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Implementing and Evaluating Mentored Chemistry–Biology Technology Lab Modules To Promote Early Interest in Science

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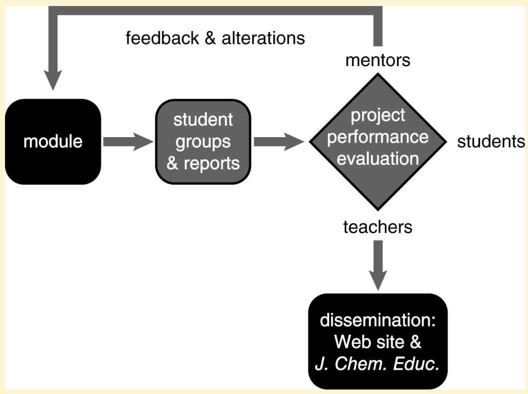
Supporting Information

ABSTRACT: Chemistry has become increasingly multidisciplinary. Starting in middle school and high school, however, the different disciplines are taught as distinct subjects and little effort is made to emphasize overlapping concepts. Development of innovative approaches to teaching science through the integration of technology is needed to provide students with a better learning experience that embraces multiple disciplines. Here, we describe an outreach and mentoring program between college and 7th grade students to: (i) encourage 7th grade students to pursue science and engineering degrees; (ii) provide the college students with mentoring experience; and (iii) assist teachers with state-of-the-art educational tools that enhance their teaching.



KEYWORDS: Elementary/Middle School Science, High School/Introductory Chemistry, Upper-Division Undergraduate, Communication/Writing, Computer-Based Learning, Hands-On Learning/Manipulatives, Applications of Chemistry, Nanotechnology, Women in Chemistry

BACKGROUND

National awareness for science education reform has come to the forefront and grants have been solicited to explore and expand innovative approaches to teaching science.[1] Because of the nature of chemical research today, chemistry education has become increasingly multidisciplinary. However, starting with middle school and extending through high school, disciplines are separated into discrete subjects with little overlap. Discipline boundaries should be blurred because many of the concepts are inevitably intertwined.

More attention needs to be given to underprivileged minorities and females in chemistry, as statistics show that these groups make up only a small percentage of the field. In terms of doctorate recipients in the physical sciences, 27.9% are female, while minorities account for much less, constituting 17.7% of recipients.[2] The fraction of individuals who are both female and part of a (racial or ethnic) minority group is only 4.9%. This problem can be addressed early on through science education at the level of K–12. Furthermore, researchers have stressed that high school and college collaborations in the form of outreach and mentoring programs have given science an "authentic voice".[3]

Technology plays a significant role in promoting chemistry education, with positive outcomes from student attitudinal survey and standardized tests.[4] Kriftcher and colleagues have suggested that modern technology makes course content more interesting and directly motivates students to consider their futures in the field.[5] In Maine, schools were selected to test and explore the outcomes of a "laptop program" where all seventh grade students and teachers are provided with laptops to use in school and to take home. This program has resulted in students with increased focus, fewer discipline problems, lower detention rates, and increased enthusiasm.[6] Higher scores in mathematics, sciences, and visual and performing arts have also been observed.[6] Integrating technology with education, particularly computers, will likely play a major role in enhancing students' early learning experiences in grades K–12.

EXPLANATION OF THE MODULES AND THE TEACHING AND MENTORING APPROACH

We have developed interactive modules based on current cutting-edge examples in chemistry and biology for 7th grade students. The main goal of our program is to cultivate students' interest in science through integration of technology as well as provide classroom support for teachers. With this program, we started a mentored network that serves three purposes with three important beneficiaries:

1. Underrepresented female 7th grade students are provided with hands-on experience in chemical and biological science with advanced technologies, fulfilling technology literacy standards.
2. Teachers can engage in professional development activities, which will familiarize them with technology and will help them to develop new instructional strategies or skills.

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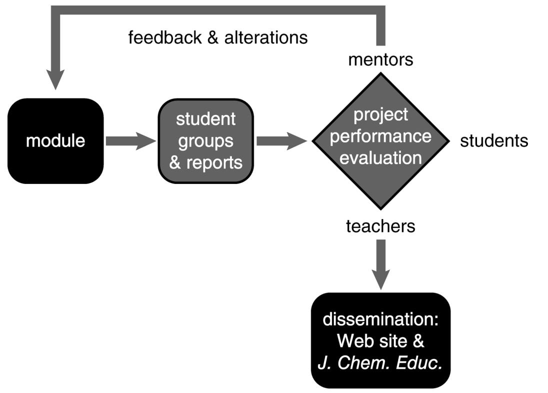

Figure 1. Module development, assessment, and evaluation flowchart. Feedback from the students, teachers, and mentors are used to improve the modules.

