sinking (Classroom A)

Ms. O'Neil introduced the science activity by telling the students (7- and 8-year-olds) their task was to discover which objects sink and which float and which might do both. The students were seated around a table in small mixed-sex groups of four. In the middle of the table was a plastic tub filled with water and a roll of paper towels for spills. On the front table, Ms. O'Neil had placed bins of objects for the students to choose from: small rubber ducks, birthday candles, feathers, and crayons with paper and without paper, different colored rubber bands, plastic berry baskets, wooden blocks, and plastic coins. The teacher established the rule that the students could choose five objects at a time, and she assigned one person in each group to be the one

Please note all schools', students', and teachers' names used in this chapter are pseudonyms.

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to get up and get them for the group. The students were told to return the first five objects and get five more to try. Once the rules were established, Ms. O'Neil let the students explore, discover, and "mess about" (Hawkins 1974). The room was noisy and busy with students getting up to get materials and making guesses to each other about which object would float or sink. Ms. O'Neil moved among the groups listening for the students' ideas about why one object would float or not and posing additional questions such as "What did you notice?" and "Tell me more."

The lesson took a little less than an hour. After about 15 min of exploring, Ms. O'Neil called all of the children to sit on the rug and report back on what they had discovered and what questions still remained especially what had confused them. She wrote all of their ideas and comments on the whiteboard. The students mentioned air, weight, size, and the materials the object was made of. The questions and ideas remained on the board until the next day when Ms. O'Neil posed another question to the students, "Could you make something that floats sink? And something that sinks float?" After doing this in the same groups and similar to the day before, Ms. O'Neil and the students added new questions on the board or erased the ones they had answered by additional exploration. On the third day Ms. O'Neil challenged each group with a scenario: they had to design a boat that could carry a piece of fruit (a small lead weight) across the tub of water to islanders who needed the food. They could use all of the materials and objects on the table, but they had to do it in silence yet cooperating with each other. At the end of each day of exploring and learning about floating and sinking, students were asked to make entries into both a group journal and an individual science journal. Ms. O'Neil looked at the ideas the students wrote about and what questions and confusions remained as a way to plan further instruction.

Floating and Sinking (Classroom B)

Ms. Abby like Ms. O'Neil introduced the science activity to the children by telling them they were going to learn about floating and sinking. As she wrote those words on the board, she asked the students what came to their mind. She then wrote those ideas on the whiteboard. The children said things like a heavy object like a rock would sink, while a light one like a seed might float. Ms. Abby had brought in a selection of fruits and vegetables (apples, grapes, oranges, carrots) and placed those objects on the desk in front of her along with a tub of water. She passed out a worksheet to all of the students who were seated at tables in small groups of four and asked each student to fill out the worksheet. They were to predict and mark on their worksheet which fruit or vegetable would sink or float and then see if they were correct as she placed them in the tub of water. At the end of the lesson, Ms. Abbey asked each student to draw a picture of what they had noticed and copy from the board the definition of buoyancy.

These two classroom scenarios, composites of science activities that I have observed, illustrate how two different teachers might teach the same science topic, floating and sinking. In structuring their lessons, the teachers make choices about how to plan instruction and which materials to use and how to group the students. In addition, whether conscious or not, teachers' decisions represent what they think science is and how it should be taught. These decisions plus a myriad of others such as how to group the children and what resources to make available to students all make up a classroom environment for learning science. The science activity described in Classroom B may look like a model science lesson. It is hands-on and the teacher has chosen interesting and appealing materials. Yet from the assessment it is unclear to the teacher whether the students have actually learned anything about buoyancy. In Classroom A, revisiting the concept of buoyancy over multiple class periods and through multiple investigations allows the teacher to scaffold the student's learning. The final assessment is a performance assessment which allows the students to show and not just tell the teacher what they understand. In this chapter, I suggest that some classroom environments may open up opportunities for all students to learn science (such as Classroom A), and other classrooms (such as Classroom B) may limit and close down opportunities especially for girls and some boys.

