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15. SCIENTIFIC CREATIVITY WITHIN THE RULES

Suggestions for Teaching Science to Gifted Children with Autism

INTRODUCTION

Many of the world's most notable, gifted, and creative scientists, such as Newton, Einstein, and Tesla, are suspected of having had autism, or at the very least, to fall somewhere "on the spectrum" of autism disorders. Recently, Buchen (2011) presented an article in *Nature,* suggesting that the reason so many notable scientists fall on this spectrum is because individuals with autism are drawn to the rules and formulas associated with scientific thinking. Buchen reports on the work of renowned autism expert Simon Baron-Cohen, suggesting that, "the parents of autistic children, and the children themselves, have an aptitude for understanding and analysing predictable rule-based systems—think machines, mathematics, or computer programs." (p. 25) The author noted that many scientists and other science, technology, engineering, and mathematics (STEM) professionals exhibit milder forms of these traits, and when these scientists have children, their children are more likely to be autistic. Other recent reports in popular media (e.g. Coghlan, 2011; Tate, 2012) support Buchen's findings that more children with autism spectrum disorders (ASD) have parents who are scientists. Coghlan and Tate both reported that geographic areas with high numbers of scientific and high-tech companies, such as Silicon Valley, California, and Eindhoven, Holland, have significantly higher than average incidences of children with autism. Correlation does not imply causation, but does leave one to wonder whether traits associated with being good scientists—such as an aptitude for rules and formulas—are passed down from parent to child, perhaps with some other traits associated with ASD, such as difficulty in social situations.[1]

However, rules and structure are not the only defining characteristics of science, and certainly not the only characteristics of scientific genius. Scientific careers also involve creativity, innovation, and exploration—some things that could be seen as breaking the rules. In order to be a successful scientist, one must be willing to think outside the box and challenge what is already known. Though an affinity for rules and order might be what leads autistic scientists to their chosen professions, it leaves science educators with a challenge: how can we best structure learning experiences for children with autism to foster creativity within these rules?

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TEACHING SCIENCE TO CHILDREN WITH ASD

Researchers and teachers from across the education disciplines—including science education and special education—recommend the use of many common practices. For example, constructivism, or the act of learners creating meaning for themselves based on their own interactions with the world around them and prior knowledge, is generally seen as a best practice for planning instructional activities (Piaget, 1964). In a science classroom, use of constructivism involves allowing student exploration of scientific phenomena before presenting content or vocabulary. In a special education classroom, a teacher might encourage students to use preferred strategies for solving problems before introducing a new method in an effort to build on prior knowledge. Social constructivism, based on the work of Lev Vygotsky, is the idea that learners create meaning for themselves as a result of interactions with others (Wertsch, 1985). This also tends to influence instruction in many educational contexts. The use and exchange of tools, expertise, and language among peers from a variety of ability levels can be structured in such a way that students make meaning of the world around them through social interactions. However, despite the prevalence of shared practices among education disciplines, there are best practices specific to individual disciplines that are important to consider when planning instruction, especially instruction that fosters creativity in students with ASD. Below, we delineate guiding principles of teaching science to children with ASD.

SCIENCE TEACHING PRACTICES

After the Cold War, the US hoped to modify science education programs in a way that fostered the development of creative and genius scientists. Since the 1950s, the United States has put forth numerous efforts aimed at reforming science education (deBoer, 1991). These reforms have included multiple goals, most of which center on inquiry and problem solving. Most notably, the National Science Education Standards (NSES) emphasized a shift in science teaching to include less emphasis on laboratory investigations for verification and "activity for activity's sake," and more emphasis on investigations that promote further questions, understanding scientific ideas that cut across multiple content areas, scientific communication, and use of evidence, argumentation and explanation (NRC, 1996). The notion of using one "scientific method," and memorizing scientific facts has been replaced with a push for teaching students to think creatively about science. The evidence as to whether science education reform efforts—stemming from research funded at large universities and disseminated to teachers through professional development—have been adopted by teachers across the United States is mixed. Many teachers across the US (and perhaps globally) rely on more "traditional" teaching methods such as reading from a text and use of "cookbook" laboratories (Fulp, 2002). Thus, much of what children know as science as learned in typical school settings may be centered on rules rather than creativity.