3. College students have the opportunity to teach and mentor students as well as develop communication skills.

We collaborated with the Urban Assembly Institute of Math and Science for Young Women, a school in which the students predominantly came from minority groups. The 7th grade class was composed of 98% African American students, 1% Latin American students, and 1% Muslim students. The college mentors specifically worked with students in the entire 7th grade class and their science teacher to implement this program. Three separate groups were taught, with class sizes in the range of 26−28 students. This program included two classroom periods for the prelude and each of the three modules (one period for reading and another for the hands-on activities), totaling about eight classroom periods. In terms of hours, the prelude and three modules took approximately 10 h of instruction time total. Considering that there are 40 school weeks per academic year and 5 science classroom periods per week, totaling 200 science classroom periods, this program took up ∼4% of the total science classroom instruction time. Two college mentors with strong chemistry backgrounds were selected by an application and interview process; they are both female and have Asian heritage. One mentor was a senior obtaining a B.S.−M.S. degree in Biomolecular Science and Biomedical Engineering; the other mentor was a junior working toward a B.S. in Biomolecular Science. Both college mentors had prior experiences as teaching assistant at their university. The 7th grade science teacher was a Caucasian female. Thus, all participants, including the teacher and the college mentors, were female, and the majority of the participants were students from underprivileged minority groups. The program ran from April 2008 to February 2009.

In the summer of 2008, three modules combining chemistry and biology were developed by the college mentors, which served to supplement the 7th grade science curriculum. These modules integrated chemistry and biology together with the implementation of ChemSketch software;[7] online videos were generated to illustrate basic concepts and visualize molecules. Cutting edge examples such as green chemistry[8] and nanotechnology[9−14] were also included so the students were aware of current technology. Each module was further modified and improved based on student feedback and teaching experience from the previous module (Figure 1).

Considering that this was the 7th grade students' first real exposure to chemistry in school, a prelude module, titled "Introduction to Chemistry", was prepared to gauge students' science reading comprehension levels so that the subsequent three modules could be further tailored to the 7th grade students. The three modules created were titled: "Exploring the Properties of Water (H_2O)"; "Understanding Chemistry through Molecular Models"; and "Carbon Chemistry" (see the online Supporting Information). On the basis of the students' and the teacher's evaluations at the end of each module, the college mentors altered the subsequent modules (Figure 1). For example, in the first module, Exploring the Properties of Water (H_2O), students seemed to have trouble identifying areas of confusion, so in-text questions were added in the second module, Understanding Chemistry through Molecular Models, to address misunderstandings of the module.[15] In general, both the reading level and the level of difficulty of the scientific concepts increased in each subsequent module. Each module was composed of prelab questions, inlab reading questions, and postlab questions. The prelab and postlab exercises were implemented to ensure that students read about the concepts and procedures involved before going to the lab, as well as having an understanding of what they did after the lab. In addition to stressing chemical concepts in each module, each concept was related to biology and the world we live in to demonstrate the overlap of the two scientific disciplines. In Modules 2 and 3, topics in green chemistry[8] and nanotechnology[9−14] were introduced to bolster students' interest in science.

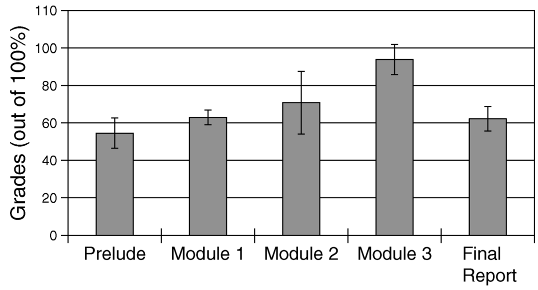

Figure 2. Comparison of averages of students' grades. A single grade was given for the work for each module. Grades are displayed as the average of the three classes (N = 26−28 students in each class). The standard deviations between the class averages for each assignment are indicated by the error bars.