Girls and Science Equity

By all accounts girls' achievement in science has caught up with boys' in the UK and the USA (American Association of University Women 2011). Although achievement tests show girls' achievement progress, we know that they do not choose careers in science at the same rate as boys. In addition, these tests assume all girls experience science learning in the same way which we know is not true. Understanding more about the multiple and sometimes contradictory ways that girls experience science in the classroom context will help shed light on the larger problem of girls' retention in science. I begin by first reviewing the long cultural history and representation of science as a masculine content area.

The Historical Legacy of Science as Masculine

Science is often thought of as a masculine subject area. It is considered masculine because we are often taught mostly about male current and historical scientists. In schools science knowledge is described as rational, logical, and hierarchical with one way to get to the right answer. Science lessons are often about learning facts and memorizing definitions. Yet it has been widely recognized that learning in science through facts and definitions is not the way science is actually done in real life by scientists. The process of doing science is messy, subjective and objective, masculine and feminine, and grounded in scientists' personal experiences and social contexts. For example, in her biography of Barbara McClintock, Evelyn Fox Keller

(1983) portrayed the woman scientist as someone who used feminine subjectivity such as intuition and awareness of relationship to notice change in corn chromosomes. By showing that science can involve practices more associated with femininity than masculinity, Keller (1985) argued for reclaiming science as a fully human activity. She drew attention to the complex range of practices undertaken by scientists that she described as collaborative and inclusive of other's ideas. Despite such debates about science, social representations and images of science as masculine, objective, and unemotional continue to circulate in society and influence how science is taught in primary schools. Students tend to represent scientists as white males who wear glasses, never comb their hair, and mix chemicals in a lab. Some argue that students will continue to reconstruct science as masculine, rational, and objective and fail to recognize the roles of emotion and intuition unless teachers actively intervene to disrupt it (Haste 1994).

In order to try and understand how girls experience science, I chose two urban primary school classrooms in Wales to study. I had the opportunity to do this while having the benefit of a research scholarship in Wales in the spring of 2008. Over a period of 8 weeks, I observed these two classrooms and sat in on science lessons. I interviewed students and teachers before and after the science activity. The children were 7 and 8 years old (Year 3 in Wales). I asked the teachers about their goals for the lesson, the curriculum they were following, and how successful they thought the activity had been. In my interviews with the students, I used the same materials the teacher had used in the class, e.g., batteries and bulbs or a ramp and a car, to help the students remember the activity. In total I interviewed 28 boys and 18 girls who represented the population of boys and girls in the classrooms.

In addition to the interviews, I took notes on the classroom environment. I noticed the layout of tables; the availability of materials, texts, and equipment; and how the teacher and students used them. I was particularly interested in the access that students had to each other, how they were grouped, and the actions of the teacher and the classroom assistants in relation to the groups. Finally, I looked at whether the students could move freely around the classroom or were restricted to sitting at a desk or table.

Science Curriculum and Pedagogy in Wales

In Wales, science education reform documents determine which science topics should be covered at each grade or age level. For example, in Year 3 (7- and 8-year-olds) the following topics are expected to be covered: scientific inquiry, life processes and living things, materials and their properties, and physical processes. How the topics are taught and what materials the teachers use to teach these concepts are at the disposal of the individual teacher. These professional documents describe science in primary school as an active process of learning where teachers build on students' prior knowledge through inquiry-based questions to help students learn science concepts with deep understanding. Students are encouraged to "mess about" with objects (Hawkins 1974), exchange ideas with peers, and use their own questions for further exploration of puzzling phenomenon (Duckworth 1990, 1996). Science knowledge does not come from the objects themselves but from the ideas that are generated by the individual in interaction with and use of objects (American Association for the Advancement of Science 2001; National Research Council 2009a, b). This child-centered way of teaching science encourages students to learn how to "think like a scientist."