However, reform efforts continue to move forward. A new framework for K-12 science education (NRC, 2012) elaborates and expands upon the goals of the NSES by incorporating goals for engineering education. The authors described several purposes and goals of scientific endeavors as such: "many scientific studies, such as the search for the planets orbiting distant stars, are driven by curiosity and undertaken with the aim of answering a question about the world or understanding an observed pattern" (NRC, 2012, p. 47). This statement about science as an enterprise illustrates the importance of understanding patterns and rules alongside curiosity and creativity. This new framework puts forth strategies for developing new standards that mesh these two seemingly disparate goals in an effort to better prepare our students for the scientific and engineering challenges of the future.

Scientific inquiry is often seen as central to creative science teaching. However, the term *scientific inquiry* can often be seen as vague and open for interpretation. In the most general sense, inquiry-based science instruction includes all science instruction that starts with a question—either generated by the student, teacher, or text. A model for a continuum of types of inquiry-based instruction can be used to help categorize inquiry-based learning experiences (Martin-Hansen, 2002; Banchi & Bell, 2008). On one end of this continuum is structured inquiry, or investigations in which the teacher presents the students with a topic, question, and procedure for investigating the question. Guided inquiry, where the teacher provides the topic and question but the students develop a procedure, sits at the middle of this continuum. Finally, open inquiry, in which the teacher provides the topic, but students pick the question and procedure sits at the other end of the inquiry continuum. Though there are varying levels of structure in each of these types of inquiry, each type can provide students with opportunities to engage in creative thinking about scientific questions. Inquiry-based instruction also often offers students opportunities to explore and work collaboratively. Good science instruction incorporates a range of types of scientific inquiries within a classroom. The new framework for science learning suggests scientific inquiry should be coupled with engineering design-type problem solving activities (NRC, 2012). This problem solving design is described as, "problem definition, model development and use, investigation, analysis and interpretation of data, application of mathematics and computational thinking, and determination of solutions." (p. 204). This focus on problem solving forces students to incorporate creative thinking into structured and methodical approaches to understanding phenomena and solving problems.

Collaboration and small group work are critical components of effective reform-based science teaching (NRC, 2012). Working with others in problem solving and inquiry-based settings allows students to consider the perspectives of others, benefit from their knowledge (e.g. Vygotsky's work as cited in Wertsch, 1985), and model authentic scientific practices (NRC, 2012). If the end goal of reforming science instruction is to develop scientists and engineers of the future, then it is essential to use small and large group collaborative settings.

Assessment is a critical component of all educational endeavors; without it, educators would have no way of knowing what their students learned (or did not learn). However, assessment and testing are not synonymous. Science education reform documents such as the NSES and Framework for K-12 Science Education advise that good assessments include multiple data points (rather than a single measure), multiple assessment types, and assessments that are purposefully designed to measure intended learning goals (NRC, 1996, 2012). The NSES encouraged science teachers to use authentic assessments, or "exercises [that] require students to apply scientific knowledge and reasoning to situations similar to those they will encounter in the world outside the classroom, as well as to situations that approximate how scientists do their work" (p. 78). Though assessment is sometimes viewed as the "necessary evil" of education, it can take many forms, and can foster our students to think creatively about science.

In summary, some of the best practices for science instruction remain the same as those recommended many years ago—move away from memorization, facts and formulas, and confirmatory exploration, and replace these experiences with those that allow students to ask questions, solve problems, and work collaboratively to better understand scientific phenomena.

PRACTICES FOR EDUCATING GIFTED STUDENTS WITH ASD

Though many educators agree on best strategies for teaching science, these must be considered within the context of the individual students. Strategies that work with one student may not be successful with another. Since it is a spectrum disorder, autism can manifest itself in a variety of ways and varying levels of intensity. However, there are some characteristics that are shared by the majority of students with autism that can be seen as disabling in the classroom setting. These students generally have difficulties with executive functions such as organization and planning, meaning that they are often very disorganized and have trouble figuring out what they should be doing. This also means that it often takes students with ASD longer to accomplish a task than it would take a typically developing peer. These students tend to be most comfortable when they are following a rigid, predictable schedule, whereas breaks in routine and unfamiliar situations can cause extreme anxiety. Anxiety can also be caused by any extreme stimulus in the environment, such as a loud noise, a bright light, or a potent smell. Many individuals with autism have either hypo- or hypersensitivity, so they can be easily overwhelmed in environments such as these and may even display problem behaviors as a coping mechanism when they are experiencing a sensory overload. Additionally, students with autism have difficulty with communication and social skills, which can pose problems for their interactions with peers (Kluth, 2010).

