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# Developing Scientific Talent in Students With Special Needs: An Alternative Model for Identification, Curriculum, and Assessment

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# Developing Scientific Talent in Students With Special Needs:

## An Alternative Model for Identification, Curriculum, and Assessment

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Can students with learning and attention difficulties in school actually be talented scientists in disguise? This article presents a model that was highly successful in identifying and developing scientific talent in these special students. The factors that contributed to the success of the model were the following: The emphasis was on helping students become creative producers. The model also featured a strong mentoring component that included role-modeling and problem solving within specific scientific domains and provided students with authentic, discovery-based, experiential, advanced level subject matter of the domain. Finally, the alternate means of assessing student achievement focused on a student's performance and the product he or she created, rather than on test scores. Students demonstrated their ability to be competitive, collaborative, and to apply problem-solving skills. These performances resulted in the students' shifting their identity from loser to winner.

Can students with learning and attention difficulties in school actually be talented scientists in disguise? If we look to history to answer this question, we see compelling evidence that giants such as Thomas Edison, Sir Isaac Newton, and Leonardo da Vinci might have been students like this. Similar to struggling students today, they had passion, curiosity, and commitment to pursue learning, often in unconventional ways. Unlike students today, however, these school failures could opt to learn elsewhere—frequently, by themselves or with a mentor.

Today, we have multiple ways to support our student scientists. There are magnet schools, special schools in math and science, Advanced Placement courses, and honors classes that purport to provide the necessary scaffolding to actualize the talent of potential scientists. For students not achieving academically, however, these options are often not available because their talent is frequently obscured by their lack of achievement, their displays of inappropriate classroom behavior, or both. More specifically, to be accepted into these special programs, students must demonstrate superior scores on standardized tests of reading and math. Clearly, had these been requirements

in Edison's day, his talent would have been neither found nor nurtured.

We know, furthermore, of some students who experience difficulties with reading and writing (areas emphasized heavily in school), but who have talents in science. Unfortunately, these students are not acknowledged for their abilities due to the restrictive criteria of test scores and grades. Therefore, Project High Hopes set out to address this critical issue: Could there be a talent development model in science that would both identify potential talent and provide a program in which reading and writing were not required for success?

### A Talent Development Model

To create a model to meet these criteria we needed sound theoretical evidence concerning students with special needs and the best practices of talent development. Specifically, we needed to address these three questions: (a) How do gifted students with special needs learn? (b) How is scientific talent

## Developing Scientific Talent

Characteristics of Gifted Students	Problems Associated With Special-Needs Students	Curricular Accommodations
Propensity for advanced-level content to accommodate the gift or talent	Limited skills in reading and math	Alternate means to access information
Producers of new knowledge through authentic products	Difficulty with spelling and handwriting	Alternate ways to express ideas and create products
Facility with and enjoyment of abstract concepts	Language deficits in verbal communication and conceptualization	Visual and kinesthetic experiences to convey abstract ideas concretely
Nonlinear learning styles	Poor organization	Visual organization schemes (e.g., timelines, flow charts, webbing)
Need for intellectual challenges based on individual talents and interests	Problems with sustaining attention and focus	Interest-based authentic curriculum
Need to identify with others of similar talents and interests	Inappropriate social interaction	Group identity based on talent or ability
Heightened sensitivity to failure	Low self-efficacy and esteem	Recognition for accomplishment

Figure 1. Fundamentals of the dually differentiated curriculum

manifested? (c) What are the stages of talent development? The answers to these questions are given below.