In the schools in Wales, there is a pedagogical document to guide teachers in how to teach science.[1] Known as CELIPS (Cardiff Effective Learning in Primary Science), this pedagogical format is based on the successful numeracy and literacy programs in Wales. In the CELIPS format, science lessons are timed and very structured. For example, there are five steps to a successful science lesson:

Engage: (5 min) whole class to get the students interested.
Explore: (10 min) (pairs or groups) to ascertain the present level of what the children know.
Challenge: (10 min) (pairs or groups) to take the learning forward.
Apply: (10 min) (whole class) apply new understandings.
Reflect: (5 min) (whole class) students say what I learned and how I learned it.

All of the teachers I observed were familiar with the CELIPS guide to teaching science. The science discourse in each activity was about making predictions and estimations, comparing and contrasting data, making accurate observations, and conducting "fair" tests. Where I found the classrooms differed is in how much time teachers gave the students to complete the investigation, i.e., multiple days or 1 h; how the teaching assistants responded to students; whether or not the students had access to the materials; and whether or not the students were able to move freely around the room to talk to other student groups or were restricted to working within a mixed-sex group. In all of the classrooms at the end of the lesson, students were asked to record their data by drawing or writing in an individual or group science notebook.

Learning as a Social Process

Classrooms are social places. Students interact with each other, teachers interact with students, and when it comes to science, students and teachers interact with the materials and objects of science, e.g., batteries, bulbs, plants, and animals. As students participate in a science activity, they bring their ideas of who they think they are as "scientists in the making" or as someone who can or cannot do science. As the teacher prepares the activity, she brings her own ideas of what science is and who can do it. These are the implicit and explicit messages that I mentioned earlier. In order for students to be able to learn in school (to gain the knowledge and skills

[1] The USA has a similar guide to teaching science called the 5 Es: *engagement, exploration, explanation, elaboration, and evaluation* (Bybee et al. 2006).

to understand science and act like a scientist), they have to be able to navigate these multiple messages and decide which particular types of information to concentrate on. For example, if Gina who likes science and wants to get better at it is asked to be the recorder in her group, she may or may not be able to actually participate in all parts of the activity because she is busy taking notes. Or if a girl who likes science is told by the teacher she is not very good at reading and writing, she may not think she is very good at science if it's taught only by reading and writing. The social dynamics of the classroom and girls' self-images and ideas about science make it difficult for some girls to be successful. It is up to the educators and policy makers to be aware of how choices and decisions around materials and pedagogy can set some girls up to fail or succeed in science. If we want girls to develop a self-identity of becoming successful in science, then we have to be aware of the social worlds of the classroom and how students fit into those social worlds.

To understand how the complex and dynamic aspects of a science classroom can influence girls' participation and potential as future scientists, I next describe and contrast two science activities in two demographically similar classrooms. I want to show how one classroom opens up opportunities for girls in science while the other closes down opportunities, thus placing the girls in the position of not being able to fully participate in the science activity. By not being able to participate fully, the girls are at a disadvantage in getting things done and are unable to understand how to access the knowledge and skills they need to be successful.

The Kingman Primary School

The Kingman Primary School was in the center of a large city in Wales with an enrollment of 420 children. When I collected my data there in 2008, 84 % of the students were ethnic minorities, primarily Somali, and for many students English was their second language. Students sat at tables and there were reference books around the room. The teacher sat at the front of the room with a computer and a *smart board* that displayed the data the students collected. After the students did their work in groups, they gathered on the rug in front of the teacher to talk about what they noticed. The following is a description of a science lesson I observed on force involving cars and ramps.