Yet, students with autism should not be defined merely by what they cannot do. The students we focus on in this chapter – specifically, students on the autism spectrum with above-average IQs – possess many unique skills and abilities that should help them to succeed in school. In addition to their high IQs, many have very strong verbal skills, often accompanied by an advanced vocabulary for their age. They tend to have incredibly strong rote memories and an ability to remember large amounts of factual information, as well as a detailed knowledge in areas of specific interest (Kluth, 2010). They can often be very creative in the sense that they think in ways that are fundamentally different from the way others think (Grandin, 2008). Although there are undoubtedly many challenges that must be faced in educating these students, they are gifted and with the right support, they have the ability to be very successful. The current push in special education is towards inclusion, meaning that students with disabilities should be educated in the general education classroom alongside their typically developing peers (Downing, 2008), and the special education field has a lot of strategies for educating these students with ASD in an inclusive classroom.

One of the most important and helpful things that can be done for a student with ASD is to provide them with a system of organization and structure. This can be done by posting a schedule in the classroom for each school day and following the schedule. If changes are going to be made to the schedule, the student should be prepared in advance about what is going to happen to help reduce anxiety. Classroom rules and routines should also be posted in the room, as students with autism seem to find comfort in being familiar with these types of procedures. Visual aids are especially helpful because the student can refer to them for step-by-step instructions throughout the day. A teacher may want to post instructions for daily routines such as sharpening a pencil, packing up at the end of the day, or turning in homework assignments (Myles, 2006). For in-class tasks and assignments, it can be helpful to provide the student with step-by-step instructions, possibly in the form of a checklist. It can be very overwhelming for a student with autism to receive a large task all at once, but it can be made manageable by breaking it down into smaller pieces. The teacher may even set a timer for each piece to work on time management, but should keep in mind that the student may require additional time or a modified assignment (Kluth, 2010).

Many children with ASD have poor handwriting, so modifications such as allowing them to use a computer to complete an assignment can be very beneficial. They may also get very stressed about test-taking, so for this reason it may be useful to consider alternative forms of assessment. Silverman and Weinfeld (2007) suggest finding other ways for the student to demonstrate his or her understanding, ways that incorporate the student’s strengths – such as a project, diagram, or slideshow presentation. Additionally, putting a system of reinforcement in place for the student can help to manage problem behaviors, and finding ways to incorporate the student’s personal preferences and special interests into the lesson should encourage the student to be more focused and attentive (Silverman & Weinfeld, 2007). When used effectively, group work can also be a great way to work on social skills. Silverman and Weinfeld (2007) suggest assigning specific roles to each student in the group so that each person has a job to do. Finally, students with ASD tend to interpret everything they hear literally. In order to avoid confusion, instructions should be given concisely and simply, and teachers should say exactly what they mean and what they expect of the student (Myles, 2006).

Students with ASD are often very good at rote memorization and learning facts and formulas – that is to say, they thrive under rules and structure. However, teachers should be encouraging their students to think more creatively. One way to do this is through a focus on problem-solving and real-life applications, which work to develop critical thinking skills.

In conclusion, students with ASD can be very gifted and are capable of achieving incredible success in the science classroom. The teacher needs only to figure out how to best accommodate the student. This might mean providing a system of organization and structure, breaking down tasks to make them less overwhelming, using alternative forms of assessment, incorporating group work into the lesson, utilizing a problem-solving approach, or any other strategy that plays to the student's individual strengths.

COMMON GROUND

Considering the research on best practices in both science education and the education of children with ASD, we can find many areas of common ground, along with areas in which these two fields differ. In Figure 1 below, these areas are depicted in a Venn Diagram.

