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From the President…

The Gathering Storm

Lawrence K. Duffy, PhD FAIC

Society is changing rapidly in many areas. At AIC meetings and other gatherings of scientists and engineers, it is common to point out today's many problems with the "traditional" ways of conducting research and educating students. It seems that a career in science or engineering is not a priority for American youth. America's challenge is how to inspire the next generations for careers in science, technology, engineering or math – the so-called STEM disciplines.

In the past, AIC has focused on service to chemists and engineers as well as industrial managers and entrepreneurs. AIC honors chemists with the Gold Medal for Outstanding Achievement, the Hyman Ethics Award and the Pioneer Award. AIC also administers the national program for Certification of Professional Chemists and recognizes professional activity and accomplishments by its Fellow's program. Currently, AIC works with universities and colleges to honor outstanding undergraduates, but we should do more. How can AIC enable its members to inspire students in chemistry as well as other scientific disciplines such as material science, biotechnology, environmental, clinical and complex systems sciences?

The National Academy of Sciences, National Academy of Engineering and Institute of Medicine's joint report "Rising Above the Gathering Storm" points out that well-trained people and the steady stream of scientific and technical innovations they produce need to be preserved; or, our economy will suffer and Americans will face a lower standard of living. It is noteworthy that as much as 85% of measured growth in the US per capita income was due to technological change. ACS's report "The Chemistry Enterprise in 2015" points out that globalization is leading to a huge generational change. William Carroll, Jr. noted that U.S. will lose its position unless bright people choose science and chemistry. I feel that "importing" people is the wrong solution, we need to invest wisely in our education systems especially to make STEM disciplines relevant to aoo our youth.

Partnerships between industry and educational organizations need to be created to foster the multi-disciplinary approaches of industry. AIC should work to enable these partnerships and encourage a curriculum that is inspiring to the young and suitable for industry's needs. I hope in future issues of The Chemist, we can highlight these partnerships and curriculum suggestions with articles and recommendations. Multi-disciplinary and interdisciplinary education and research leads to innovation, and is our best protection against the storm. At the individual level AIC members should invite students – high school, undergraduate and graduate – into their labs and work places and become co-educators. Many universities and colleges now developing service learning programs – get affiliated, get involved.

ANTI-ESTROGEN CROSS RESISTANCE IN HUMAN BREAST CANCER

Joseph A. De Soto[*,1,4], Elizabeth B. Fryar[1], Felix E. Grissom[2], William M. Southerland[3], Sidney Green[1], Donnell Bowen[1]

Abstract

Introduction: Recently, the STAR study showed that raloxifene works at least as well as tamoxifen in preventing breast cancer. It is of interest to know whether raloxifene may be used in the treatment of breast cancer and whether it would be effective in those who have developed resistance to other anti-estrogens. **Methods**: Estrogen receptor positive (er+) and negative (er-) breast cancer cells were exposed to tamoxifen, raloxifene or faslodex for 48 hours and the efficacy and potency of these drugs determined. MCF-7 breast cancer sub-lines lines resistant to tamoxifen (TAMR), raloxifene (RALR) or faslodex (FASR) were developed and used to determine cross-resistance among anti-estrogens **Results**: The efficacy of tamoxifen, raloxifene, and faslodex in inhibiting the proliferation of MCF-7 estrogen receptor positive er+ breast cancer were equivalent though theirs potencies differed. However, anti-estrogens were unable to inhibit the growth of er- breast cancer cells. TAMR sub-lines were resistant to raloxifene and faslodex, while FASR sub-lines were resistant to tamoxifen and raloxifene. RALR sub-lines however, were sensitive to treatment with tamoxifen in vitro and in vivo. **Conclusions**: The anti-estrogens tamoxifen, raloxifene and faslodex are equally efficacious in inhibiting breast cancer growth in er+ tumors. RALR sub-lines are sensitive to tamoxifen treatment.