### How Do Gifted Students With Special Needs Learn?

Twice-exceptional students possess a duality of learning characteristics reflecting both their traits of giftedness and their difficulties with learning basic skills (Baum, Cooper, & Neu, 2001; Nielsen, 2002; Van Tassel-Baska, 1992; Weinfeld et al., 2002). Specifically, when involved in their area of talent, they are more likely to exhibit positive learning characteristics. Conversely, while struggling in school, these students display behavior that is more problematic. Well documented in the literature (Renzulli, 1978; Tannenbaum, 1983; Van Tassel-Baska; Whitmore, 1980), the characteristics of gifted students include a propensity for advanced content, a desire to create original products, a facility with and enjoyment of abstract concepts, nonlinear learning styles, and task commitment in areas of their talent and interest. Gifted students also identify with others of similar talents and interests, and they possess a heightened sensitivity to failure or injustice.

The strength of these traits notwithstanding, these characteristics are frequently offset or complicated by deficits typically impeding the success of students with learning difficulties. The most commonly reported problems include limited read-

ing skills, poor handwriting and spelling, difficulties with expressive language, and lack of organizational skills. In addition, these students often demonstrate an inability to focus and sustain attention, often display inappropriate social interaction, and exhibit low self-efficacy and diminished esteem (Individuals With Disabilities Education Act, 1995). Thus, any program we developed for these twice-exceptional students would need to accommodate their strengths and problem areas simultaneously. Figure 1 lists these contradictory traits and the curricular modifications we made to help our students flourish in spite of their learning and attention problems (Baum, Cooper, & Neu, 2001).

### How is Scientific Talent Manifested?

How do we transform these reluctant learners with strong science potential into actual scientists? How can we help them demonstrate their talent by thinking, feeling, and acting like practicing professionals? What are the skills scientists use in their work? What are the methods and materials they use? What probing questions do they ask? What are the concepts and principles of the discipline?

Not at all new ideas, these points were espoused by Bruner (1960), Dewey (1967), and others about the need to make a classroom a veritable laboratory for the exploration of ideas and sci-

entific inquiry and an authentic setting for practicing science skills (Gardner, 1991; Renzulli, Leppien, & Hayes, 2000). In other words, these learners should be actively engaged in the discipline of science, not merely reading and writing about science.

The aim is to involve students in the discipline, not just in the subject matter. If I grind glass, study the refraction of light waves through it, and make a pair of spectacles, I am involved in the discipline of optometry; if I simply read about the process, I am involved only in the subject matter. Thus students need to conduct genuine scientific inquiry, not simply experiments with known answers. *They need to do what people involved in a discipline actually do.* (Arnold, 1982, p. 454 emphasis added)

The new national- and state-level curriculum standards emphasize this inquiry-based approach to teaching and learning science. The National Association for Gifted Children's curriculum standards (Landrum, Callahan, & Shaklee, 2001) for example, provide for inquiry-based teaching and learning in its positions on the importance of curricular differentiation as modifications of content, process, product, or learning environment, each of which is respectful of the individual differences of the students involved (Tomlinson, 1999). Another example of inquiry-based learning is the New York State Assessment Program in Grade 4, which requires students to design and conduct their own experiments and report their results.

Mindful of widespread national- and state-level reform initiatives, we needed to engage students in several domains of science as they acquired the knowledge, skills, and dispositions of scientists by participating in authentic science experiences.

### What Are the Stages of Talent Development?

Talent development is a sequence of experiences leading students from novice to expert within a domain. Researchers examining this phenomenon (e.g., Bloom, 1985; Csikszentmihalyi, 1993) have found that students must first be exposed to topics and become excited about them. The second stage involves purposeful, discipline-intensive lessons from masters in the discipline through which students learn the principles, concepts, and skills of that particular discipline. The final stage of talent development is the stage at which students become more independent in their learning, that is, they become more interested and active in problem finding and seek alternate solutions to authentic problems within their field of intense interest (Bloom). It is this point at which students become creative producers. According to Renzulli (1977), the student makes a conscious shift from consumer of knowledge to producer of new knowledge. Organizing talent-development experiences to match this

sequence would become a critical task for us as we helped students on their journey from novice to expert throughout the course of the project.

With these understandings as building blocks, the model we constructed consists of the three traditional elements of identification, curriculum, and assessment. What makes the model unique, however, is how we operationalized and implemented each of these components.

