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## BEGIN Partnership: Using Problem-Based Learning to Teach Genetics & Bioethics

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# BEGIN Partnership: Using Problem-Based Learning to Teach Genetics & Bioethics

## **Abstract**

A science education center at a university medical school had grant funding to develop a genetics curriculum unit, but needed a dissemination plan. A statewide science teacher organization that provided professional development training was facing decreased funding. These two groups combined their efforts, and created a unique partnership, called BEGIN (Biotechnology, Ethics and Genetics Instructional Network) that has brought together university medical and science faculty and high school biology teachers. The main goal of this partnership is to provide high school biology teachers with new instructional tools to face the challenges of teaching genetics and bioethics in a manner that is content-rich, research and standards-based, and relevant to students' lives. This article describes the BEGIN partnership and summarizes the tiered approach used for designing, pilot-testing, and disseminating a new problem-based learning (PBL) curriculum module on the bioethics of DNA testing for Huntington's disease. The article also provides some preliminary data on the effectiveness of this approach in transforming teacher practice.

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## BEGIN Partnership:

# Using Problem-Based Learning To Teach Genetics & Bioethics

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SHAW-REE CHEN   MICHAEL WISCHNOWSKI

A science education center at a university medical school had grant funding to develop a genetics curriculum unit but needed a dissemination plan. A statewide science teacher organization that provided professional development training was facing decreased funding. These two groups combined their efforts, and created a unique partnership, called BEGIN (Biotechnology, Ethics and Genetics Instructional Network) that has brought together university medical and science faculty and high school biology teachers. The main goal of this partnership is to provide high school biology teachers with new instructional tools to face the challenges of teaching genetics and bioethics in a manner that is content-rich, research and standards-based, and relevant to students' lives.

This article describes the BEGIN partnership and summarizes the tiered approach used for designing, pilot-testing, and disseminating a new problem-based learning (PBL) curriculum module on the bioethics of DNA testing for Huntington's disease. The article also provides some preliminary data on the effectiveness of this approach in transforming teacher practice.

## BEGIN: A Unique Partnership Between University Faculty & Science Teachers

BEGIN was launched in 2003 using grant funding from the National Institutes of Health's National Human Genome Research Institute (NHGRI). This collaborative partnership brings together faculty and staff of the Life Sciences Learning Center (a hands-on science education laboratory located at the University of Rochester School of Medicine and Dentistry) and science educators from the New York State Biology-Chemistry Professional Development Network. The goal of this project is to develop and disseminate PBL-based activities that introduce high school students to the ethical, legal, and social implications (ELSI) of genetic testing. BEGIN focuses on curriculum and professional development, working primarily with high school teachers who teach biology

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courses based on the New York State *Living Environment* core curriculum (NYSED).

In order to increase the likelihood that teachers will adopt new curricula and instructional practices, BEGIN uses an ongoing, multi-year process of curriculum development and professional development with teachers from the New York State Biology-Chemistry Professional Development Network. The process introduces PBL and other instructional strategies that are based on current educational research on effective, best practices.

The centerpiece of the BEGIN partnership is a five-part PBL curriculum module called *Family Secrets* (Markowitz et al., 2006). This module engages students in constructing knowledge about DNA testing, Huntington's disease, and the bioethics of genetic testing. Using PBL strategies, students access and interpret relevant scientific information and data, collaborate with other students, and develop ownership of their "solution" to a real-life problem. These skills are all key characteristics of science inquiry, and correlate with the inquiry skills found in the *National Science Education Standards* (NRC, 1996).

*Family Secrets* is the result of a three-year process of curriculum development, statewide pilot-testing, dissemination, and feedback. *Family Secrets* was created by a Development Team of master teachers from the New York State Biology-Chemistry Professional Development Network, and scientists, a pediatric geneticist, and a bioethicist from the University of Rochester. A group of ten biology Pilot Mentors from throughout New York State pilot-tested the initial version of *Family Secrets* in their classrooms, and provided year-long feedback to the Development Team. A revised version of *Family Secrets* was then introduced to 62 statewide Biology Mentors at a four-day summer institute at the University of Rochester Medical Center. Mentors field-tested the revised curriculum, and provided the Development Team with preliminary evaluation data to assess the impact of *Family Secrets* and the PBL process on classroom instruction and student learning. Mentors currently use the final version of *Family Secrets*, and provide the Development Team with data to study the impact of this PBL module on teacher instruction and student content knowledge.

