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# Using the Purdue Three-Stage Model to Develop Talent in the Science and Technology

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**Abstract**

This paper reports on current work using the Purdue Three-Stage Model to create enrichment classes in science, technology, engineering, and mathematics (the STEM disciplines). First, the history of the Purdue Three-Stage Model and general principles of curriculum and instruction for gifted and talented learners in math/science are reviewed. Then a detailed description of the Model is presented. Following the general description, five specific teacher applications of the Model are presented and compared with respect to the STEM disciplines and developmental levels addressed, and the relative emphasis of each unit on the different stages of the Model. Finally, the advantages of the Model as a framework for curriculum development in science, technology, engineering, and mathematics classes for talented youth are discussed.

## Using the Purdue Three-Stage Model to Develop Talent in Science and Technology

The Purdue Three-Stage Model is a general framework for program and curriculum development in gifted education. At the program level, the Model proposes that gifted programs need (a) clear, defensible goals; (b) broad-based, program-specific identification procedures; (c) grouping structures that allow gifted students to interact with each other; (d) well-trained instructors; and (e) differentiated instruction based on the Purdue-Three Stage Model curricular framework (Feldhusen & Kolloff, 1986; Moon, Feldhusen, Powley, Nidiffer, & Whitman, 1993). At the curriculum level, the Model suggests that curriculum for the gifted should include advanced disciplinary or interdisciplinary content and challenging activities that develop higher level thinking, creative problem solving skills, and independent learning abilities (Feldhusen & Kolloff, 1986; Moon, 1993; Moon et al., 1993). Research on the model suggests that it increases thinking skills, problem solving skills, and the self-regulatory skills needed to successfully complete independent projects (Kolloff & Feldhusen, 1984; Moon, Feldhusen, & Dillon, 1994). The purpose of this paper is to provide guidance for teachers and program developers who would like to use the model to develop enrichment units for 9-18 year-old learners with talent in science and technology.

*History of the Purdue Three-Stage Model*

The Purdue Three-Stage Model was originally developed in the 1970's for use in college-level educational psychology classes (Feldhusen, 1980). In the 1980's, the Purdue Three-Stage Model was adapted for gifted education with the development of PACE, a model for pullout enrichment programming at the elementary level (Feldhusen & Kolloff, 1978, Sept/Oct; Feldhusen, Kolloff, Cole, & Moon, 1988; Feldhusen & Kolloff, 1986; Kolloff & Feldhusen, 1981, May/June). The PACE program was implemented in many schools in the United States. It provides gifted and talented students with an opportunity to develop creative thinking, critical thinking, and problem solving skills and to apply those skills to a self-selected independent learning project. Evaluations of the PACE model have demonstrated its effectiveness in developing thinking skills and independent learning (Kolloff & Feldhusen, 1984; Moon et al., 1994).

In the 1990's the Purdue Three-Stage Model was extended to the secondary level (Moon, 1993; Moon et al., 1993). Some of the secondary extensions of the model have been similar to the PACE program. For example, Moon worked with colleagues teaching a pullout enrichment program at the middle school level to develop a series of enrichment seminars based on the Purdue Three-Stage Model (Nidiffer & Moon, 1994). Like the PACE program, these seminars emphasized process over content i.e. the emphasis was on further development of gifted students' thinking and learning skills, rather than on advanced content in a specific discipline. In addition, however, she worked with subject-matter specialists at the high school level to develop domain-specific adaptations of the model for high school students talented in language arts (Powley & Moon, 1993) and science (Whitman & Moon, 1993).

One of these secondary extensions, the Science Research class, was designed by a high school teacher to provide high school juniors and seniors with the opportunity to conduct scientific investigation with the assistance of a practicing scientist (Whitman & Moon, 1993). The class operated as a scheduled elective in a regular high school over a period of four semesters (two years). During the first semester, students were acclimated to the program through a variety of Stage I and II activities designed to enable them to accept responsibility for their own learning and build the skills needed for a successful independent investigation. They also began Stage III by identifying a real scientific problem on the cutting edge of one or more existing science disciplines. In the second and third semesters, students carried out their investigation, often in a university science laboratory under the tutelage of a professor whose interests matched those of the student. In the final semester, they compiled their results and shared them with others at a local, state, or national contest in the form of a poster with an accompanying written research report. Many of the student participants in this class won national awards and honors for their pioneering work. As is often the case in classes emphasizing Stage III of the Model, some of the greatest benefits the students gained were related to the development of personal talent i.e. they gained confidence, self-reliance, self-regulation skills, and increased commitment to excellence (Moon, 2003a; Whitman & Moon, 1993). These secondary extensions suggested that the Purdue Three-Stage Model was an effective framework for challenging instruction for honors classes at the middle and high school levels. They also suggested that teachers with substantial experience in a content domain could learn the principles of gifted education by applying the Model to their subject area expertise.