Understanding Force Using Cars and Ramps

The science activity of the day involved rolling a plastic red car down a ramp and measuring how far it would travel on four different surfaces, e.g., sandpaper, rubber, plastic, and carpet. The teacher told the students that in order to make it a "fair" test, two children should measure how far the car traveled on each of the different surfaces. Students were assigned to mixed-sex groups and instructed to decide among themselves who would do what task (e.g., measure distance, collect data, or roll the car). The teacher worked with one group and the male assistant teacher with the other. The assistant teacher's role appeared to be in managing discipline especially in reporting to the teacher which girls were talking. Three other mixed-sex groups were told to work on their own to complete the task and to gather the data. I noticed many students seemed confused when trying to read the tape measure, and the teacher often interrupted the activity to explain to the whole class that they were not meant to be working out how *fast* the car could travel but how *far*. In the group with the assistant teacher, the only girl in the group of five, Liv, was asked by the assistant teacher to be the recorder and was told by the boys in the group and the assistant teacher what data to write down on the whiteboard and how to spell it. As a result, Liv was not given a turn to roll the car down the ramp nor to collect the data herself. Her job as scribe afforded her both positive and negative positions. Initially she reported that she felt included:

> I like being the recorder because then it's something for me to do (that's) really fun. And it's nice because I have fewer things to do and it's fun to help people. (Liv aged 7)

On the negative side, however, Liv was given a marginal position with respect to the action. She did not roll a car down the ramp. To give up the role of the scribe would be to defy the assistant teacher's authority with the danger of losing her position as "the good girl" (Walkerdine 1989). Yet, her complicity prevented her from fully engaging in the science activity and limited her access to the subject.

Other girls and boys assigned to groups without an adult to help were told by the teacher to "work things out for themselves." I noticed that the girls in one group without a teacher or an assistant teacher seemed to need more direction to get started without someone in their group to take on leadership role. Mira gave me a clue about what she thought might have helped her and the other girls to understand the science activity. Her expectation of cooperative learning appeared to be at odds with the teacher's.

> It's hard with only one teacher. It's easier like in Maths when you get two (teachers) to help us work it out. I get to work with my friend but we don't get it and (the teacher) tells us to work as a team. There's a boy to listen, Mason, sometimes he tells me what to do. Yesterday he asked me what's the answer to my test and I told him. I'm not supposed to because the teacher doesn't want us to tell each other the answers. (Mira aged 8)

For Mira, the classroom messages are conflicting and appear to be inconsistent. On the one hand, without Mason to help her, she doesn't know what to do, yet the rules of the classroom appear to be to do your own work. Laya another girl at the same table expressed similar ideas:

> In science, I'm confused about everything. While I'm on the carpet I don't talk in science. I just keep quiet because I don't know about science. Because of the spelling and the writing my teacher says I don't understand it and that's the truth, I don't understand it. (Layla aged 7)

Both Layla and Mira were confused and did not understand what was going on in science. For Layla, the carpet (where the teacher brought the students together to talk about what they had observed in the science activity) is a specific space where the restricted movement and the teacher's comments had come together as a message for Layla which she seemed to experience as "I don't talk in science." By acting out her feelings of incompetence by not speaking, she further excluded herself from becoming a participant in science. Mira, for her part, mentioned the possibility of working with a friend in mathematics, suggesting that when the setting allowed she was able to use others as a resource (cf. McDermott 1993) and feel more competent as a learner. However, the teacher's orchestration of the setting and the assignment of groups in science placed her in a group without her friend. When comparing science with mathematics, Mira indicated that a boy, and not her friend, sometimes helped her. Her comment, "the (classroom) teacher does not want us to tell each other's answers," suggests that she had read the classroom environment as a place where sharing knowledge with others was not legitimate. These messages in the science setting seemed to indicate conflicting messages about cooperative learning and independent work: work in a science lab group knowing that science is ultimately done by oneself and not as a cooperative venture. Without teacher intervention, these girls' self-identification as the "one who doesn't understand" was likely to become their dominant social identity in science. To manage the incompetence they were feeling and expressing, the girls drew on what they knew best, the feminine aspects of being a girl (Duveen and Lloyd 1990, 1992; Ivinson and Duveen 2005); they kept quiet, sat still, and tidied up the classroom tables.[2]