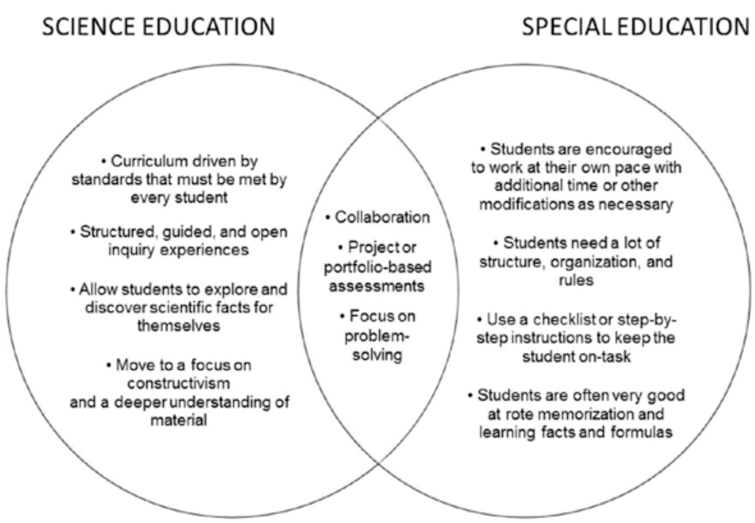

Figure 1. Similarities and differences between practices in Science and Special Education

If our end goal is to develop strategies and suggestions for best practices in teaching science to gifted children with ASD to foster creativity, then we should draw our attention to the areas in which science educators and special educators agree: creating collaborative environments, assessing students authentically, and focusing on problem solving. We can also reflect on the experiences of gifted scientists to help guide our recommendations moving forward.

CREATIVE AND GIFTED AUTISTIC SCIENTISTS

While the scientific and popular literature (e.g. Buchen, 2011; Coghlan, 2011; Tate, 2012) reports on affinity for rules and structure as the main trait shared by scientists with ASD, other similarities in these individuals can also be found. Rawlings and Locarnini (2008) found that scientists with autism scored highly on the Autism Quotient (AQ) subscale associated with both attention to detail (rules) and that of imagination (creativity). Interestingly, this study also found that artists with autism scored higher in other areas, such as schizotopic tendencies. These findings corroborate the speculation by many that some of the most gifted scientists may have had autistic characteristics. A few other examples can be seen in the vignettes below. The first details the experiences of David Finch, and the second that of Dr. Temple Grandin.

David Finch

Engineer-turned-author David Finch, an individual diagnosed with Asperger's Syndrome as an adult, has recently been in the public eye after the publication of his autobiography, *The Journal of Best Practices: A Memoir of Marriage, Asperger Syndrome, and One Man's Quest to Be a Better Dad and Husband,* in 2012. In it, he describes his personal experiences before and after receiving an ASD diagnosis and reveals how this diagnosis helped him to develop coping mechanisms that were useful in everyday life, eventually leading to a better level of self-understanding.

Growing up, Finch's parents helped nurture his interest in science, "My dad regards almost everything through a scientific lens. He and my mom both took time to explain why things happen and how they happen. I would watch my dad analyse a problem from a thousand different angles before approaching the solution. It was cool!" (D. Finch, personal communication, July 30, 2012). Finch also had a life-long love for and fascination with mathematics, and he credits his high school physics teacher, Mr. Anderson, with illuminating the application of mathematics throughout everyday life (D. Finch, personal communication, July 30, 2012). Not surprisingly, he followed his brother's footsteps to pursue a degree and career in music engineering at the University of Miami (Finch, personal communication July 30, 2012). There, under the guidance of Professors Ken Pohlmann and Will Pirkle, he developed an interest in audio and digital signal processing. As he explained, "Besides my music courses, these were the only classes in which my mind didn't wander. I was engaged the entire time and wanted to spend more time learning about these topics." (D. Finch, personal communication, July 30, 2012). After completing his degree, Finch began a career as an audio engineer. He so enjoyed writing software and reports that he often went into a state of flow when doing so. He was able to demonstrate his creativity in designing audio systems. Later, when working in technical marketing on the business side of his profession, he was also able to use his creativity through problem-solving (D. Finch, personal communication, July 30, 2012).