*Developing Talent in the STEM Disciplines*

STEM is an acronymn for Science, Technology, Engineering, and Mathematics. Gifted educators who are interested in developing talent in the STEM disciplines have focused most of their efforts on science and mathematics because these are core subjects in most K-12 schools. Much less attention has been paid to talent development in technology and engineering, in part because these subjects are not as well represented in general education pre-college curricula. Recommendations of gifted educators for talent development in mathematics vary. One group of scholars recommends rapid acceleration through existing mathematical curricula using diagnostic-prescriptive instruction (Assouline & Lupkowski-Shoplik, 2003; Benbow, Perkins, & Stanley, 1983; Benbow & Stanley, 1983; Stanley, 1996). Another group puts more emphasis on exposure to nonroutine problem solving, mathematical modeling, real-world mathematical applications, computer programming, and advanced mathematical concepts (Chamberlin & Moon, 2004; Hersberger, 1994; Lesh & Doerr, 2003; Lesh, Hoover, Kelly, & Post, 2000; Wheatley, 1994; Wood & Moon, 2004). The Purdue-Three Stage Model approach is aligned with the second group, especially with the emphases on nonroutine problem solving and real-world applications.

In the sciences, there appears to be more consensus. Experts on curriculum and instruction in the field of gifted education almost universally recommend a strong emphasis on inquiry and problem-based learning along with exposure to advanced scientific content (Gallagher, 1997; Schiever & Maker, 2003; Sher, 2003; VanTassel-Baska, 1994, 1998). Acceleration alone is not enough. Students with talents in the sciences must also develop scientifichabits of mind, problem finding abilities, and the ability to pursue independent research projects. Gifted educators recommend developing these abilities in two ways: through open-ended instruction using strategies like problem-based learning (Gallagher, 1997) and by implementing more structured instruction that is based on carefully crafted, interdisciplinary, science concept units using a curricular framework such as the Integrated Curriculum Model (ICM) which emphasizes advanced content, higher order thinking, and issues, themes, and concepts (Van Tassel-Baska & Little, 2003). The Purdue Three-Stage Model approach to science talent development is related to both of these approaches, but also differs from them in important ways. The Purdue Three-Stage Model approach is more structured and comprehensive than the PBL approach. It also places more emphasis on the development of foundational thinking skills and on independent learning than PBL. The Purdue Three-Stage Model is conceptually similar to the ICM approach, but it is a simpler model that is easier for teachers to implement in situations where they need to develop their own curriculum units for gifted and talented learners, as is often the case in the United States (Reger, 2004).

Using the Purdue Three-Stage Model to Develop Talent in the STEM Disciplines

The Purdue Three-Stage Model has been described in detail in previous publications (Feldhusen et al., 1988; Feldhusen & Kolloff, 1986; Moon, 1993; Moon et al., 1993) . Here the focus is on applications of the Model to the STEM disciplines. As with other applications of the Purdue Three-Stage Model, applications of the Model to the STEM disciplines begin with several assumptions: (a) Three-Stage Model curriculum units will combine advanced content with the learning strategies stressed in the Model and will be developed prior to instruction; (b) students who have talent the STEM discipline(s) addressed by the unit will be grouped together for instruction; (c) the teachers who develop and/or teach the Purdue Three-Stage Model units will have advanced content expertise and developing expertise in the general principles of gifted education; (c) the teachers will receive training in the skills required for effective implementation of instruction based on the Purdue Three-Stage Model.

*Stage 1 Instruction*

The Purdue Three-Stage Model has three stages of instruction that build on each other. The first stage is the most like typical instruction in the STEM disciplines. In the first stage the teacher leads the class in short-term creative and critical thinking activities designed to help the students master advanced, core content. These activities ensure in-depth learning of core content. Lecture is de-emphasized as an instructional strategy in favor of activities that actively engage students in thinking about the core content of the unit and diagnostic-prescriptive instruction in specific skills for those who need it. Once students can read, they are expected to gain much of the core content of the unit on their own through reading, learning centers, and individualized instructional packets.