## Project High Hopes

To test our model we designed and implemented a highly successful, research-based talent development program called Project High Hopes. Although the project served students with various talents, for the purpose of this article we will focus on the domains of science and engineering.

The project served 130 students in grades 5–8 at nine sites in Connecticut and Rhode Island, including six public schools, a private school for the learning disabled, and two schools for the deaf. Of the students identified, 72 (55.4%) attended a special school, 19 (14.6%) received resource room services in their school, and 39 (30%) were mainstreamed. These students were selected from the special-education population at each site and had been identified as having one or more of the following: learning disabilities, attention deficits, emotional or behavioral disorders, pervasive developmental disorders, and hearing impairments.

### Stage 1: Exploration and Talent Identification

Authentic, domain-based activities during Stage 1 of the model introduced students to the domains of biological science, physical science, engineering design, and the visual and performing arts. These activities were part of the Talent Discovery Assessment Process (TDAP), a valid and reliable assessment tool (Baum, Cooper, Neu, & Owen, 1997), and served as audition sessions in which students' potential talent could surface. Use of this audition tool was based on the philosophy that the most accurate predictor of potential talent is information gleaned from observing student behavior over time when students are engaged in authentic domain-specific activities.

All students were invited to the audition activities, which took place over the course of 3 months. The activities were designed and administered by a professional or content expert (specialist) within each domain, and two observers recorded behaviors on corresponding observation sheets targeting specific behaviors associated with the domain being observed. Upon completion of each session, the observers and specialist discussed their observations and rated the students holistically,

Science	Engineering
Displays curiosity by asking relevant questions.	Actively manipulates materials.
Shows considerable knowledge related to topic of session.	Tries to predict outcomes.
Actively manipulates materials.	Understands the main concepts of session's topic.
Communicates clearly the results of the project.	Product shows clarity of thought and focused plan of action.
Systematically tests hypotheses.	Puts materials together in a unique way.
Tries to predict outcomes.	Explains the logic of alternative solutions.
Represents ideas in the form of a model.	Shows problem solving by pursuing an unprompted investigation.
Finds means of overcoming obstacles in problem solving.	Observes patterns in experimentation.

Figure 2. Domain-specific behaviors observed to identify student talent in the sciences and engineering

Physical Science	Zoology	Botany	Engineering
Liquid surfaces	Microscopes	Carnivorous plants	Topography
Qualities of Air	Predatory behavior of the hydra	Genetic variation in plants	Leonardo's wagon
Water purification	Pond organisms	Cells Alive	Rocketry

Figure 3. Sample lesson topics in Project High Hopes curriculum

using a score of 1 to 3 to indicate a student's readiness for more advanced development in that particular talent area. These ratings were then recorded on the student summary form for use in the final discussion. Observers were encouraged to take notes on their observations and enter them on their note sheets. A list of behaviors for each domain appears in Figure 2.

### Stage 2: Discipline-Intensive Lessons

From the Talent Discovery Assessment Process we selected 63 middle school students for advanced study in life and physical sciences and 36 for engineering opportunities. It must be noted that some of these students were identified for talent in both domains, making for a duplicated count in several instances.

During the project's second stage, the activities focused on teaching the students the skills and methods of the discipline in which they had displayed talent. The dually differentiated curriculum (see Figure 1) allowed the students to compensate for problematic weaknesses. Instruction in this highly personalized curriculum took the form of biweekly 90-minute lessons taught by zoologists, botanists, a biological illustrator, physicists, and engineers.

The skill development curriculum was rooted in Renzulli's (1977) Enrichment Triad Model, with activities designed to

elicit specific cognitive, creative, and affective (dispositional) behaviors characteristic of practicing professionals in each domain. The types of activities within each domain were advanced well beyond the actual grade level of students participating in Project High Hopes. Sample topics are listed in Figure 3. Emphasis was on experiential learning that differed significantly from the traditional classroom setting. Reading and writing served the experience instead of becoming the experience. In-depth, firsthand involvement in the authentic skills of the discipline characterized the biweekly lessons taught by content specialists.