Miriam, in contrast, a girl in another mixed-sex group, appeared to do everything herself. I watched as she rolled the car down the ramp, measured the distance herself, and recorded the data on the small whiteboard without the assistance or involvement of any of the other students in her assigned group. In my interview with Miriam, I found that she was the only one who could describe what she did and how the data she collected might relate to the concept of force. Yet by working alone Miriam placed herself in the danger of being seen by the other students or the teacher as someone who does not cooperate and collaborate since her actions excluded the other girls (and boys) in her group.

What I have illustrated is that the messages made available to all of the girls in this classroom were complex. In their interviews, many of the girls reported that they liked science and wanted to be successful in doing science, but it is clear that the mixed messages they received prevented them from seeing how they could be successful. Their only recourse was to defer to what they knew worked in being a "good girl" (Walkerdine 1989, 1998): be quiet, sit still, and clean up.

In the next example, I contrast the Kingman school classroom with a classroom at the Campbell school. In doing so I want to show how another classroom with similar demographics can open up possibilities for girls as they negotiate meaning in science.

[2] Pseudonyms have been used for the schools, students, and teachers in all quotes and references.

Campbell Primary School

The Campbell Primary School has a similar demographic profile to the Kingman School. Located in a residential neighborhood in the center of a large city in Wales, students were primarily from Bangladesh and Nepal. For many students English was their second language.

In this particular Year 3 science classroom, students worked in pairs at tables and were allowed to choose who they wanted to work with. This resulted in same-sex pairings as girls chose girls and boys chose boys. Located around the room were numerous reference books, a carpeted area to sit on, and three computers for the children's use. The science activity of the day was to make a bulb burn brighter.

Batteries and Bulbs

In a previous lesson, the children had learned how to make a simple circuit. In the lesson I observed, the teacher asked the students to once again try and light their bulb with batteries and wire, but this time "try and make your light bulb burn brighter." On a table at the front of the room, the teacher had placed three large bins of materials containing bulbs, bulb holders, batteries, and wire. The classroom was active, busy, and noisy as children gathered materials, talked with each other, visited other tables, looked through books, and tried different ways to get their bulb to burn brighter. In contrast to the first classroom described above, the teacher circulated around the classroom asking children about their ideas and making suggestions. In this way she was able to notice what the students were doing, answer any questions they might have, and monitor their progress. There was an assistant teacher who stayed with a small group of girls and boys who appeared to need more help.

Mim and Taci, two 7-year-old girls, sat together at that table with the female teaching assistant. I observed Mim and noticed that some boys at another table had placed five AA batteries together to get their bulb to burn brighter. I watched as she tried it herself and succeeded. Taci, who was in the same group, having watched Mim, went and found her own set of batteries and a bulb and mimicked Mim's approach. Her bulb however did not light up. The female teaching assistant who was watching both girls suggested that perhaps Taci's bulb was faulty and she got up to get her a new bulb. The new bulb worked and Taci successfully got hers to burn brighter. I noticed she repeated the experiment four or five times while smiling to herself. She then went over to another table and showed Gabrielle and another girl how to line up their batteries correctly so that they too could be successful. Later when I asked her about visiting the other table, Taci said that her friend was "stuck" and she liked "to help."

Tab, another girl, was looking through a reference book and saw a battery and bulb setup and attempted to copy the diagram with the materials. The classroom teacher immediately sat down on the carpet with her and worked together to duplicate the diagram. Later when the whole class got together to discuss their results, the teacher showed them Tab's configuration of batteries and bulbs that had made a bulb burn less bright not brighter.

