The Human HPLC Column

"Minds-On" Neuroscience for the Next Generation

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ABSTRACT: Science education researchers have suggested that neuroscientists can play an important role in science education programs for adolescents by creating "minds-on" teaching and learning modules for scientists and teachers to use in classrooms. Effective educational partnerships between teachers and visiting scientists not only ignite student interest but also provide opportunities for scientist and teacher professional development. The aim of the present teaching module was threefold: (1) to introduce adolescents to the acute neurochemical effects of psychomotor stimulant drugs and their analysis using high performance liquid chromatography (HPLC), (2) to spur maturation of analytical reasoning skills among adolescents, and (3) to spark enthusiasm for science education.

KEYWORDS: adolescents; science education; analytical reasoning; learning module

INTRODUCTION

During the school year, adolescents spend approximately one-third of their time in school, making the school environment key to their cognitive, social, and physical maturation.[1] With specific reference to the development of critical thinking and skills related to science literacy, early science classes influence abilities and interests in fields such as neuroscience.

To increase science literacy, it is crucial to change current trends in education. Only 26% of U.S. high school seniors are predicted to perform at a C-level or better in undergraduate courses.[2] Initiatives in education reform emphasize inquiry-based active learning and real-world relevance.[3,4] These approaches yield rapid intellectual development[5] and may increase interest and motivation to learn science.[4] One highly relevant topic for adolescents is the impact of drug abuse on the nervous system. Out of 43,700 U.S. secondary school students surveyed, more than half will have tried an illicit drug by the time they complete high school.[6] Neuroscientists who study this and other relevant topics are therefore prime candidates to assist in education reform.

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Neuroscientists already visit schools to discuss educational paths and career goals. As per recommendations of science education researchers, neuroscientists can help further by creating "minds-on" teaching and learning modules for scientists and teachers to use in classrooms.[7] Effective educational partnerships between teachers and visiting scientists not only ignite student interest but also provide mutually beneficial opportunities for scientist and teacher professional development.[3]

The aim of the present teaching module was threefold: (1) to introduce adolescents to the acute neurochemical effects of psychomotor stimulant drugs and their analysis using high performance liquid chromatography (HPLC), (2) to spur maturation of analytical reasoning skills among adolescents, and (3) to spark enthusiasm for science.

METHODS

The use of HPLC was placed in the context of drugs of abuse and their effects on brain neurochemistry. First, basic brain anatomy and reward circuitry were presented. Second, neurotransmission was reviewed, with a focus on dopamine release and

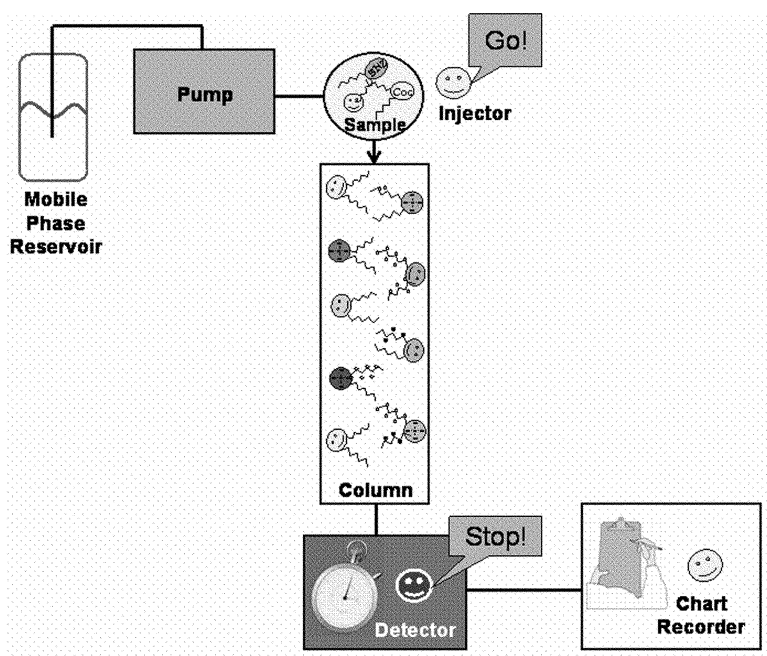

FIGURE 1. The human HPLC column actively involved adolescents in their own science exploration. They played roles including solid phase particles and analyte molecules in a sample.

its facilitation by psychomotor stimulant drugs. Finally, recording *in vivo* neurochemical events using microdialysis coupled with HPLC was introduced. Visual aides for background materials were obtained in part from the National Institute on Drug Abuse Slide Teaching Packets (www.nida.nih.gov).