The deep understanding these students gained of the principles of engineering and science through the dually differentiated, highly advanced Project High Hopes curriculum led to students' achieving unprecedented success as learners, as well as a newfound respect from their peers. Authentic content and advanced skills comprised each session. For example, over the course of several engineering sessions, students were taught to use a transit (an instrument used by surveyors to measure angles) to measure the gradation of the school's auditorium. From these measurements, they first constructed a topographic map and then a scale model.

In biology, students assumed the role of scientists as they discovered what constitutes the diet of an owl. They carefully dissected owl pellets and, by referring to an anatomy chart,

identified parts of the skeletal structure as they located them. Many of the students actually reconstructed a vole in the process. They also learned key concepts of a sustaining habitat, including the structure of the food chain and the carrying capacity necessary for a viable owl population. Comparison and contrast were used to determine important facts about what the owls had consumed, and probing questions led to higher level extrapolation, inference, and deduction.

### Stage 3: Creative Production

In Stage 3, students applied skills and concepts learned in the Stage 2 advanced level lessons to solve authentic problems and create original products. To initiate this stage, we created a 1-week residential program in which 27 identified students worked in research teams to solve a genuine problem associated with the pond on the property. This problem-based experience gave these middle-schoolers a rare educational opportunity to become bona fide real-world problem solvers. The students were assigned to interdisciplinary teams of not only scientists and engineers, but also visual and performing artists, the other disciplines served by Project High Hopes. Within their teams, students collaborated on the problem, the goal of which was to produce a proposal containing a creative solution for reconstructing the pond (see Figure 4).

Learning took place in an advanced-level laboratory environment in which specially selected, highly qualified teacher-facilitators coached the individual research and development teams, or "companies," of students in the Creative Problem Solving process (Treffinger, 2000). When needed, content-area specialists (mentors) from the four domains (science, engineering, performing arts, and visual arts) furnished technical advice on tools, techniques, and materials used by practicing professionals in those specific domains. Both teacher-facilitators and mentors taught students to capitalize on their innate talents and strengths as they created a relevant proposal with supporting data, products, and budget considerations.

From Sunday through Wednesday morning, students on their respective teams were fully focused on the Creative Problem Solving process. Which species of animal life had once inhabited the pond? What degree of stress had the existing bridges tolerated? By Wednesday afternoon, students had begun to finalize plans for their forthcoming presentations to the board of directors and eagerly sought advice from the mentors on how to polish those presentations creatively and professionally.

At the Presentations Forum, held on the final day of the conference, each research and development company presented its proposal to a board of directors for the site. Before the board and the 300 or so adults and other students gathered for the presentations, the students introduced themselves as the professionals they had become in the course of the week's work.

As you are about to see, [this property] has a water feature. The feature has some problems. You will visit the site and be provided with the resources and information about the site. Once at the site, your group will be asked to gather information about the site and use resource people to help develop your plan for improving this water feature. Original, creative, innovative, useful solutions are encouraged. There is no one right answer to this problem. Groups will be recognized for excellence in their plans. Your group's task is as follows:

1. Identify the existing problems and future potentials of the site.
2. Review the resources.
3. Decide on additional information that you might need.
4. Brainstorm solutions to the problems.
5. Develop an action plan to fix the problems.
6. Prepare a presentation of your plan. (It is important to note that plans will be presented to a panel of people, some of whom have the authority to consider and implement your plan.)

Figure 4. Introduction of pond problem to students.

*Note.* From "Project High Hopes Summer Institute: Curriculum for Developing Talent in Students With Special Needs," by M. Gentry and T. Neu, 1998, *Roeper Review*, 20, 291-296.

"I'm Joseph, and I'm the botanist in this firm," one student explained to the audience.