In this classroom the teacher orchestrated a setting that allowed students considerable autonomy. Students worked with friends, walked around the room freely, and accessed texts when they wanted. This freedom of movement the students had allowed them to engage in the science activity in multiple ways, e.g., looking things up on a computer, comparing experiences with others, and helping other students, trying new things out themselves. These multiple entry points into the science activity positioned all of the children as active and legitimate participants. By being able to negotiate meaning for themselves with the help of others, adults and children, the girls experienced active participation, achieved success, and arguably were in a position to form positive social identities in science. For example, Taci was able to act, make mistakes, and redo the task until she achieved success. She also fulfilled her feminine identity as one who "likes to help others." All of the girls that I interviewed in this classroom described in detail what they had done and could describe how to make a light bulb burn brighter or in Tab's case, less bright.

Discussion

Using these two classroom examples, I have showed how there are multiple and sometimes conflicting messages to girls in a science classroom. These messages and, more importantly, the meaning that the girls make of them can either open up opportunities for them to learn in science or create barriers and trap the girls into fixed positions like always being the recorder. The way both teachers orchestrated the setting in terms of movement, grouping arrangements, and instructional discourse provided different opportunities for engagement and experimentation.

In the first classroom, the teaching assistant acted as a disciplinarian and assigned the one girl in the group he worked with as the recorder. When their movement was restricted, the girls in the first classroom example lost a sense of being active participants in the science activity. In that classroom the girls floundered without a teacher or a boy (their words) to help them out. A long historical legacy of linking science with masculinity ensures that the social identity of incompetence rather than competence in science is more readily available to girls. In the first classroom example school, I noticed the girls when they weren't sure what to do remain quiet, tidied up, and at times took their cues from the boys and the male assistant teacher. However, I wish to point out that this was not the case for all girls in that classroom and that Miriam, for example, managed the situation in a different way.

In the second classroom, the assistant teacher assigned to help the girls recognized what they needed for support, and she provided it by suggesting the materials might be faulty and encouraging one girl to try getting a fresh bulb. In that classroom, Taci and Mim were able to move from just repeating the actions of the boys to exploring on their own. I realize that there is a distance between completing the task and understanding of broader concepts, but at least in this classroom, the girls were able to tell me in their follow-up interview exactly what they had done and the result they achieved. We know that mimicry is an initial step in learning (Collins et al. 1989), so I suggest that the girls were on their way in developing an understanding of how batteries and bulbs work. Taci went a step further and shared her expertise with another group of girls to "help them out." In this way Taci demonstrated Keller's depiction of science as a fully human activity (Keller 1983, 1985). She was able to complete the science activity with success *as well as* help her friend. This allowed the girls to impose meaning on activities which were personal as well as scientific.

I noticed that many girls looked to or deferred to boys as more expert in science and consequently took less initiative in conducting the science investigation. This may be related to how the teacher placed children in groups. For example, in the first model school classroom, the teacher placed girls and boys into mixed-sex groups. We also noted that the girls in these groups acted as if the boys and the teacher knew more about what to do in science than they did. Girls did not speak out or actively join in activities except in isolated instances. This silencing was partly to do with the position afforded by the setting and the girls' tendency to take up social identities of incompetence historically extended to girls in science. In contrast, in the second school with the same demographic profile, boys and girls worked in same-sex groups, thus excluding gendered practice in which girls deferred to boys. The same-sex groups ensured that the boy-competent, girl-incompetent gender dynamic did not arise. In that way, the message systems available in the science classroom *opened up* possibilities for girls to engage in science, and they responded by doing science and working in cooperative ways that might be associated with femininity. In the first classroom, the mixed-sex groups *closed down* the possibilities for girls to participate in science.

What I hoped to illustrate is that science itself is not a content area that girls cannot learn, or that girls need extra help or a different kind of science like "kitchen science." Science learning is not something that excludes girls and always sets them up as passive, oppressed, and disadvantaged in schools. Although historically the association between science and masculinity is strong, much can happen in small movements in a classroom that complicate this legacy.