## Statewide Mentor Network for Professional Development

The Biology-Chemistry Professional Development Network is a statewide organization of approximately 60 biology and 35 chemistry teachers called "Mentors." Created in 1991, the Network has been developing educational resources and providing high school science teachers and



**Figure 1. Correlation of *Family Secrets* with National Science Education Standards (NRC, 1996).**

*Family Secrets* addresses the following Science Teaching Standards:

Teachers of science should ...

- A. Plan an inquiry based program that nurtures a community of learners (pages 31-32).
- B. Guide and facilitate learning to orchestrate discourse among students (page 36).
- C. Engage in ongoing assessment that guides students in self-assessment (page 42).
- D. Guide and manage learning environments and structure time to engage students in extended investigations (page 44).
- E. Develop communities of science learners to nurture collaboration among students (page 50).

*Family Secrets* addresses the following grade 9-12 Content Standards:

- The Cell (pages 185-185)
- Molecular Basis of Heredity (page 185)

administrators throughout New York with strategies and sustained support for their implementation of instructional, curricular, and assessment reforms.

The Network uses a tiered structure, with a small group of 20 biology and chemistry Coordinating Mentors training a larger group of 80 Regional Mentors. Coordinating Mentors receive approximately 50 hours of training each year from national and state experts in pedagogical techniques and science content. They use this training to create classroom and workshop-ready professional development materials that model how research-based instructional strategies can be integrated with standards-based science curriculum. Coordinating Mentors then provide training to Regional Mentors at an annual, three-day fall institute and at regional two-day spring meetings. These training sessions support Regional Mentors in incorporating the new content and strategies in their own classrooms. Regional Mentors also receive training in how to present professional development programs for local teachers. Regional Mentors in turn provide ongoing training to local teachers and support these teachers in incorporating the new content and instructional practices. Regional Mentors also provide feedback to the Coordinating Mentors about new content, strategies, and topics important to local teachers.

The Biology-Chemistry Professional Development Network has embraced the use of student-centered, inquiry-based instructional strategies such as PBL. Materials produced and used by the Mentors are designed to meet the needs of students with diverse backgrounds and ability levels. The instructional materials are teacher-ready and can be embedded directly into school curricula and professional development plans.

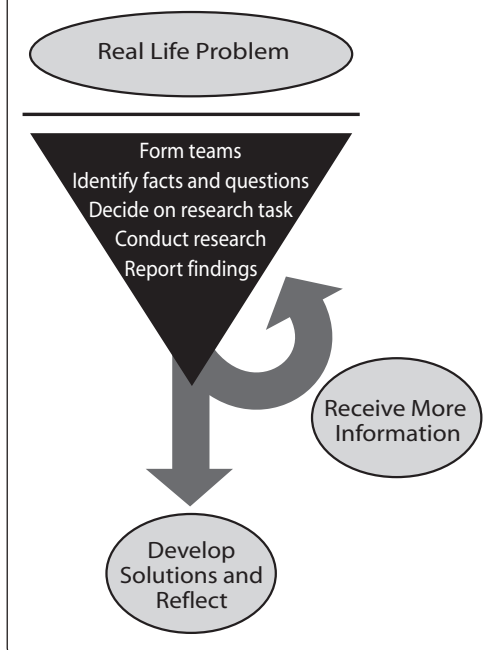
***Family Secrets*: A Problem-Based Learning Module on the Bioethics of Genetic Testing**

Problem-based learning (PBL) is a complex, collaborative, inquiry-based, student-centered teaching and learning strategy. In PBL, learners work in collaborative groups to identify problems, formulate questions and hypotheses, and then to gather and synthesize information to arrive at “best fit” solutions (Torp & Sage, 2002). The *Family Secrets* curriculum uses a progressive disclosure PBL model in which instruction is organized around a carefully-designed “ill-structured” (or incompletely structured) series of problem scenarios that mirror real-world issues in medicine and life sciences (Figure 2). The *Family Secrets* scenarios are presented as read-aloud scripts. They provide “hooks” as relevant and motivating contexts to engage students in the scientific and ELSI content that will emerge from each script.

In the *Family Secrets* PBL sessions, students work first individually and then in teams of four to list what they know (the “facts”) about the scenario, and then to develop questions they think are important to ask. This question-generating activity allows students to organize and scaffold the knowledge that they are constructing. The process of listing “facts” and creating “questions” is especially helpful for students who need more structured learning environments to process new knowledge and practice new skills required for collaborative and independent inquiry. Students next select questions of importance to them and use print and Web-based resources to research answers to their questions. They then report the results of their research to their PBL team and/or the whole class as part of this problem-solving process. As the *Family Secrets* scenarios unfold, additional information is given, and new and more complex questions are created.