Once familiar with a context for HPLC, students became a "human HPLC column." They acted out components of the column and its stationary phase, regulated passage of "molecules" (other students) down the column, collected data on retention time for different types of molecules (e.g., dopamine and its metabolites), and graphed the results. Specifically, six to eight volunteers were recruited to serve as "solid phase" by lining up facing one another and waving their arms as though the arms were hydrocarbons attached to a silanol surface on the silica beads comprising the solid phase (FIG. 1). Three to six "analyte" volunteers, labeled as dopamine, cocaine, or benzoylecgonine (metabolite of cocaine), gathered at the top of the "column" awaiting further instructions. An "injector" volunteer initiated "sample injection" by saying "Go!" to the "analyte" lined up at the head of the column.

Different molecular interactions between solid phase and analytes were modeled as follows: "Dopamine" students progressed down the "column" freely, by walking between the "solid phase" students waving their arms. "Cocaine" students progressed down the "column" waving their own arms, causing brief contact with the "solid phase" students still waving their arms. "Benzoylecgonine" students progressed down the "column" shaking hands with each "solid phase" student, simulating intermolecular attractions between analyte and solid phase.

When each "analyte" reached the end of the column, a "detector" volunteer announced the completion of the run by saying "Stop!" A "timer" volunteer noted "retention time" by recording the number of seconds required for each molecule to progress down the column. A "chart recorder" volunteer placed retention times on a table he or she created on the chalkboard.

Data were plotted with retention time on the *x*-axis and amount of analyte (i.e., number of students of the assigned type of molecule) on the *y*-axis (FIG. 2). This graphing exercise aided in student review of graphing techniques and enabled students to create a type of chromatogram. Students were then challenged to consider and graph changes in the data that would follow administration of a higher dose of a stimulant or repeated administration of the same dose (i.e., elevations in brain levels

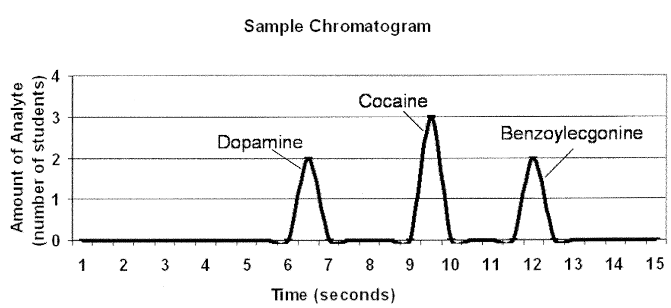

FIGURE 2. A sample "chromatogram" from the activity.

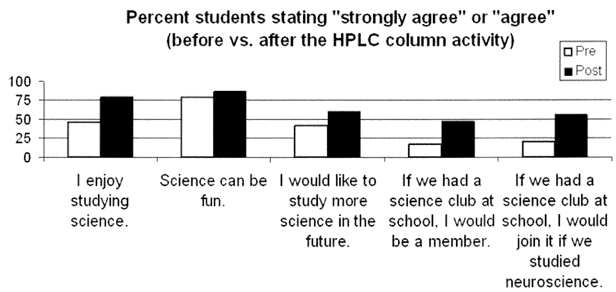

FIGURE 3. Attitudes toward science improved after the activity, as measured by answers to questions including those abbreviated on the columns.

of dopamine, cocaine, and benzoylecgonine after cocaine intake, or increase in dopamine response after repeated cocaine). Advanced students were led in a discussion of limitations of the model. For example, there was no mobile phase; the intricacies of chemical detection following the separation were ignored, and dopamine, cocaine, and benzoylecgonine are not likely to be separated and detected on the same HPLC system.

RESULTS

Attitudes toward science improved after the HPLC column activity, according to surveys of 10–12th grade students conducted before and after the HPLC column activity ($N = 25$; FIG. 3). "Being active and creating models" was the "top favorite" way of learning for 33% of students in 10–12th grade ($N = 32$; data not shown). (Notably, 41.7% ranked "listening to my teacher talk" as their least favorite way of learning.) Over 90% of students stated that they "had fun" in class that day.

DISCUSSION

The human HPLC column created an active learning environment while teaching a relatively complex concept in analytical chemistry. Future educational endeavors should combine and evaluate this and other activities in order to describe progress in reasoning skills among adolescents who participate consistently in such "minds-on" neuroscience modules.

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