*Stage II Instruction*

In the second stage of the Model, the role of the teacher begins to change to that of a designer and facilitator of complex problem solving experiences. The teacher functions like a coach of a sports team. Students work collaboratively in small groups on inquiry-oriented, problem solving activities related to the core content of the unit. These activities typically take more time to complete than the more short-term activities in Stage I. The second stage of the Purdue Three-Stage Model is a particularly good fit with the STEM disciplines. All of the STEM disciplines have creative problem solving of some sort at their heart. Adult engineers, computer programmers, and scientists find and solve problems in their work. The problem solving in Stage II takes slightly different forms in the different STEM disciplines. In mathematics and real-world applications of mathematics in fields like computer programming and engineering, modeling is a central form of problem solving so Stage II activities in these disciplines may involve creating mathematical models from data sets, as is the case with Model Eliciting Activities (Chamberlin & Moon, 2004; Lesh & Doerr, 2003; Lesh et al., 2000), or various design tasks, such as those that are stressed in the pre-engineering curriculum of Project Lead the Way (http://www.pltw.org). In science, more emphasis is generally placed on problem finding and on mastering the techniques of the scientific method to discover new knowledge. In all disciplines, an emphasis is placed on open-ended, creative, nonalgorithmic problem solving. Problems have been categorized into five types which differ in what is known to the problem presenter and the problem solver (Getzels & Csikszentmihalyi, 1967; Schiever, 1990). Typical school problems in the STEM disciplines are the simplest type (Type I), i.e. problems where the problem and solution method are known to the teacher and the learner, but the solution is known only to the teacher. Stage II of the Purdue Three-Stage Model emphasizes the other four types, all of which are more complex and difficult because less is known in advance by the learner and, in the more difficult problems, the teacher. In Type II problems the methods of solution and the solution are known to the teacher, but not the learner, requiring the learner to invent problem solving methods. Type III problems are similar but there is a wide range of solutions and methods that may fit the problem which are known to the teacher, but not the learner. In other words, the discipline has developed a range of problem solving methods for this type of problem which are known to the teacher, but not the learner. Hence many approaches to the problem are possible. In Type IV problems neither the teacher nor the learner knows the methods or solutions to the problem. In the STEM disciplines these problems are those on the cutting edge of the discipline. The most difficult problems (Type V) are those where even the problem is "unknown" because it is poorly defined; these types of problems are the focus of most basic scientists. Real-life problems in the STEM disciplines range from Type II to Type V. When using the Purdue Three-Stage Model to develop talent in the STEM disciplines, Type I problems are used in Stage I. The remaining problem types (Types II-V) are the focus of Stages II and III of the model. When implementing Stage II of the Purdue Three-Stage Model in the STEM disciplines, the problems utilized should emphasize the types of problems encountered by adults working in that discipline.

*Stage III Instruction*

The final stage of the Purdue Three-Stage Model, Stage III, builds skills in problem finding because students work independently on self-selected projects related to the unit topic. This stage of the Model builds independent learning skills and the dispositions needed to persist over time in the face of obstacles while pursuing long-term goals. Younger children can complete shared inquiry activities under the direction of the teacher as their Stage III project. Older students will be able to complete more complex, longer-term projects with less direction from their teachers. All students participating in Stage III are building skills in self-direction and self-regulation. The timeframe for Stage III activities can range from a few weeks to several years, depending on the complexity of the independent problem being pursued. Students can work on their Stage III projects alone or in small teams. Collaborative Stage III projects may be desirable for units in applied disciplines where most real-life projects are completed by teams (e.g. many areas of engineering).