ASSESSMENT OF THE STUDENTS

Overall, although the difficulty of the coursework increased in each module, the 7th grade students' performances improved (Figure 2). The exception to this trend was Module 3: Final Report, in which the 7th grade students received 55% for their grade. The drop in grade between Module 3 and Final Report was attributed to the fact that the modules contained more complex and up-to-date information that the 7th grade students could not review in textbooks. Although this information could have been found on the Internet, many of the students did not have their own personal computers at home, making the students' research difficult to conduct. This could be improved by giving the 7th grade students more time to work on the computers in school in the future, or providing laptops as in the Maine Laptop Program.[6] Essentially, the students were able to gradually learn the new concepts as demonstrated by the increase in grades for earlier modules (Figure 2). This trend illustrated that the students' comprehension of the material increased over time with the aid of the supplementary reading and visualization tools.

By contrast, the grades for the final report were lower than the last module (Figure 2). The lower grade could be because the final report required an extensive review of the overall course material. The 7th grade students had a science portfolio due at the same time, which made it difficult for them to complete the final report. A primary difference between the module work and the final report was that for each module, the 7th grade students were expected to do a match-up of vocabulary and concepts to their terms or definition, while the final report required communicating what they learned in a written format. Although the grades for the final report were lower, most students chose a topic covered in the modules for their class science portfolio. This suggested that they did learn the material and found the topics interesting.

The 7th grade students were originally reluctant to participate and complete the written work. To overcome this problem, short-answer questions were incorporated in the reading modules asking students to recall information from each section in their own words and share their answers in the classroom. The 7th grade students were awarded prizes (i.e., pencils, stickers, candy) when they participated, which helped motivate them and increase their attention span. The prize system was a common tool that the teacher employed and thus was implemented throughout the program. Although the problem of completing the written work was overlooked, this will be kept in mind for future mentors and as a target area for improvement in next year's module.

EVALUATIONS OF THE MODULES

According to the evaluations from each module, the 7th grade students' interest in science was affirmed by their excitement over current topics, with students' comments mentioning the desire for more labs and hands-on activities. Students' level of participation drastically increased and the type of questions changed from mere curiosity to focused questions pertaining to the concepts introduced. Owing to the design of the module, the main topics taught were a review of material they started covering during the school year. The teacher found that the modules did a good job reinforcing what was learned. Furthermore, the 7th grade students that selected topics from the modules for their science portfolio projects had a stronger grasp of the science over other chemistry topics covered in their curriculum.

As evaluations from the students, teacher, and the college mentors were obtained right after each module, it was possible to gauge interest, identify problems, and implement changes to the reading material as well as the method of teaching (Figure 1). Repetition was found to be useful in aiding students to grasp the concepts. On the basis of the 7th grade student evaluations and suggestions, the new vocabulary was placed before the reading material, and presented as bold text throughout (see the online Supporting Information). After reading the module content, the 7th grade students were asked to define or explain the new terms in their own words and answer questions. This exercise, in conjunction with the match-up questions given at the end of each module, greatly helped students to retain concepts that were introduced.

In addition to the 7th grade students, their teacher and the college mentors also benefited from the program (Figure 1). The 7th grade teacher was now familiar with ChemSketch and with cutting-edge research topics; moreover, she expressed that she would employ the computer visualization and modules in future classes. A unique collaboration was forged during class time, in which the college mentors taught the class and the teacher stepped in at certain times to help explain a concept or relate a current topic to something previously learned. The college mentors were provided with experience of teaching and researching current topics. As time went on, the teacher noted how the mentors became more relaxed as they became comfortable with the 7th grade students; this was manifested by the mentors' willingness to repeat material when the students seemed confused or asked questions. In particular, the college mentors felt that they learned a great deal from teaching the 7th grade students, as it required extensive patience and the ability to explain complex concepts with simple words. The 7th grade students were excited to learn something new in addition to what their usual curriculum provided. The fact that the college mentors were females made a direct impact on the girls because it exposed them to individuals who share similar backgrounds and moved on to studying science in college.

Evaluation feedback from each module allowed the mentors and teacher to monitor the 7th grade students' performance throughout the module; the evaluations also served as an indicator of how well the module was organized, the level of difficulty of the materials introduced, and how well the college mentors were interacting with the students (see the online Supporting Information). Because it was the first time such a program was being developed, the evaluations proved to be helpful in revising each module to better serve the 7th grade students. It was the design of the module and the evaluation of each step that made for a successful experience for all the participants: the 7th grade students, their teacher, and the college mentors.