Before his diagnosis, Finch relied on various strategies to "get by," many of which were based on problem solving and rule following, which are typical characteristics of individuals with Asperger's (Finch, 2012). He also relied heavily on mimicking others. After receiving his diagnosis, he was able to better understand how his own mind works and improve his confidence, which then allowed him to perform as an engineer at a higher level (D. Finch, personal communication, July 30, 2012). Despite this newfound understanding, Finch decided to leave the field of engineering to pursue a career as a writer, as it allowed him an opportunity to focus on his creativity. Despite this career change, he maintains a personal interest in the sciences and hopes to pursue scientific hobbies and endeavors with his children as they get older (D. Finch, personal communication, July 30, 2012).

DR. TEMPLE GRANDIN

Temple Grandin, an individual with Asperger's Syndrome, led a childhood marked by frequent temper tantrums, poor grades, and a lack of desire to interact with other people. In fact, she was nonverbal for the first four years of her life. And yet, despite all this, she has gone on to become probably the most well-known person with autism. She holds a Ph.D. in animal science and is now a professor at Colorado State University. She has published many books on autism and frequently lectures on the topic. She is also an incredibly successful engineer; approximately one-half of all the livestock handling facilities in the United States have been designed by her (Grandin, 2008).

Temple Grandin attributes much of her success as an engineer to her ability to think visually. Part of the way her mind works is that she processes information completely in pictures. She is able to design livestock handling systems in her head, in a manner that resembles a 3D design program on a computer. Grandin writes that she is "able to 'see' how all the parts of a project will fit together and also see potential problems" (Grandin, 1986, p. 142). She can visualize designs by taking parts of already existing equipment and piecing them together in her head to create something new. She can "see" this design from many different perspectives and can even rotate images or make them move, much like a computer program would. Grandin can visualize many different test situations, enabling her to "see" how the equipment will work and solve problems and design flaws long before it is ever built.

However, it took a long time to harness and direct these talents of Grandin's. Growing up, she had a very difficult time in school because her teachers did not understand the way her mind worked. She often did poorly on tests and assignments because they were not designed for visual thinkers. The rote memorization tasks that were often required of her were incredibly difficult, and she struggled in working with abstract concepts. Because of this, she was labeled as "brain damaged" for the first few years of her life.

It took the help of a few creative, unorthodox teachers to uncover Grandin's abilities. She could not learn by reading a textbook; instead, Grandin recalls hands-on, real life activities and experiments that encouraged her creativity. She learned about the solar system by drawing it and looking at models, and barometric pressure was something she only understood after her class used milk bottles to make their own barometers. Ever since she was little, Grandin was fascinated with a machine she calls "the squeeze machine," a machine that cattle are placed in before they receive vaccinations. The machine squeezes up against the sides of the cattle and calms them down. Grandin longed for that sort of pressure and tactile stimulation, and she began designing her own squeeze machine that she could get in herself. Most of her teachers and her family discouraged this fixation, but it was all Grandin could think about. It took her high school science teacher, Mr. Carlock, to realize that he could use this fixation to get Grandin interested in schoolwork. He showed her how science could help her to understand how the squeeze machine worked and could give her the ability to build an even better one. This provided the motivation Grandin needed to learn science, and it was at this point that an incredibly successful engineering career was born. If there is one thing to be learned from Grandin's story, it is that the minds of people with autism work differently than the minds of typical students. A good teacher will figure out how to use this to the student's advantage, and with the right support, the student can excel.

EDUCATING FUTURE SCIENTISTS WITH AUTISM

When we consider the literature on best practices for science education as well as those for teaching children with ASD (see Figure 1) alongside the vignettes about David Finch and Temple Grandin, we can conclude that several key strategies can be implemented to help foster scientific creativity in gifted students with ASD.