*Current Work with the Purdue Three-Stage Model*

For the past four years, the staff of the Gifted Education Resource Institute (GERI) at Purdue University have been doing action research on the PURDUE THREE-STAGE MODEL as a framework for university-based enrichment courses, with special emphasis on the STEM disciplines. Because Purdue has both a world class center for gifted education and an international reputation for excellence in the STEM disciplines, it is an excellent context for interdisciplinary research on the identification and development of talent in the STEM disciplines. Hence, Purdue has been the primary research and development "laboratory" for the development of STEM enrichment units that use the Purdue Three-Stage Model as a curricular framework. GERI staff have used the Model in a several talent development programs. *Super Saturday* is a nine week enrichment program for gifted and talented students age 4-12 which is offered on Saturday mornings on a university campus. Students select the classes they want to take from a catalogue that includes brief descriptions of each course. Classes are cross-graded with most classes including an age range of about 3 years or two school grades.

*Super Summer* is an enrichment program for gifted and talented students ages 4-8 that is offered in the summer months on the Purdue campus. Several one-week sessions are offered in the Super Summer Program, with a selection of classes in each session and the opportunity to participate for a full-day by taking two classes, one each morning and another each afternoon, or just a half-day by taking only a morning or afternoon class. *GERI Summer Camps* are a series of residential programs with more challenging and accelerated classes for gifted and talented learners ages 10-18. GERI Summer Camps emphasize the holistic development of gifted and talented youth by providing both academically challenging classes and a variety of fun extracurricular activities designed to nurture social/emotional development. For more information about these programs please see the GERI web site (retrieved May 28, 2004, from http://www.purdue.edu/geri/youth/). The teachers who teach the classes in all of these programs create original curriculum units for their classes using the Purdue Three-Stage Model as a framework. An online manual created by GERI staff provides guidance for the teachers as they develop their curriculum (Retrieved May, 28, 2004, from http://www.purdue.edu/ geri/manual/). A more comprehensive *Teacher's Guide to the Purdue Three-Stage* Model has been developed by GERI staff in a CD format with funding from the Indiana Department of Education (Bangel & Moon, 2004). The teachers for GERI enrichment programs range from experienced public school teachers to inexperienced teacher education candidates who have not yet earned their teaching license. Very few of the teachers have any training in gifted education. In order to ensure that the classes these teachers develop are appropriate for gifted and talented learners, GERI staff provide several types of professional development including a half-day workshop, access to an online training manual, curriculum conferences with the teachers as they develop their units, and on-site structured observations of their teaching using the Purdue Teacher Observation Scale as an assessment instrument (Hansen & Feldhusen, 1994). The Purdue Three-Stage Model is described in detail in the online staff manual and provides a clear and simple framework for helping this wide range of teachers develop their content expertise into units of instruction that are adapted to gifted and talented learners because they provide multiple experiences with higher order thinking and problem solving and the opportunity to develop an independent project related to the course topic. This work has suggested that the Purdue Three-Stage Model may be an especially effective curricular framework for courses in the STEM disciplines because experts in these disciplines are skilled problem solvers who conduct independent investigations (math/science) and/or manage complex projects (technology/engineering).

*Examples of Purdue Three Stage-Model Classes in the STEM Disciplines*

In developing a Purdue Three-Stage Model unit in one or more of the STEM disciplines, the teacher needs to keep in mind both the nature of the discipline and the developmental level of the students. The examples of specific classes and units that follow show different ways of implementing the Model in the four STEM disciplines at different developmental levels. All of these units were developed by teachers in GERI enrichment programs. More complete descriptions of several of the units are available on the *Teacher's Guide to the Purdue Three-Stage Model* CD (Bangel & Moon, 2004).

*Architectural Math.* An interdisciplinary unit that was developed for Super Saturday and Super Summer students aged 9-10, the Architectural Math unit develops measurement skills, creative visualization skills, visual arts skills, spatial skills, and design skills (Woermbke, 2004). Stage I activities in this unit involve a variety of discovery learning activities designed to introduce concepts that are foundational to the Stage III project that is the centerpiece of the unit i.e. real-world applications of AutoCAD software and modeling techniques that enable students to create a unique structure. The foundational concepts for this unit include *geometry concepts,* such as line segment congruence, perimeter, and area; *visual arts concepts* such as styles and periods of architecture; and *architectural design concepts* such as construction processes, floor plans, and elevation drawings. For example, the Stage I lesson that exposes students to different styles of architecture involves creating several different stations or learning centers in the classroom for different countries. At each station students complete a math/geometry activity that is relevant to the style of architecture characteristic of that country (e.g. constructing a dome using dowel rods, carving "marble" column out of soap, or creating a tessellating design to represent mosaic construction). In Stage III of this unit, architectural design is emphasized. First, students use their imaginations to create sketches of a unique structure in a unique style. Then they learn to use AutoCAD software to design a floor plan and elevation drawing for their structure. Finally, they construct a three-dimensional model of their design. As the culminating activity in this unit, presentations are given to the class where students elaborate on the function, quality, process, and area of the structure, demonstrating mastery of the concepts that the unit is designed to teach. This is an example of a unit for younger children that moves directly from Stage I to Stage III with little emphasis on Stage II.