Key Words: Medical/Pharmaceutical Chemistry, breast cancer, raloxifene

Introduction

Breast cancer is the most common malignant neoplasm in women worldwide and in the United States.[1] It is estimated that there are about 45,000 deaths in women and 400 deaths in men from breast cancer each year in the United States.[2] The number one risk factor in the development of breast cancer in women is the life time exposure to estrogen.[3,4] Estrogens act in human breast tissue by promoting the proliferation of human breast cells. The selective estrogen receptor modulator (SERM) tamoxifen (trans-1-(4-beta-dimethylaminoethoxyphenyl)-1,2-diphenylbut-1-ene), which is currently the most commonly used hormonal treatment for breast cancer has been shown to be effective in treating patients with advanced disease as an adjuvant in treating patients with primary breast carcinoma and as a preventative agent in those patients at high risk for developing breast carcinoma. Tamoxifen is effective in estrogen receptor positive breast cancers and there is also some evidence to suggest that it may inhibit the growth of estrogen receptor negative breast carcinomas[5]. However, resistance to tamoxifen inevitably occurs with 2-5 years after the beginning of treatment with no evidence suggesting a beneficial use after 5 years[6,7]. In addition, tamoxifen use is associated with a significant increase in endometrial carcinoma and tumor flare [8,9]. Recently, it was reported that raloxifene ([6-hydroxy-2-(4-hydroxyphenyl)benzo[benzo[b]thien-3yl]-[4-2-(1-piperidinyl)ethoxy]phenyl]-hydrochloride) was at least as effective as tamoxifen in preventing breast cancer without the associated increased risk of endometrial carcinoma[10]. In this paper, we evaluate the ability of raloxifene to inhibit breast cancer proliferation in comparison to tamoxifen and faslodex and investigate cross resistance among these three anti-estrogens.

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Methods

Cells and Reagents: MCF-7 and MDA-MB-436 human breast cancer cells were obtained from American Type Tissue Culture in Manassas VA. Cells were grown in Dulbecco's Modified Eagles Media (DMEM) with 10% fetal bovine serum (FBS), in a 5% CO_2 incubator in 37°C. Cells at 80-85% confluence were trypsinized, washed with phosphate buffer solution (PBS) and plated for each experiment. Tamoxifen was obtained through Sigma-Aldrich, St. Louis, MO, raloxifene from Eli-Lilly, Indianapolis, IN, and faslodex **(**7-alpha-[9-(4,4,5,5,5-penta fluoropentylsulphinyl)nonyl]estra-1,3,5-(10)- triene-3,17-beta-diol) from Tocris-Cookson, Ellisville, MO.

Measuring cellular proliferation: 25,000 cells were plated in 12 well costar flasks. After 4 hours, anti-estrogen was added and the cells were incubated for 48 hours. The cells were then treated sequentially with 1% thiazolyl blue tetrazolium 20 minutes followed by 2-propanol for 30 minutes. Absorption was read with the Perkin-Elmer 1420 multi-label counter. Each data point on each curve was replicated at least 10 times**.**

Establishment of MCF-7 cell sub-lines partially resistant to anti-estrogens: 4-5 million MCF-7 cells were placed in 75 cm^2 Costar culture flasks with 20 ml of DMEM and 10 % FBS with either10 µM tamoxifen, 10 µM raloxifene or 0.1 µM faslodex. The cells were subcultivated every 3 days for 2-3 months, with at least 1 million cells being placed in each of the flasks. The cells were tested for anti-estrogen resistance by measuring their inhibition of growth in the presence of anti-estrogen after each fifth passage.

*Tumor allograft studies***:** 5 million raloxifene resistant sub-lines were implanted subcutaneously and bilaterally in the flanks of nude mice. The nude mice were fed water enriched with 8 mg/L of estrone daily. There were five mice in each of the control or treatment groups. Treatments were initiated when measurable tumors were present in all mice. Mice received either vehicle, tamoxifen at 2 mg/ kg or raloxifene 2 mg/kg daily per os. The mice were monitored daily.