Collaboration

The image of a scientific genius working alone in a lab is antiquated and inaccurate. The best acts of scientific creativity occur through collaboration, including those that result in acts of genius. In a typical elementary classroom, collaboration tends to manifest itself as group work among students. Group work is certainly a practice which science educators and special educators can agree is beneficial, both to the student with autism and to their typically developing peers. For students with autism, social and communication skills are often a challenge and need to be taught to the student. Group work provides a great opportunity to use language, initiate conversations, respond to the questions and requests of others, and take turns, as students work to meet social skills goals while simultaneously learning the curriculum (Wertsch, 1985). Working collaboratively with peers also teaches gifted students with autism about other people and about how to accommodate differences as the group works together to achieve a common goal. Special educators often look at peers as a very important tool for the inclusion of students with autism, because they tend to be very good at finding ways to involve the student in the lessons and activities. Frequently the creativity and open-mindedness of other students in the classroom means they come up with ideas that even the special educator may have overlooked. Plus, students with autism are generally more engaged and receptive to working and learning when it involves their peers (Downing, 2008).

For science educators, group work encourages the sharing of thoughts and ideas, giving students the opportunity to hear multiple perspectives. This broadens their horizons and enables them to think in new and different ways. It also models science and engineering situations that would be faced in real life, therefore making collaborative work a more authentic way of teaching science, as recommended in the Framework for K-12 Science Education (NRC, 2012). Peer interactions allow students to verbalize their prior conceptions, learn from the experience of others, and see scientific phenomena from novel perspectives, resulting in more creative approaches to scientific understanding.

However, placing gifted students with autism in groups can create very stressful situations if not done correctly. Social interactions often cause anxiety for these students, as do activities that are unstructured or unpredictable. Therefore, group work situations can be incredibly overwhelming and may cause the student to shut down rather than open up. One solution to this problem would be to provide more structure for the group. Open inquiries may not be the best choice for a student with autism, especially not before familiarizing the student with structured and guided inquiries first. Yet, it is not impossible to create successful collaborative scientific activities for classes that contain gifted students with autism—as Temple Grandin explained, teachers can often sense the needs of individual students and in doing so can elect to structure educational experiences based on the needs of these individuals. Silverman and Weinfeld (2007) recommend providing a clear set of goals and expectations for the group, so that the student understands what he or she should be accomplishing. Additionally, they suggest assigning roles for each of the group members that play to their strengths. For example, the gifted student with autism might excel at reading aloud, remembering the steps of the task and making sure they are accomplished, or recalling and recording data. The situation will be much less stressful if the student is familiar with his or her specific responsibilities. The teacher can also help decrease the student's stress by scaffolding social interactions, ensuring that the student has the tools necessary to communicate effectively with the group. As long as teachers are aware of and work to accommodate these challenges, collaborative group work can result in a meaningful and effective learning experience for everyone involved.

Authentic Assessments

Testing can be stressful for all students, especially those with ASD. It can often disrupt the intended schedule in a school day or incite test anxiety in any child. Yet, assessments are not limited to tests alone. Science education reform efforts have pushed to move the focus of assessment away from rote memorization and toward authentic assessments (NRC, 1996, 2012). These authentic assessments can include a range of different formats, and can be tailored based on individual students' needs and teachers' preferences. For example, one teacher might choose to ask students to create models of various phenomena, while another might challenge students to design an instrument or procedure to answer a scientific question. In both of these situations, rather than simply responding to questions or prompts, the students are engaging in scientific practices.

In the NSES, the authors note that assessment and learning are two sides of the same coin (NRC, 1996). Thus, it is critical to engage students in authentic scientific practices throughout instruction, not simply at the end of it. Both David Finch and Temple Grandin reported being most engaged with science instruction that modeled scientific practices—Finch described a high school teacher who pointed out the application of mathematics to physics concepts while Grandin's high school teacher helped her to create a scientific instrument. Providing students with authentic scientific experiences throughout instruction also allows teachers to use an inquiry-based constructivist approach to education (Piaget, 1964). In doing so, students are able to interact with and explore the world around them, and build upon prior knowledge. However, these strategies aren't always the easiest to implement, especially when working with students who fall on the ASD spectrum. Each student comes to their class with a different background and set of experiences and challenges that must be met, thus teachers must approach this type of instruction with flexibility and a variety of teaching strategies.