*Chemistry.* In the United States, chemistry is one of the most popular enrichment topics for children ages 6-10. Enrichment classes in chemistry always fill quickly and completely when offered through Super Saturday or Super Summer. In her advanced chemistry unit for 9-12 year old gifted and talented students based on the Purdue Three-Stage Model, Rovira (Rovira, 2004) introduces a variety of chemistry concepts through active, hand-on learning activities that develop creative and critical thinking skills. For example, one of the first classes in this unit is on properties of liquids and solids. Concepts like density, solubility, and immiscibility are introduced through Stage I activities such as a chromatography color burst, silly putty pick up tests, density and frustration bottles, and wonderful window cleaner. Most of the problems in this class are Type II problems where the method and solution are known to the teacher, but not to the students. The activities engage students in learning and applying skills such as observing, inferring, predicting, and hypothesizing, skills that scientists use for their investigations of Type V problems.

The activities for a science class like advanced chemistry require considerable preplanning by the teacher to ensure that the necessary materials are available for the lesson and that students learn from the activities. For example, a lesson on physical and chemical change that occurs near the end of the unit begins with a Stage I demonstration lesson that takes only 10-12 minutes to complete but requires the following materials: aluminum foil, a hot plate, oven mitts, a cookie tray, crayons, and various kinds of paper (Rovira, 2004). The teacher draws with crayons on heated aluminum foil, causing the crayons to melt. Then white paper is pressed down over the crayons to create a print. The teacher follows the demonstration with a discussion of the processes that create state changes in physical objects (e.g. from solid to liquid or liquid to solid).

Later in the same class session, students participate in a 40-55 minute Stage II activity that involves experiments with light sensitive paper. This activity requires materials such as solargraphic paper, colored cellophane, and a variety of different light sources and involves students in data gathering and hypothesizing. The class is divided into small groups and challenged to design an experiment to test the effects of light from various light sources. The students need to identify the experimental conditions that they will vary and those that will remain the same. They then carry out their experiment recording the results in a data table. At the conclusion of their experiment the teams prepare a report that includes the experiment title, the light source they used, the distance that the light sensitive paper was placed from the light source, the test samples and record of the exposure time for each sample, the controls and variables in the experiment, their results, and their conclusions based on those results.

For Stage III the instructor organizes a mini-science fair. Students create and carry out self-selected independent science projects. In the fall of 2003, students created projects with titles like Static Electricity; How to Grow Crystals; Acid and Bases; Carbon Dioxide from Alka-Seltzer Tablets; and Glue out of Skim Milk. On the final day of Super Saturday, the students present their projects to their classmates and parents. The projects are evaluated by Purdue graduate students and research staff using an instructor-designed rubric with criteria such as creativity, scientific thought, thoroughness, skill, and clarity.

*Forensic Science.* Gifted and talented students are fascinated by forensic science because forensic scientists are detectives who solve mysteries. Forensic science is also inherently interdisciplinary. It includes fields ranging from chemistry to mathematics to physics. In this enrichment class for children ages 12-14, science is combined with mystery writing (Schlee, 2004). Stage I activities introduce students to the steps involved in a forensic analysis and many of the tools of forensic science. For example, students watch a video about forensic science and then meet and interview experts in fields such as forensic entomology, ballistics, and DNA fingerprinting. Both Stage I and Stage II activities in this unit involve students in simulated forensic science analyses. Scaffolding techniques are used to relate new concepts to concepts the students already know. For example, in a Stage II lab on blood spatter analysis students learn how geometric principles they already know relate to the trigonometry they will use in the lab to determine blood angles. In addition, during Stage II students begin working in small groups to apply their knowledge of forensic analysis to solve actual and simulated crimes. During Stage III, students create their own mystery stories, stories that can be solved by applying the principles of forensic science that they have learned in the class. These mystery stories are combined by the instructor into a bound book that is given to all class members. Individual students share their mysteries with the class and their parents in the final session of the class. Using mystery stories as the vehicle for Stage III projects in this course accomplishes two instructional goals. First, students have the opportunity to bring together all of the scientific principles they have learned in one project. Second, science students are given the opportunity to improve their writing skills, skills that are essential for real scientists when they write for publication.