Results

Inhibition of breast cancer proliferation: In the first set of experiments, we evaluated the ability of the anti-estrogens tamoxifen, raloxifene and faslodex to inhibit MCF-7 estrogen receptor positive (er^+) breast cancer growth. The efficacy (E_{max}) of the anti-estrogens as measured by maximum inhibition of MCF-7 cell growth was 30.2 ± 2.1 % tamoxifen, 30.75 ± 2.9 % raloxifene and 29.0 ± 2.6 % faslodex respectively. The potency of these anti-estrogens, as defined by the amount of drug needed to produce 0.5 of the maximum efficacy are, 0.479 µM tamoxifen, 0.355 µM raloxifene, and 0.013 µM faslodex. That is faslodex was 36.8 times as potent as tamoxifen and 27.3 times as potent as raloxifene in its ability to inhibit MCF-7 growth, while, raloxifene was 1.3 times as potent as tamoxifen (Fig 1). Next, we wanted to see if anti-estrogens could inhibit er^- breast cancer cells as reported in some articles[5]. In order to improve clinical relevance tamoxifen, raloxifene, and faslodex were dissolved in human blood at various concentrations until crystals or precipitation was seen under microscopy. Crystallization was observed at slightly over 10 µM for tamoxifen and raloxifene and at 0.11 µM for faslodex respectively. It was assumed that these levels might represent approximately the maximum dose available *in vivo*. A literature search, found that the maximum reported blood level reported for tamoxifen was about 4-5 µM, consistent with our model [11]. er^- MDA-MB-436 breast cancer cells were exposed to vehicle, 10 µM tamoxifen, 10 µM raloxifene or 0.1 µM µM faslodex for 48 hours. There was no inhibition of MDA-MB-436 proliferation observed, differing from previous reports. It was noted however that in these earlier reports, 25 µM to 1000 µM concentrations were used, an amount of drug that cannot be obtained *in vivo*, these earlier reports may have represented a clinically non-relevant approach.

Anti-estrogen cross resistance: MCF-7 sub-lines including (TAMR) 83.4 fold resistant, raloxifene (RALR) 190.8 fold resistant and faslodex (FASR) 87.0 fold resistant, were developed through continuous exposure to their respective anti-estrogen. The TAMR sub-lines were exposed to raloxifene or faslodex for 48 hours and the inhibition of breast cancer proliferation was measured by MTT assay. TAMR cells were 3.1 fold and 1.5 fold resistant to raloxifene and faslodex respectively. Next, RALR sub-lines were exposed to tamoxifen and faslodex. Interestingly, we found that the RALR sub-line was 22 fold as sensitive to inhibition by tamoxifen as wild type MCF-7 cells. The RALR sub-lines were 2.6 fold resistant to faslodex. Additionally it was found that FASR sub-lines were 1.9 and 1.5 fold resistant to tamoxifen and raloxifene respectively. Hence, cross resistance

was present for nearly all combinations of treatment except, for the apparent sensitivity of RALR sub-lines to tamoxifen. We next tested this apparent *in vitro* sensitivity of the RALR sub-lines to tamoxifen *in vivo*.

Raloxifene resistant (RALR) xenografts treated with tamoxifen: RALR sub-lines were implanted subcutaneously on the flanks of five nude mice per treatment group, mice were fed per os, either vehicle, raloxifene or tamoxifen daily. The tumor size was measured every other day with calipers. There was no significant difference between the mean tumor size between the control (treated with vehicle) mice and those exposed daily to raloxifene. However, there was a significant difference between the mean tumor size of the control mice and those mice given tamoxifen daily. At week 28, the tamoxifen treated tumors were approximately 25 % smaller. Necroscopy of the mice however, indicated a fatty liver in two of the tamoxifen treated mice and one of the raloxifene treated mice.