One of the goals of the BEGIN partnership is to develop methods to help teachers overcome their hesitation about teaching ethical issues in science. Mentors have indicated that they feel more comfortable delving into bioethics when their students engage first in factual learning about a topic before they are asked to make an ethical decision related to that topic. *Family Secrets* provides teachers with tools for teaching bioethics within the context of a content-rich PBL module. Students first learn about and then search for more information on Huntington’s disease and genetic testing before they are asked to consider the question of whether or not “Jenny” (the main character in *Family Secrets*) should undergo genetic testing.

**Figure 2. Progressive Disclosure PBL Model.**



In Part 1, *A Family Disease*, and Part 2, *The Dilemma*, students learn about Huntington’s disease (HD) and issues involving genetic counseling, DNA testing, and informed consent. Students work in teams to identify facts and then research questions based on real-life scenarios about teen-aged Jenny, as she and her family are faced with decisions related to DNA testing for HD.

In Part 3, *A Difficult Choice*, students read the script about Jenny, who is now a young adult, as she contemplates having genetic testing. They use an eight-step, ethical decision-making model to learn about major concepts, principles, and values in the fields of ethics and bioethics and struggle with the question, “If you were Jenny, would you get tested?” The *Family Secrets* ethical decision-making model was modified from a similar model used by bioethicists at the University of Rochester Medical Center. Teachers are provided with methods for introducing their students to the four major ethical principles of autonomy, justice, beneficence, and non-maleficence (Beauchamp & Childress, 2001). Students also learn about ethical values such as confidentiality and privacy, honesty, fidelity, and integrity. As student teams progress through the *Family Secrets* decision-making model, they are guided to weigh the ethical principles, values, risks, and benefits of each possible course of action. Then, students work individually to select a course of action and create a written position statement to support their selection.

In Part 4, *Testing for the HD Gene*, students take on the roles of laboratory technicians to perform a hands-on, agarose gel electrophoresis laboratory activity in which they test simulated DNA samples from Jenny, her father, and her brother for the Huntington’s gene. They then write technical reports. In Part 5, *Making Decisions*, students contemplate additional ethical, legal, and social implications (ELSI) and questions the family may face after it learns the results of the tests. Teachers are provided with ten alternative assessment options which could be used as culminating activities for the *Family Secrets* PBL module.

*Family Secrets* is accompanied by a teacher instructional guide that includes a wide selection of print- and Web-based instructional resources on human genetic disorders, genetic testing, and ELSI, as well as instructional, assessment, and group-processing resources. The BEGIN Development Team created *Family Secrets* for teachers with no prior expertise in genetics and bioethics. The teacher’s role is to provide students with the resources needed to answer the questions that his/her students select to research. Therefore, rather than relying on the teacher to tell them information, students engage in collaborative information-gathering as part of the PBL process of discovery. The *Family Secrets* teacher’s guide also contains background information and suggestions on how to facilitate PBL, detailed lesson plans, classroom-ready handouts, and laboratory preparation information.

To support students’ understanding of complex genetics concepts and laboratory procedures, BEGIN also developed a “Virtual DNA Testing Lab” on CD. This CD illustrates and explains essential background information on genetic disease and genetic testing. It also provides an interactive computer simulation of the HD genetic testing laboratory procedure that is completed during Part 4 of *Family Secrets*.

## Three-Part Peer-Led Professional Development

Research has indicated that before teachers can effectively use a new instructional method such as PBL in their classrooms,

they need to be given the opportunity to experience the instructional method from a learner’s perspective (Shreffler, 2002). Professional development is especially necessary when teachers are using new instructional materials in their classrooms (Kreuger & Sutton, 2001). For most high school science teachers in New York State, PBL is a radically different approach to instruction, one that requires ongoing encouragement and support if it is to be effectively incorporated into teacher practice. BEGIN created



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- University of Chicago Laboratory Schools, Chicago, IL 60637
- Ware Shoals High School, Ware Shoals, SC 29696
- Wooster High School, Reno, NV 89502

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a peer-mentored, supportive and sustained approach to introduce teachers to the PBL process. This approach uses a series of professional development workshops to involve Mentors in experiencing the PBL strategies guided along by experienced PBL facilitators.