CONCLUSIONS

In conclusion, the project accomplished its original goals, benefiting the teacher, 7th grade students, and the college mentors. The teacher learned about current research in the field and technology-driven approaches to education. The 7th grade students learned about cutting-edge science that they might have heard of in the news or from people around them. The 7th grade students were also exposed to a different teaching style, infused with technology and visualization tools. The mentors gained teaching experience and a keener understanding of the material taught by writing the modules and a final paper for publication in this *Journal*.

In the future, this could be implemented with other groups of students. With this program, it can be possible to foster inspiration and deep interest in the sciences and lessen the divide between different disciplines, in particular chemistry and biology. Because our modules were designed to fit into a typical 7th grade science curriculum, others can easily adapt the material and incorporate it into their syllabus accordingly. The entire set of modules are provided in the online Supporting Information as well as at our Web site[15] and others are welcome to use all or parts of the modules for their curricula. In the future, the program will be continued with the design of more advanced topics such as polymer chemistry as well as exploring the chemistry of proteins and DNA. Providing a mentored network that infuses technology into an interdisciplinary sciences curriculum can enrich education, as demonstrated here.

ASSOCIATED CONTENT

Supporting Information

Summary of Modules; Prelude: Introduction to Chemistry; Module 1: Exploring the Properties of Water (H_2O); Module 2: Understanding Chemistry through Molecular Models; Module 3: Carbon Chemistry; Evaluations. This material is available via the Internet at http://pubs.acs.org.

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REFERENCES

(1) How To Educate Young Scientists. *The New York Times*, July 3, 2006, p A14.

(2) Fiegener, M. K. *Doctorate Recipients from U.S. Universities: Summary Report 2007—2008*; National Science Foundation: Washington, DC, 2009.

(3) Collins, K. D.; Taylor, T. M. *J. Chem. Educ.* **2009**, *86*, 21–22.

(4) Derting, T. L.; Cox, J. R. *J. Chem. Educ.* **2004**, *85*, 1638–1643.

(5) Walia, M.; Yu, E.; Iskander, M.; Kriftcher, N. In *Advances in Computer, Information, and Systems Sciences, and Engineering*; Elleithhy, K., Sobh, T., Mahmood, A. Iskander, M., Karim, M., Eds.; Springer: Dordrecht, The Netherlands, 2006; pp 357—362.

(6) Muir, M.; Knezek, G.; Christensen, R. *Learn. Leading Technol.* **2004**, *32*, 6–11.

(7) ACD/ChemSketch Software, Advanced Chemistry Development, Inc., 2008; http://www.acdlabs.com/resources/freeware/ (accessed Mar 2011).

(8) Wald, M. L. A plastic wrapper today could be fuel tomorrow. *The New York Times*, April 9, 2007, p C5.

(9) Drexler, E. K. *Engines of Creation 2.0: The Coming Era of Nanotechnology*; Doubleday: New York, 2007.

(10) A New Cornell "Nanoguitar", Played by a Laser, Offers Promise of Applications in Electronics and Sensing. *Cornell News*, November 17, 2003; http://www.news.cornell.edu/releases/Nov03/NEMSguitar.ws.html (accessed Mar 2011).

(11) Igaki, J.; Kometani, R.; Nakamatsu, K.; Kanda, K.; Haruyama, Y.; Ochiai, Y.; Fujita, J.; Kaito, T.; Matsui, S. *Microelectron. Eng.* **2006**, *83*, 1221–1224.

(12) Steele, B. Cornell Researchers Create DNA Buckyballs for Drug Delivery, Demonstrating Use of Synthetic DNA as Building Blocks. *Cornell News*, August 28, 2005; http://www.news.cornell.edu/stories/Aug05/DNABuckyballs.ws.html (accessed Mar 2011).

(13) Ahuja, A.; Taylor, J. A.; Lifton, V.; Sidorenko, A. A.; Salamon, T. R.; Lobaton, E. J.; Kolodner, P.; Krupenkin, T. N. *Langmuir* **2008**, *24*, 9–14.

(14) Pabba, S.; Sidorov, A. N.; Berry, S. M.; Yazdanpanah, M. M.; Keynton, R. S.; Sumanasekera, G. U.; Cohn, R. W. *ACS Nano* **2007**, *1*, 57–62.

(15) Chem—Bio Technology Lab Web Page. http://research.poly.edu/~cbtl/ (accessed Mar 2011).