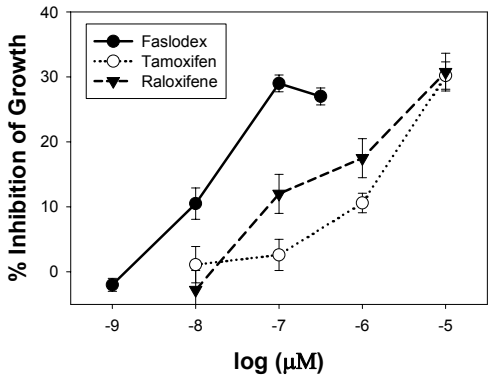
Discussion

Tamoxifen remains a front line agent for women who are at high risk for developing breast cancer or who are at risk for re-occurrence. However, tamoxifen also increases the risk of endometrial carcinoma. The STAR study, which recently, found that raloxifene is just as effective as tamoxifen in preventing cancer is welcome news as this drug does not impose the increased risk of endometrial carcinoma and is also used as a potent drug for osteoporosis found in post-menopausal women [12]. However, could raloxifene also be useful as a therapy for er^+ breast cancer? The *in vitro* studies presented here indicate that raloxifene is at least as efficacious as tamoxifen and the steroidal anti-estrogen faslodex in inhibiting breast cancer proliferation. None of the anti-estrogens evaluated here however, were able to inhibit the growth of er^- tumors. The next question was that since many women who take tamoxifen for breast cancer will inevitably become resistant to treatment with tamoxifen in two years, would these resistant tumors be susceptible to raloxifene or perhaps faslodex? The results here indicated that these tamoxifen resistant tumors would have partial resistance to raloxifene and faslodex. Yet, this increased resistance to these anti-hormones might not prevent the clinical treatment with raloxifene or faslodex of tamoxifen resistant tumors as the cross resistance is minor. One might simply increase the dosage of either raloxifene or faslodex in tamoxifen resistant tumors. Clinically, speaking this may be done when resistance is less than ten fold for a particular drug. Partial cross resistance to tamoxifen and raloxifene was also observed by faslodex resistant cells lines. Again, the cross resistance was mild but, present. The same principle then might apply in treating breast cancer tumors that have become resistant to faslodex, that is, one could increase the amount of an alternative anti-estrogen. This might be especially important in pre-menopausal women with er^+ breast cancer as aromatase inhibitors in this group tend to be ineffective and hence, aromatase are approved only for post-menopausal women[13]. *In vitro* and *in vivo* studies presented here suggest that at least some raloxifene resistant breast cancers might be sensitive to tamoxifen. This in turn implies that one possible treatment protocol would be to start a patient on raloxifene and after either a relapse or progression one could switch the patient to tamoxifen. Caution must be taken however, as it is assumed that the raloxifene resistant cell lines developed *in vitro* in this study are similar to those which develops in a patients after continuous exposure to anti-estrogen. It is suggested that further studies include the use of breast cancer tumor biopsies from patients who have developed resistance to an anti-estrogens and their subsequent evaluation.

Conclusions

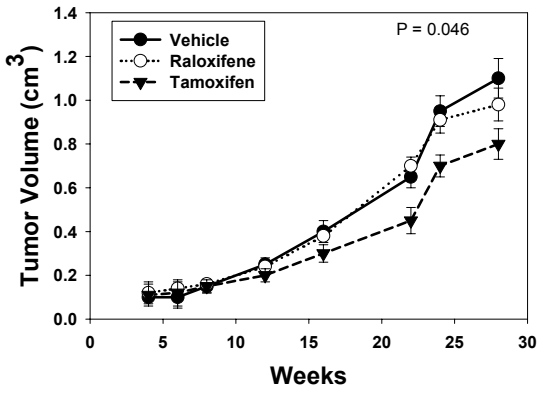
The efficacy of the anti-estrogens tamoxifen, raloxifene and faslodex are similar, however, their potencies differ. Mild cross resistance generally exist between anti-estrogens though RALR sub-lines remained sensitive to tamoxifen. Whether, the cross-resistance observed precludes the use of alternative anti-estrogens clinically remains to be evaluated.

Figure 1



The anti-estrogen dose response curve. The percent inhibition of MCF-7 breast cancer cell growth by faslodex, raloxifene or tamoxifen versus the log of the concentration of anti-estrogen is represented above. Solid circles and a solid line represents the faslodex curve, inverted triangles and dashed line represents the raloxifene curve and open circles and a dotted line represent the tamoxifen curve.

Figure 2



Treatment of raloxifene resistant xenografts with tamoxifen. Raloxifene resistant sub-lines (RALR) were exposed to vehicle (solid circles and solid line), raloxifene (open circles and dotted line) or tamoxifen (inverted triangles and dashed line) daily for 28 weeks. The y-axis represents the mean tumor size of 10 tumors on 5 nude mice per curve.

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TEACHING CHEMISTRY ONLINE

Karen Tobias and Dr. David D. Kumar, FAIC*

Abstract

This paper describes teaching chemistry online using examples from Broward Virtual, a franchise of Florida Virtual School. Selected activities that enhance the online chemistry learning experience are presented along with some observations about teaching chemistry in the online environment. Advantages and disadvantages of online chemistry are discussed.

Key Words: Chemistry Education, Online Chemistry Education

Introduction

Developments in supercomputers and high-speed Internet have increased opportunities for a wide range of online education innovations. It is quite possible to teach chemistry online as the ability to incorporate laboratory simulations, video clips, and soon to come video streaming with the aid of high-speed Internet. Online courses are on the rise both at secondary and post-secondary institutions. The number of online courses continues to increase every year. In the State of Florida, the Florida Virtual High School officially came into existence in August 1997 (1). The current enrolment is over 40,000 students anywhere in the world. This paper describes an online chemistry course offered by the Florida Virtual School through the Broward Virtual Education.