In BEGIN's three-year PBL professional development model, Mentors first assume the role of "students" as they learn to use PBL. Then, in their role as "teachers," Mentors implement PBL in their classrooms. Finally as "Mentors," they are trained to share their knowledge and experience with other teachers. This three-part approach allows Mentors to better understand PBL strategies and their roles as PBL "coaches," and to more effectively adapt the student-centered PBL approach into their own professional practices.

In Year 1 of the BEGIN partnership, Mentors were introduced to PBL through use of a simple "training" PBL called *Penguin Peril* which describes a fictitious species of hot-headed, Penguin-eating moles living under the polar ice cap. *Penguin Peril* is modified from a PBL activity created by Harold White of the University of Delaware, and is based on an article published in the 1995 April Fools Day issue of *Discover* magazine (Pazzo, 1995). The purpose for using this training PBL was to engage Mentors in the use of PBL strategies and tools. An example of these tools is students using a three-column, "PBL chart" to first list the facts presented in the scenario ("What do you know?"), then to form hypotheses ("What do you think is going on and why?"), and finally to create questions that arise from the scenario ("What additional information would you like to have?"). The *Penguin Peril* training PBL also introduced Mentors to the use of team problem-solving tools such as brainstorming. Mentors also used a second training PBL, *High Energy Battery Company*, that presents a fictitious (but potentially real-life) scenario of lead poisoning of children living near a battery factory. This more content-rich PBL engaged Mentors in learning about additional PBL instructional skills such as categorizing and prioritizing questions, using print and Internet sources to search for biomedical information, collecting data, presenting individual information to the PBL team, and presenting PBL team information to the class. Mentors were encouraged to use at least one of these training PBLs with their students prior to using *Family Secrets*.

In Year 2 of the BEGIN partnership, Mentors experienced *Family Secrets*, initially as "students" as they attended a four-day summer institute at the University of Rochester, and then as "teachers" as they used *Family Secrets* in their own classrooms. Also during Year 2, Mentors led "Introduction to PBL" workshops for other science teachers in their local regions using the *Penguin Peril* and *High Energy Battery Company* training PBLs. In Year 3, Mentors again used *Family Secrets* in their classrooms, and then conducted *Family Secrets* workshops for local science teachers.

Mentors continue to lead day-long *Family Secrets* workshops for teachers in their local regions throughout the state. Almost 1,000 teachers attended *Family Secrets* workshops during the 2004-2005 through 2006-2007 school years. Workshop participants receive the *Family Secrets* teaching materials in print and on CD. As part of the NHGRI grant, each Biology Mentor received a classroom set of electrophoresis laboratory equipment and supplies. Mentors use the equipment for their own classrooms, for their *Family Secrets* workshops, and for a loan program to local teachers who attend their workshops.

## Transforming Teacher Practice

To evaluate the effectiveness of the *Family Secrets* module and professional development, the BEGIN Development Team used qualitative and quantitative data collected from surveys and interviews. Evaluation data collected from *Family Secrets* teacher workshops indicate enthusiastic praise for both the *Family Secrets* PBL curriculum and for the Mentor-led workshop program. These workshops have been so successful that Mentors have received requests to present additional *Family Secrets* workshops beyond the three-year grant period.

*As a person, who in a "past life" used to organize and present teachers' workshops, I can appreciate all the long hours you put into making the workshop run without a hitch. You made it look effortless and a lot of fun. I have been reading the program booklet and perusing the CD and can't wait to use it with my kids.*

—High school biology teacher and *Family Secrets* workshop participant

Evaluation data collected from surveys and interviews of Mentors and teachers who are using *Family Secrets* in their biology classrooms indicates that this PBL module is a successful vehicle for transforming teacher practice. Through the training and technical assistance provided by Mentors, teachers report a boost in self-confidence in terms of implementing PBL strategies, addressing the ethical, legal, and social implications of genetic testing, and conducting an agarose gel electrophoresis lab.

"I appreciated the excellent directions," stated one teacher about the module and the training. "The students worked well [playing] their roles in the teams, generating a lot of questions. Students were generally very intrigued by the story, and constantly asked when we would get back to it since I broke up the different parts between other genetic lessons. The ethics and bioethical discussion was excellent, perhaps due to the Terry Schiavo [right-to-die] controversy occurring at the same time. It was very different from what we normally do." Teachers also indicated that their students feel empowered by their new knowledge. "My students see how their knowledge of genetics can help them to make important decisions," commented a teacher from New York City.