Each company then presented its proposed solution for reconstructing the pond by using an innovative approach reflecting the Creative Problem Solving techniques the students had been using all week. Combining artistically enhanced overhead transparencies, video clips, 3-D models, and dramatic performances, students illustrated both the deteriorating pond conditions they had analyzed and their respective groups' recommendations for correcting them. Most of the companies redesigned the existing structures; one team even built a scale model of the pond and constructed prototypes of a new bridge and dam.

Another team began its presentation by portraying the pond environment. The scientists then described why the pond was in the condition that it was, and the engineers explained their solution using the visual sketches designed by the artists. The group concluded its presentation with a return of the actors who then portrayed a clean, healthy pond environment, results that could be expected should their proposed plan be approved for implementation.

Domain	Opportunity	Results
Engineering	Odyssey of the Mind	Of the five teams participating, two won in second place; one, third place.
Engineering Science	Egg-drop competition Science Fair	Two students entered award-winning solutions. Seven students entered; one received written commendation for high quality.
Science	Physics Day Competition	Twelve students entered; nine received recognition for their problem-solving ability.
Science	Advanced science classes	Two students were accepted into their respective district's advanced science class for gifted students

Figure 5. Sample accomplishments of Project High Hopes students

To be successful in this simulation, these students required a host of skills that all scientists and engineers use in a real-world setting. These skills involved math, communication, organization, and teamwork, areas traditionally problematic for students with special needs. In this context, students were able to focus on both applying their science talent and overcoming their individual learning difficulties.

In every aspect of the students' presentations, their integration of basic skills was evident. For example, one company had calculated the cost of implementing its proposal and included in its presentation an itemized budget, which reflected the higher level skills of comparison and contrast, forecasting, and evaluation. Likewise, basic science skills were integrated into the students' curriculum. Students applied the basic skill of classification as they learned to identify insects with the help of their science mentor. In addition, they applied the scientific method as they developed original experiments to test the effect of temperature on pond creatures.

Basic communication skills were enhanced by incorporating the use of video, a technique several companies employed. Their videos reflected thorough planning and organization, including creative photography, smoothly flowing scripts, and appropriate sound effects.

Students also learned the skills of organizing for work. Delineating tasks, sequencing logically for carrying out those tasks, determining who was responsible for each task, and deciding on the time needed to complete the tasks became a natural function of each company once they assembled for work. The challenges of solving authentic problems within a given time frame forced the students to organize their efforts efficiently, effectively, and economically.

Collaboration, too, is an important skill for students with special needs to learn. In one school, for example, two students collaborated as their company's scientists to develop the script for their presentation. One of these students used her

superior verbal skills while a classmate, who was deaf, signed the message for the nonhearing members of the audience.

As students focused on their tasks over the course of the week, they frequently relinquished free time to continue working on their project. Students with few social skills bonded a round similar interests and purposes. On the final day, there was no doubt in anyone's mind that each of these youngsters was highly talented. For this 1 week they seemed to have left their handicaps at home.

Maintaining the focus on creative productivity, Project High Hopes encouraged students to engage in activities in which they could continue to solve problems and develop their talents at levels commensurate with their nondisabled peers. These students, regarded by teachers and students alike as failures in grades 5 and 6, began to gain entrance into their districts' traditional gifted education programs, including advanced science. Figure 5 displays the accomplishments of the members of this talented cohort as their identity gradually shifted from feeling like students with special needs to being students with gifts and talents. One young woman, for example, conducted a study on animal behavior and won a commendation at her district's science fair competition.

### Evidence of the Model's Success

Three compelling reasons signify that the model we created to develop scientific talent in gifted students with special needs was highly successful. First is the three-stage sequence of the model. Discipline-based audition activities in Stage 1 clearly discriminated levels of student talent. This cohort of students then participated in advanced-level, discipline-based lessons in Stage 2 to develop their talent. Finally, in Stage 3, when students were knowledgeable of and skillful with the discipline, they were able to apply their learning and understandings to the solving authentic problems.