Adaptations

Teaching online is a demanding task and it requires the teacher to realize that your time is not spent creating and delivering lessons; your time is spent in guiding the students through the online curriculum. Telephone and email contacts with each student are essential to substitute the face-to-face time. Another adaptation is that the student is allowed to submit assignments at least twice for full credit. The student submits an assignment to the teacher and the teacher grades it giving detailed information about the sections of the assignment that are incorrect. This helps the student review the information they have not yet mastered. Then the student is allowed to redo the assignment and submit it for full credit. Each course has a pacing guide that dictates the minimum number of assignments that are to be submitted each week. An important part of the teacher's job is to track the student's pace and to contact the student if they fall behind. Many students comment that it is very easy to get sidetracked by other activities and fall behind in an online course.

Online Activities

The Online High School Chemistry course incorporates all possible learning styles and learning domains. For example, activities such as students writing a poem about an element, composing a song about petroleum refining, and designing a bookmark extolling the virtues of antioxidants are a

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part of the chemistry course. The assignments are designed to increase the student's computer skills along with chemistry knowledge. The students must construct data tables, incorporate graphics, design a concept map, convert document files to rich text files (.doc to .rtf) and use a discussion board along with being able to attach a file to turn in their assignments.

At the beginning of the course, a review of basic math and computer skills such as data collection, conversions, graphing, and exponent rules that a student needs to take an online chemistry course is provided. Online graphing programs and graphing calculators are often found on the Internet, free for the students to use as needed in the course. Students have access to all needed information at their fingertips - one click away - it doesn't rely on the student to be organized and retain all of the class notes and work.

The Online High School Chemistry is a laboratory-based course. Often, one of the first questions asked by teachers, students and parents is how the students complete this component. Several chemistry laboratory activities can be adapted to be performed at home fairly easily - those that cannot be adapted at home can be found on the Internet as simulations. It is quite possible to perform most classroom experiments at home with a thermometer and some measuring devices. The thermometer is provided to the students, but the measuring devices are not. If the student does not have measuring cups and spoons with metric measurements labeled, then the student must use conversions to see how many milliliters are in a tablespoon, teaspoon, or cup. Following are some brief examples of experiments contained in the Online High School Chemistry course.

1. Creating Lewis dot models using gumdrops and toothpicks.

2. By crushing red cabbage in hot water until the water turns into a pH indicator that can be used to determine whether chemicals are basic, neutral, or acidic. If the solution turns red/pink it is an acid, if it stays purple it is a base, and if it turns green/blue the solution is basic.

3. By using the red cabbage indicator, vinegar and a variety of antacids, the student can compare the effectiveness of the antacids.

4. An adapted calorimeter experiment, using a burning peanut to warm water in a suspended soda can.

5. Discovering the effect of size, temperature, and agitation on the rate of solution by using rock salt and table salt. This activity is also useful for introducing nanoscience.

6. When vinegar is combined with baking soda - a gas is given off and the students are asked to design an experiment to conserve the mass. They are asked to submit the numbered steps along with the balanced equation.

7. Using Alka-Seltzer and different temperatures of water, you can determine the effect of temperature on reaction rates. Additionally, by using whole, broken and crushed tablets, you can determine the effect of surface area on reaction rates.

8. Phase changes can be studied by using a pan with water on the stove and a thermometer. Starting with ice, the temperature is taken every 15 seconds, while the pan is heated on the burner. At the end students complete a phase change graph.

9. Students first learn about exothermic and endothermic reactions. Then they measure the temperature inside an empty jar, while soaking a steel wool pad in vinegar. Remove the steel wool from the vinegar and wrap it around the tip of the thermometer and place it back into the jar. Record the temperature and determine whether the reaction is exothermic or endothermic and write the equation.

10. A counterintuitive demonstration to show the effect of temperature on air (mixture of gases) and the effect of pressure: students heat a soda can in hot water, and then immerse it quickly (upside down) into cold water.