*Mathematical Modeling.* This unit has been taught as a two-week summer intensive for 7th and 8th graders and as a unit in a 7th grade self-contained class for gifted students. The unit focuses on exposing students to at least three Model Eliciting Activities (MEAs), a type of semi-structured problem developed by mathematics educators to encourage learners to create mathematical models to solve a wide variety of simulated problems for simulated clients (Chamberlin & Moon, 2004; Lesh & Doerr, 2003; Lesh et al., 2000). Examples of Model Eliciting Activities are available on line (retrieved May 31, 2004, from http://smsc.soe.purdue.edu/lesh/digital_library2/middle_school_activities.htm).

This unit focuses almost exclusively on Stage II of the Purdue Three Stage Model. MEAs are Type III or IV problems, where a range of possible methods and solutions are possible. These methods and solutions may or may not be known to the instructor depending on his/her level of mathematical expertise; they generally are not known to the students. Students work in groups to solve the problems. Research suggests that these problems are not as interesting to gifted students as the developers had hoped but do elicit superior mathematical performances from mathematically talented students, as compared to students with more average levels of ability, when implemented in homogenously grouped classrooms (Chamberlin & Moon, 2004). The problems build experiential and conceptual understanding of modeling as an essential mathematical skill.

*Aerospace Engineering.* This class exposes high school students attending an intensive, two-week, summer camp for talented youth to the basic concepts of aerospace engineering using hands-on instructional methodology that emphasizes both computer aided and mechanical design work. Through a variety of Stage I creative and critical thinking activities, students are exposed to the basic principles of aeronautical engineering. For example, they fly a simulated aircraft as a flight simulator pilot and listen to short lectures about concepts like lift and drag. In Stage II they use computer software to research and design futuristic air and spacecraft. In Stage III they create aerospace models based on their designs and test their flight properties in class labs. This unit exposes learners to Type I-III problems and the "design and test" methodology used by most fields of engineering to create new structures.

*Unit Comparisons.* The table below summarizes the examples that have been presented and shows the relative emphasis on each of the stages of the Model in each class. Note that the classes vary quite a bit in the emphasis they place on the different stages of the model. Format can constrain the use of Stage III. It is difficult to engage students in real-world Stage III projects in a Super Saturday enrichment program or an intensive class in a summer residential camp. However, independent projects that can be shared with classmates and families at the end of the program are possible. Greater emphasis on Stage III is possible in typical school settings, if the class lasts for at least a semester, as was the true for the Science Research Class described in the literature review (Whitman & Moon, 1993). The Science Research Class had a very strong emphasis on stage III, while most of the enrichment program classes have a slight to moderate emphasis. Enrichment programs, however, are an ideal context for Stage II. Freed from the constraints of required curricula, teachers in enrichment programs find it quite easy to engage students in complex problem solving activities. The units developed for younger children have a greater emphasis on Stage I activities. Younger children tend to need more time in Stage I before they move on to complex problem solving and/or independent learning than older children do.

Table 1. Relative Emphasis of the Sample Units on the Different Stages of the Purdue Three-Stage Model

| CLASS NAME | Discipline(s) | Format | Target Ages | Stage I | Stage II | Stage III |
|---|---|---|---|---|---|---|
| Architectural Math | MATH, TECHNOLOGY, ENGINEERING | Super Saturday* | 9-10 | XXX | | XXX |
| Experimental Chemistry | SCIENCE | Super Saturday* | 9-12 | XXX | XX | XX |
| Forensic Science | SCIENCE | Super Saturday* | 12-14 | XXX | XX | XX |
| Mathematical Modeling | MATH | 2 week Intensive** | 12-14 | | XXXX | |
| Aerospace Engineering | ENGINEERING | 2 week Intensive** | 16-18 | XX | XX | XX |

Notes:
KEY: Blank = no emphasis; X=slight emphasis; XX=moderate emphasis; XXX=Strong emphasis; XXXX= very strong emphasis
*Super Saturday classes are taught two hours each Saturday for nine weeks (18 hours contact time) during the academic year or as one-week intensives in the summer (15 hours contact time)
**Two week intensives are taught in the summer (30 hours contact time)

## Discussion

The examples illustrate the value of the Purdue Three-Stage Model as a curriculum development framework for enrichment units for learners who are talented in the STEM disciplines. Strengths of the Model include fit with the structure of the STEM disciplines, development of thinking skills, increased student motivation, and ease of implementation, especially for novice teachers.