Feedback from Mentors praised the PBL process for improving student engagement, providing real-world applications, and promoting discussion of bioethics. Mentors indicated how much they like using PBL, and have asked for additional PBL modules that they could incorporate into other parts of their curriculum. Due to an overwhelming request from Mentors, the BEGIN Development Team provided Mentors with instruction on how to write their own PBLs. To date, Mentors have written at least 100 new PBLs on topics ranging from toxic environments, to evolution, to genetic engineering. Some Mentors have conducted action research projects that focus on collecting quantitative and qualitative data to study the impact of PBLs on student learning. Some of these projects include error analysis of New York State's *Living Environment* standardized test data and tracking student performance on items related to genetics.

Results of student performance on the June, 2005 *Living Environment* exam provided direct measurable evidence of the impact of *Family Secrets* and PBL on student learning. Students of Mentors who used *Family Secrets* during the 2004-2005 school year scored significantly higher on three of the exam questions related to DNA testing using gel electrophoresis, when compared

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to a control group of high school biology students whose teachers did not use *Family Secrets*.

- 96.7% of *Family Secrets* students could identify a diagram of DNA gel electrophoresis versus 72.8% of the control students.
- 50.5% of *Family Secrets* students understood the process of DNA movement during gel electrophoresis versus 39.5% of the control students.
- 62% of *Family Secrets* students could describe how DNA was treated with restriction enzymes prior to gel electrophoresis versus 26% of the control students.

## Conclusion

The BEGIN project is an example of the power of a successful collaborative partnership between university scientists and master teachers to create and disseminate new curricula and instructional methods. Throughout this project, the BEGIN Development Team continually solicited and incorporated feedback from the Mentors. The ten Pilot Mentors provided feedback from their initial use of the first version of *Family Secrets*. They then assisted in making revisions to the *Family Secrets* curriculum and support materials. Pilot Mentors also assisted in designing and leading the four-day *Family Secrets* summer institute at the University of Rochester. The trained Mentors then field-tested the final version of the *Family Secrets* PBL in their classrooms and provided formative and summative evaluation data.

Problem-based learning through the *Family Secrets* module is an innovative approach to teaching genetics through the power of real-life storytelling, using, as one teacher describes, “the progressive disclosure format—revealing the parts in stages with ‘thinking time’ in between.” Maybe the greatest lesson learned, as stated by a teacher, is that “... genetics has real-world applications. Students can learn first-hand that genetic disease has an impact not only on the family involved, but also on society as a whole.” BEGIN has demonstrated through *Family Secrets*, and a university faculty and science teacher partnership, that PBL holds great promise for teaching about bioethical issues in high school science classrooms. As summed up by one teacher, “*Family Secrets* really tied together a lot of aspects of genetics and made students think about ethics in a new way.”

## Acknowledgments

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## References

- Beauchamp, T. & Childress, J.F. (2001). *Principles of Biomedical Ethics, 5th Ed.* New York: Oxford University Press.
- Krueger, A. & Sutton, J. (2001). *EDThoughts: What We Know About Science Teaching and Learning.* Aurora, CO: Mid-Continent Research for Education and Learning.
- Markowitz, D., DuPré, M., Holt, S, Chen, S. & Wischnowski, M. (2006). Family secrets: The bioethics of genetic testing. *The Science Teacher, 73*(8), 28-32.
- National Human Genome Research Institute. Retrieved from the WWW on 7/25/08. <http://www.genome.gov>.
- National Research Council (NRC). (1996). *National Science Education Standards.* Washington, DC: National Academy Press.
- New York State Biology-Chemistry Professional Development Network. Retrieved from the WWW on 7/25/08. <http://www.flcc.edu/biochem>.
- New York State Education Department (NYSED). *The Living Environment Core Curriculum.* Retrieved from the WWW on 7/25/08. <http://www.emsc.nysed.gov/ciai/mst/pub/livingen.pdf>.
- Pazzo, A. (1995). Hotheads: ice borer, new species of mammals discovered in Antarctica. *Discover, 16*(4), 14-15.
- Shreffler, M. (2002). Learning every day from everyday problems. *ENC Focus, 9*(2), 47-48.
- Torp, L. & Sage, S. (2002). *Problems as Possibilities: Problem-Based Learning for K-16 Education.* Alexandria, VA: Association for Supervision and Curriculum Development.
- University of Rochester Life Sciences Learning Center. Retrieved from the WWW on 7/25/08. <http://lifesciences.envmed.rochester.edu>.
- White, H.B. *Hot-Headed Moles in Antarctica.* (1997). University of Delaware. Retrieved from the WWW on 7/25/08. <http://www.udel.edu/pbl/hotheads.html>.