Online Learning Resources

United Streaming is a company that has over 5,000 video clips (5-25 minutes in length) that can be utilized in an online course fairly inexpensively. A video clip gives the student a live or animated version of the science content. Another way to deliver interactive experiences for the students is by searching and using suitable simulations available on the Internet. Examples of Internet resources follow.

http://www.hazelwood.k12.mo.us/~grichert/explore/dswmedia/density.htm (This site allows students to predict and find the densities of various objects.)

http://gcsescience.com/ (This site allows students to see and play with the activity series.)

Note: Some sites may require the students to join, while others are free.

Discussion and Summary

There are both opportunities and challenges for teaching online chemistry. According to a report from the Office of Program Policy Analysis and Government Accountability (1) the Florida Virtual School is "generally attaining its mission of reaching underserved students, including students in rural school districts and students in high minority schools" (p. 1). Access to the online teacher is an advantage because the teacher is much more available for help when the student needs it mostly around the clock.

The availability of content rich resources to select a suitable theme to deliver the content around is a positive aspect of teaching chemistry online. In the Chemistry course the themes are the water treatment plant, petroleum refinery, nuclear power plant, hospital, a fertilizer manufacturing company, and a special effects studio. These themes involve science, technology and society (STS) interactions and help students to realize the importance of chemistry in everyday life.

Another positive aspect is the limitless opportunity for students to revisit and review the information in the lesson numerous times, until comprehension occurs. This helps English as Second Language (ESL) students.

Unfortunately cheating remains an issue with online courses. Cheating can be reduced by using software products, like Turn-It-In-Dotcom. This software searches the web and any previous student work entered into the program to look for authenticity. In math-based subjects the student are required to identify all variables, state the appropriate equation and then solve the problem to receive full credit. Cheating is also not uncommon in the brick and mortar schools and often the teacher is

the best line of defense against it.

Often online courses are portrayed as a panacea for improving education. One of the critical factors overlooked in online education is the nature of the subject matter. Chemistry courses demand powerful personal computers for multimedia presentations, simulations, high-level critical interactive discourse, and adequate technical assistance for uninterrupted delivery through the Internet. Teaching chemistry online demands access to a variety of scientific information and the availability of quality chemical information on the Internet. Likewise, policies that favor adequate administrative, fiscal and instructional resources for implementing online chemistry are needed. If not delivered properly, online courses could lead to shallow learning experiences (2). More research and development efforts are critical to shaping technology as an efficient tool for delivering online chemistry instruction. How the Internet is developed to the advantage of students engaged in chemistry learning will determine the success of online chemistry courses.

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INTERNATIONAL PROGRAM TO PROMOTE CREATIVE THINKING IN CHEMISTRY AND SCIENCE

Dr. Dana M. Barry* and Dr. Hideyuki Kanematsu

Abstract

An international program to promote creative thinking in chemistry and science has been initiated by educators / researchers in the United States and Japan. This paper provides a short description of the program and its components. Also the topics of creativity and creative thinking are briefly discussed.

Introduction

A new program, which promotes creative thinking in chemistry and science, has been initiated by educators and researchers in the United States and in Japan. This unique project (with sponsorship from the Northern New York Section of the American Chemical Society and Suzuka National College of Technology in Japan) includes the preparation and use of innovative teaching techniques and tools. Its main goals are to turn children onto chemistry and engineering, and to prepare them (our future leaders and scientists) to creatively solve problems and to adapt in our ever changing world.

This program in creative education actually serves as an umbrella to several innovative teaching techniques (developed by the authors) for science instruction in grades K-12. Each technique (the multisensory teaching approach, science fairs, and the use of mystery stories) includes its own creative tools and activities. The multisensory teaching approach (referred to as the Chemical Sensation Project) is the only program component that has been carried out extensively. Details of this national award winning project are published in journals of various countries. Some include *The Chemist* (2003) in the United States, *Science Education Review* (2003) in Australia, and Tokai Kagaku Kougyoukai (2003) in Japan. The other components of this international effort are in the preliminary stages, so data is still being collected for them.

Creativity and Creative Thinking

A brief discussion of creativity and creative thinking is presented to give a better understanding of the program. Creativity, which has been important since the beginning of time, is the ability to produce original work or ideas. It is also the ability to take existing objects and ideas and combine them in different ways for new purposes. An excellent and very useful example is the wheelchair, which is composed of wheels and a chair. Three important components of creativity (Barry, 2005) are the creative person, the creative product, and the creative process. A creative person is usually energetic and full of ideas. The creative product is one that never existed before. It may be a new book, movie, toy, song, or invention. The creative process starts with the creative person (examples: artist, musician, scientist) and results in the creative product. It includes the thinking and the acts that take place to produce an original item.