Second, in all three stages, we paid close attention to providing experiences in which the students acted like practicing professionals. The use of authentic equipment, inquiry methods, tools, and materials that scientists and engineers employ motivated students and encouraged their active engagement over time.

The final reason for the model's success was our assumption that we needed to use dual differentiation to curriculum and instruction. This approach required the use of instructional strategies offering students access to high-end learning opportunities in ways that would circumvent their learning difficulties. How this was done is outlined below.

- During talent-development activities, reading and writing were deemphasized. Students' successes depended not on the traditional reading and discussing routines, but on authentic activities of constructing and applying knowledge within meaningful, experiential contexts.
- Instruction involved a minimum of teacher talk. Observations of the mentors or other professionals as they worked with these youngsters revealed that none of them spent much time lecturing to the students, especially at the start of an activity.
- Complex learning tasks were typically broken down into several manageable parts that culminated in a final product. Breaking the whole into smaller, doable tasks is a concept difficult to master for students with poor organizational skills (see Figure 1).
- Clear and consistent communication regarding expectations was essential to the students' success. The mentors who experienced the least amount of difficulty with student discipline tended to be clear about their expectations. They presented to the group the activity's objective along with clear and succinct directions that specified what each student was to do to achieve the objective. Mentors also invited questions to clarify their directions and modeled each activity for those students who needed to see firsthand precisely what was being required of them. Finally, mentors explained to the students that, since the youngsters were being regarded as professionals, they were expected to act professionally. This expectation included the students' care and respect for the animals they were observing, as well as for the instruments and tools (microscopes, transits, drills) or materials (clay, wood, motors) they used in their advanced-level work.
- Nonemotional, verbal cues for behavior seemed effective in reminding students of their responsibility and accountability for professionalism.
- Incorporation of a problem-solving approach that results in creative products or discoveries motivated the students to engage actively in the curriculum. Experiential activities that promote problem solving benefited these students in

three ways. First, because they were actively involved in learning, their attention span increased. Second, this approach allowed students to think and act in modes commensurate with their strengths. Last, learning that occurred in a meaningful context allowed for improved memory and transfer to novel situations.

- Alternate assessment procedures incorporating experiential activities and product-based learning were important in gauging students' achievement. Using experiential activities to communicate in lieu of the traditional reading and writing requirements enabled students to demonstrate their scientific knowledge within the contexts of problem solving and product development.

## Conclusion

This model, purposely somewhat unconventional in its beliefs about learning, presents an alternative to traditional thinking about student identification, appropriate curriculum, and assessment of student achievement. First, identification relies not on test scores, but on audition activities, which constitute a "tryout" for a student to demonstrate his or her talent in a specific domain. Next, the curriculum differs from what schools generally offer in several ways: (1) its purpose is for the students to become creative producers; (2) it features a strong mentoring component that includes role-modeling and problem solving within specific domains; and (3) it provides these talented students with authentic, discovery-based, experiential, advanced-level subject matter of that domain. Finally, the alternate means of assessing student achievement focuses on a student's performance and the product he or she creates. Students are competitive, collaborative, and goal-oriented; they are able to apply problem-solving skills; and they experience a major shift in their own identity from loser to winner. In short, what this model assesses is the degree to which a student manifests scientific talent.

Although this model, which uses an alternate approach to identification, curriculum, and assessment, was designed for students with special needs, we are firmly convinced that it can be generalized to all students across all domains. Using this experience-based model may open the doors to talent development for many more students than those identified through the use of traditional criteria.

Traditional models often limit possibilities for personal growth, academic achievement, and success in life. Not only are talented students overlooked, but the curriculum offered to students who are identified represents more book learning than real-world problem solving. In short, as Renzulli (2001) has asserted, effective talent development occurs when "the

mind, spirit, and values of each student are expanded and developed in an atmosphere that is enjoyable, meaningful, and challenging” (p. 21). We believe that our model of talent development fulfills this vision

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