Project-based instruction and assessment can be a good strategy for educators—both in the science classroom and the special education classroom—to accomplish the goal of creating more authentic instructions and assessments to meet the needs of all students. Project-based instruction and assessment can be done either in collaborative groups or alone, and it often starts with some sort of problem or question that students must work to solve. This type of learning is ideal for gifted students with autism because it allows them to work at their own pace, in a variety of mediums and settings, and on a topic of interest to them. Often, gifted students with ASD have a special area of interest – anything from cars to whales to famous dates in history – on which they are very focused and know a great deal about. Some educators tend to discourage this fixation, but the student's area of interest can actually be a great starting point for project-based learning because of the student's motivation to learn about the topic. For example, a fixation with cars could turn into a physics project in which the student explores concepts such as velocity and acceleration, while an interest in whales could turn into an exploration of marine life, the oceans, or even the organ systems that make up a whale. Reading from a textbook or listening to a teacher lecture can be almost impossible for a student with autism, but being able to do projects that are personally interesting to the students can be very effective. Plus the projects allow the students to explore outside of the classroom, use technology, and possibly interact with others, while also afford teachers the opportunity to modify assignments and assessment techniques, extend deadlines, or otherwise support the student with autism.

Problem Solving

Solving problems means being faced with a novel challenge or obstacle and being able to analyze the situation and develop a solution (Silverman & Weinfeld, 2007). Successful problem solving requires a wide range of analytic and critical thinking skills, as well as creativity. As Temple Grandin (2008) writes, "it involves training the brain to be organized, break down tasks into step-by-step sequences, relate parts to the whole, [and] stay on task" (p. 47). The ability to solve problems is absolutely necessary in order to function in everyday life, and yet all of the aforementioned skills are very difficult for individuals with autism. As such, problem solving is something that people with autism really struggle with, and yet it is a skill that Grandin believes is not incorporated enough into their educations.

The science classroom is an ideal place to teach and practice problem-solving skills. Careers in the STEM fields are based on problem solving; scientists need to be able to do this successfully every single day. Therefore, a good science curriculum should also focus on developing strong problem solving abilities, and it can be done in the context of the lessons.

Grandin says that for her and many others with autism, abstract concepts are very difficult to understand. She learns best from physically doing things. Children with autism (and, in fact, all children) have a natural curiosity about how things work, which can certainly be an advantage in a science classroom. Grandin recalls a windy day when she made a parachute out of a scarf. It took her many, many tries to figure out how to make the parachute fly as far as it could and to keep the strings from tangling, but she continued to try new ideas until the problems were solved. Likewise, Finch found learning by "doing" or solving problems to be the most effective way of learning himself. In his first book, he describes taking apart appliances and searching for order in everyday things. These activities helped him to understand how the world around him worked (Finch, 2012). Good teachers can leverage everyday questions (e.g. how do parachutes work) to structure activities that allow students to utilize problem solving skills. Problem solving skills are something that special educators agree should be taught to students with autism (Kluth, 2010). However, oftentimes teachers do no more than teach the students a list of general problem-solving guidelines (identify the problem, define the problem, organize information, etc.), and this is simply not enough. Gifted students with autism will only become good problem solvers if they are given many real-life opportunities in which to apply these strategies; the more experiences they have, the more they will be able to generalize and apply what they know to novel problems. Science is a perfect application for these skills, and lessons that are taught with a problem-solving focus will not only be good for the gifted student with autism, but will make science memorable, fun, and meaningful for all of the students in the classroom.

CONCLUSIONS

It is not surprising that increased numbers of ASD diagnoses have emerged across areas characterized by high numbers of STEM professionals (Coughlan, 2011). Many of the traits that characterize science—systems, order, organization and classification systems—are also interests of individuals on the ASD spectrum. Yet, these are not the only traits that characterize science or ASD. Science is characterized by exploration, problem solving, creativity, and imagination. Many gifted and creative scientists and other STEM professionals fall on the spectrum of ASD; David Finch and Temple Grandin serve as two examples of successful adults with autism working in STEM careers. Much can be learned from these two examples alongside the literature in both science education and special education about how to best prepare gifted children with ASD for scientific creativity and genius. We believe that modeling authentic scientific practices through collaboration, problem solving, and authentic assessments can be the first steps in developing classroom environments structured to nurture scientific creativity.

NOTE

[1] It should also be noted that the definition of ASD has broadened over the past several decades, and this can also explain some of the increased number of diagnoses.

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