### *Fit with the STEM Disciplines*

The Purdue Three-Stage Model is an excellent fit with the STEM disciplines as they are actually practiced by scientists and engineers. It also provides a good antidote to the over-emphasis on content memorization that occurs in many P-16 science and math classes which are taught in a lecture format. Teaching STEM courses using the Purdue Three-Stage Model framework helps students to learn the design skills utilized by engineers and computer programmers and the investigative skills used by scientists. Practicing scientists and engineers use more creative thinking processes to solve problems in their domains than most P-16 teachers realize, especially when they are solving Type V problems on the frontier of their field (Lesh & Doerr, 2003). The emphasis on creative thinking in the Purdue Three-Stage Model helps talented students learn the skills needed to make scientific and engineering breakthroughs. The hands-on, engaged learning that results from STEM units based on the Purdue-Three Stage Model is also very effective in helping students master advanced scientific concepts years before those concepts will be introduced in more typical state or national curricula.

### *Thinking Skills*

Many curriculum experts in the field of gifted and talented education recommend focusing GT curricula on higher order thinking processes (Feldhusen & Treffinger, 1985; Renzulli, 1977; Renzulli & Reis, 1986; VanTassel-Baska, 1994). The Purdue Three-Stage Model is exceptionally balanced and parsimonious in the thinking skills it emphasizes. Stage I activities provide equal emphasis on creative and critical thinking skills, providing students with the divergent abilities they need to generate solutions as well as the convergent abilities they need to assess the ideas they generate and decide which ones to implement. Stage II activities provide extensive experience with complex problem solving. Stage III activities provide students with the opportunity to select topics for in-depth investigation so they learn more about their interests and passions. As they implement their investigations, they develop skills in managing long-term projects and sharing their work with an audience. The thinking skills taught in the Purdue Three-Stage Model are those that are most needed for professional work of all kinds. These skills are especially crucial for talent development in the STEM disciplines.

*Personal Talent*

Personal talent is exceptional ability to select and achieve difficult goals that are good fit with ones interests, talents, values, and contexts (Moon, 2003b). STEM enrichment units based on the Purdue Three-Stage Model build personal talent by enabling students to explore their interests in the STEM disciplines, learn about STEM concepts in an active and engaging instructional format that increases intrinsic motivation, increase their resilience by learning to persist when they encounter obstacles, frustration, and failure while working on challenging problems, and develop the self-regulatory skills needed to conceptualize, complete, and share a long-term project. STEM enrichment units based on the Purdue Three-Stage Model provide both direct and indirect opportunities for the development of personal talent (Moon, 2003a). Indirect opportunities for personal talent development occur when students select the courses they want to take and engage in complex problem solving activities. Direct opportunities occur when instructors provide assistance to students in narrowing their Stage III topics or instruction in creative problem solving skills such as brainstorming. Participation in multiple Purdue Three-Stage Model STEM units, such as the ones described in this paper, helps students develop personal talent just as much as it helps them develop talent in specific STEM disciplines.

*Professional Development*

The final strength of the Model is its value as a professional development tool for novice teachers. The Model is simple and easy for novice teachers to grasp. It provides excellent scaffolding for teachers with advanced STEM content knowledge who want to learn more creative and engaging ways to teach that content to talented youth. At Purdue, we have used the Model with a wide variety of novice teachers and almost invariably have found that they can produce effective Purdue Three-Stage Model enrichment units with minimal training and supervision. Experienced teachers also like the model because it gives them a flexible framework for ensuring that they teach advanced concepts to gifted learners and develop key STEM skills such as problem finding, problem solving, iterative design, and management of long-term projects. In summary, the Purdue Three-Stage Model provides a flexible, effective framework for the development of enrichment units in the STEM disciplines by both novice and experienced teachers with advanced STEM content knowledge.

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