By focusing on the small movements between and among teacher and students within everyday classroom practice, it is possible to understand how each girl's experience of science can be individual and varied. The messages the girls receive can be affirming or contradictory to how they think of themselves as students doing science and help explain why some girls in comparison to boys fail to overcome the historical legacies of science that position them as on the fringe rather than as central participants in science (Cervoni 2011). This awareness has implications for classroom practice in science and in the professional development of classroom teachers.

Questions for Teachers to Ponder

Learning science is more than just memorizing definitions and doing hands-on activities. It's about having students develop a deep understanding of how the world works and being able to see themselves as someone who can do science. If we want students (boys *and* girls) to be able to think like a scientist, e.g., to explore, to discover, to make mistakes and redo, to collaborate with others, and to be curious, then students need time to do this. Students need to experience for themselves how ideas build on other ideas and how those ideas can come from personal experience or peers or the teacher and ideas in books. Students have to be able to experience science as the fully human activity it is, where emotion and intuition interact with careful observation and detailed record keeping.

Students enter our classrooms with ideas of who they are in relationship to science. They bring their prior knowledge of how the world works and their ideas of who they are as students learning new content. When students are blocked from full participation or trapped into positions of incompetence by peers or teachers, students cannot fully develop an identity of competence or being successful in science. For example, even though Liv liked being a recorder, she wasn't able to engage in the science activity and consequently couldn't tell me anything that she had done or understood. Teachers have authority in the classroom, and even off-handed comments have powerful effects on how students think about themselves as capable of learning. I encourage teachers to ask students how they think about their work in science so that they can access more of this nuance in the identity-building students are doing.

Even though national and state-mandated science curriculum frameworks guide which topics we teach, it is often at the discretion of the classroom teacher to determine how she will use the materials assigned. In the UK and in the USA, there are pedagogical documents that help guide the instruction. Effective structure comes with practice and knowing your students. If students are to work in groups, then it is important for teachers to visit each group making sure students understand the directions and making sure each student gets a chance to participate. Teachers need to mix groups up and assign different roles to see how each student participates in different groups. Science is a collaborative enterprise, and students need to be encouraged to learn from each other and from the teacher as well as how to use resources such as books and the Internet. This means the classroom teacher needs to relinquish some control and allow students to explore their ideas, to act as a guide rather than authority/truth holder.

Time to make mistakes is also very important. Some science lessons require more than an hour for students to really grasp an understanding of how batteries or bulbs work or what it means for an object to float. In the floating and sinking lesson described in the introduction, the teacher broke the lesson down into three sections: an introduction where students could just mess about with the materials; another task where the students had to make something float, sink, and vice versa; and finally a design challenge where students had to make a boat. This design challenge acted as the performance assessment. This way the students had a chance to check out their predictions and redo their designs which is important in learning science. In the classrooms where girls were successful, the teacher moved from group to group checking in and asking students about their thinking and making suggestions to further their thinking. This is in contrast to Classroom B where the teacher had the students copy the definition of buoyancy from the board. She was unaware of the questions the students still had about what they had noticed, and even though the activity was hands-on with interesting materials, there was no discussion about what confused the students and what they would like to do next.

Teachers influence how students see themselves as learners and as scientists in the making, and it is important that teachers take a reflective approach to lesson development that considers students' emerging identities. As teachers plan instruction in science, they might ask themselves the following questions:

(a) How and in what ways do the students in this class think about themselves as scientists in the making? What are each student's strengths and what do they need to work on?
(b) Are my learning objectives clear to me? What will I accept as evidence that the students have learned what I set out to teach?
(c) Have I chosen materials that are interesting and appealing to both boys and girls? Do I have enough materials?
(d) What other resources do I need that will extend students' ideas?
(e) Is the task clear to all of the students and does every student have a chance to participate?
(f) Have I built in enough time for students to explore and discover and ask questions?
(g) Am I available to all students, checking in with them and hearing their ideas? What will I do next as a result of hearing these ideas?
(h) Does my performance assessment make the students' learning visible to me and to them?

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