Creative thinking stimulates curiosity and includes the skills of originality, fluency, flexibility, and elaboration. It is exploratory, looks for relationships, and develops many original and diverse ideas. These new ideas are then evaluated by critical thinking, which involves logic, reasoning, and science process skills (of comparison, classification, evaluation, etc.).

Creative thinking is part of our thinking process, which is explained in a simple way by Ebert's Cognitive Spiral Model (Ebert, 1994). This model includes five modes of thought (Perceptual Thought, Creative Thought, Inventive Thought, Metacognitive Thought, and Performance Thought) which

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occur in sequence along a spiraling path. They recur over and over again, but do not return to the exact spot from which they began. In Perceptual Thought the brain detects stimuli (such as flower fragrances) and translates them into neuro-chemical impulses. The next step of the model is called Creative Thought. This is defined as the search for patterns and relationships between a perception and the individual's knowledge. A person's long term memory is searched for prior experiences that are similar to the new one. If the sound of a ringing bell is perceived, then Creative Thought comes up with possible sources for the sound such as a telephone, doorbell, or alarm clock. During Inventive Thought, the information provided by Creative Thought is assembled into a product (such as a ringing telephone). Then Metacognitive Thought (popularly referred to as critical thinking) evaluates the product. If this product is found to be an acceptable solution, then it is expressed (in the model's final mode) through a performance like speaking or writing. However if it is not acceptable, then the process starts again (but at a new starting point).

The teachers' important role in creative education is to promote creative thinking and encourage students to express innovative ideas. Educators must prepare the younger generation to think for themselves so they can solve new and challenging problems and adapt to our ever changing world. To be successful, individuals must be able to understand, process, and synthesize information into unique ideas, purposes, and products. Teachers (in a creative education program) should be open-minded, seek imaginative solutions to problems, and encourage students to do their own thinking. They should also value originality, mention that several solutions may exist for any given problem, and engage the class in meaningful activities that incorporate individuals' abilities, interests, and backgrounds.

The international effort to promote creative thinking in science began in November of 2005 when Barry served as a Visiting Professor for Suzuka National College of Technology, Japan. She gave teacher training seminars for Creative Education to teachers and instructors in Japan and led four science fairs throughout the Country. She is in the process of providing similar workshops for K-12 instructors in the United States. (These workshops define creative thinking and its importance, describe the teachers' role in creative education, and provide sample activities to develop children's creative thinking skills.)

Components of the Creative Education Program

This section describes the program's innovative teaching techniques and tools to develop creative thinking and problem-solving skills in students of all ages.

1. Multisensory Teaching Approach

This method, known as the Chemical Sensation Project (Barry & Kanematsu, 2003), takes advantage of students' senses. Some students learn by listening. Others learn by seeing, writing, or performing laboratory activities. The multisensory approach (Barry & Others, 2003) is designed to meet individual student needs and requires teachers to incorporate visual, writing, listening, and laboratory activities (utilizing the senses of smell and touch, where appropriate) into their science lessons. One example is a lesson about the element carbon and its various forms. While three-dimensional models or pictures are used to visually represent the diamond and graphite forms of carbon, students listen to information about them (e.g. in a song or audible presentation). Then they perform a laboratory activity to determine and compare the physical properties of various forms of carbon (e.g. diamond, graphite, charcoal). Finally the students write a short report about their results.

Teachers may imitate this approach by incorporating available multisensory materials into their lessons. Creative materials (tools) used in the Chemical Sensation Project include a music CD

(Barry, 1996) of original chemistry songs with diverse music styles and words, overhead transparencies, pictures to serve as visual aids, and chemical experiments, to complement existing high school / college chemistry curriculums.

The authors successfully carried out the Chemical Sensation Project (which received a ChemLuminary National Award of Excellence from the American Chemical Society in 2004) at colleges and high schools in the United States and Japan. They traveled to these organizations, and provided teacher training sessions and assistance for carrying out and evaluating the project. A variety of evaluation forms were used to rate the program. Project participants include Suzuka National College of Technology, Takada High School, and Kanbe High School in Japan and Clarkson University, Edwards-Knox High School, and Canton High School in the United States.

2. *Science Fairs*

This method gives students an opportunity to select an interesting problem to solve for their science project. They brainstorm about many topics to come up with an exciting idea for their investigation. Then they prepare a list of possible materials and a creative procedure for carrying out their experiment. This method helps students develop problem-solving and critical thinking skills by performing mental exercises in collecting, analyzing, and interpreting data to draw conclusions about the outcome of their science projects. In addition, science fair participants are encouraged to use their imagination and talents to prepare exciting, multisensory displays of their work.

Creative materials (tools) used in this project may include any books about science fairs and science projects. The authors prepared special books written in English and Japanese for this purpose.

Both books include a problem-solving model and the necessary skills, information, and activities to prepare students to successfully identify and creatively solve problems. In November 2005, the authors used their Japanese book to lead four major science fairs at Katada Elementary School, Kitarissei Elementary School, and Suzuka National College of Technology in Japan. Highlights of these very successful events appeared in prominent Japanese newspapers and on the TV news in Tsu City, Japan.

Figure 1. Japanese elementary school students prepare data sheets for their science fair display. (The books on the table are written in Japanese and have the English title: *Science Fair Fun in Japan*.)

3. *Reading Stories and Solving a Mystery*

This innovative method provides students with an opportunity to develop critical thinking and problem-solving skills by reading stories and solving a mystery. This technique can be used in any classroom. Students are assigned to read a mystery and to treat it as a research project. They define the problem (the crime in the story), obtain data, carry out the steps of a problem-solving model, and solve the crime. One example is to have the class read Agatha Christie's book titled *The Mirror Crack'd*. In this mystery a film star throws a large party, at which a guest

sips a poisoned cocktail and falls dead. The students must identify and solve the problem (crime). They gather and record data (evidence) about the contents of the poisoned drink and about the possible suspects and attendees of the party. Then they organize and analyze the data to draw conclusions and solve the problem (crime).

The creative materials (tools) prepared by the authors for use in this project are two special books (one written in English and to be published in the United States and a Japanese version of the book to be published in Japan). The books target upper middle school / senior high school students (ages 13 – 18 years old) and their teachers. They include two short stories ("Mail Mystery" and "Mind Games Plus") and a detailed science education component. Students master the steps of a problem-solving model by acting as detectives to analyze each short story and solve its crime (problem). The books also include a special foreword (to the mysteries) by Hollywood actor Eric Barry, who performed the science education rap song "Chemicals" featured in the national award winning Chemical Sensation Project.

4. ***Other***

There are numerous ways to promote creative thinking in science for students of all ages. Barry teaches the course "Using Hands-on Activities to Creatively Stimulate Your Mind" for SOAR (a program of stimulating opportunities after retirement). One of her activities is called "Creative Art Using Chemicals." Participants prepare unique paintings using fruits and vegetables. Each person is given 10 cotton swabs, a paper cup full of water, paper towels, 2 large sheets of white construction paper, and a variety of fruits and vegetables. Cooked peas (containing the chemical chlorophyll) provide a green color. Cooked beets (containing chemicals classified as flavonoids) provide a red color, while blueberries (also containing flavonoids) provide a blue color. Also a piece of charcoal (containing carbon) can be used for black.

Summary

This ambitious program in creative education is an international effort to promote creative thinking in science and chemistry. Chemistry is very important to our global society. People eat, drink, breathe, wear, and use chemicals everyday. Chemistry teachers should provide students with enjoyable and meaningful experiences in science. They should encourage creativity in the laboratory (use some open-ended research activities) and also inform their classes of the importance and many uses of chemicals in their daily lives such as in medicine, cosmetics, clothes, paints, homes, food, drinks, cars, etc. In addition to teachers, chemists should also take the role of turning students onto science. They can serve as judges at science fairs and share the excitement and discoveries of chemistry as volunteers in the classroom.

This program in creative education includes the preparation and use of innovative teaching techniques and tools. Its main goals are to turn children onto chemistry and science, and to develop their creative problem-solving skills. The relatively new program continues to grow and to attract schools and students in various countries. Also the authors are in the process of preparing additional activities and materials to stimulate and promote creative thinking in students of all ages.

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MANUSCRIPT STYLE GUIDE
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