The Oil Game: Generating Enthusiasm for Geosciences in Urban Youth in Newark, NJ

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ABSTRACT

A hands-on game based upon principles of oil accumulation and drilling was highly effective at generating enthusiasm toward the geosciences in urban youth from underrepresented minority groups in Newark, NJ. Participating 9th-grade high school students showed little interest in the geosciences prior to participating in the oil game, even if they had completed an Earth Science course. Benchmark surveys showed that only 9.7% of these students would consider a career in the geosciences prior to playing the game. The oil game teaches principles of fluid density, porosity and permeability, stratigraphy, seismic reflection profiling, and petroleum traps and shows practical applications in a problem-based learning format. The exercise is run like a game show, where groups of students earn money by best applying geologic principles. The streetwise participants in the study were 64% African American and 29% Hispanic/Latino American, faced inner-city dangers daily, and were generally difficult to motivate about the geosciences, according to teachers. It was evident from student excitement and engagement during the activity that they enjoyed the oil game immensely. Postgame surveys confirmed its positive impact, as 65.9% of the participating students indicated an interest in pursuing a career in the geosciences. © *2016 National Association of Geoscience Teachers*. [DOI: 10.5408/10-164.1]

Key words: urban youth, underrepresented minority, applied geosciences, hands-on activities, problem-based learning

INTRODUCTION

The geosciences are traditionally, by far, the least racially and ethnically diverse of all sciences (Jackson, 2002; Karsten, 2003; Burrelli and Suiter, 2004; Huntoon et al., 2005; Huntoon and Lane, 2007; Czujko et al., 2008). As the demographics of the population shifts, this lack of diversity is projected to result in significant shortages in appropriately trained professionals (American Geological Institute, 2011). An education project was begun in Newark, NJ, with the premise that a primary reason for this lack of diversity stems from a lack of exposure to the field and related career opportunities for students in diverse urban areas, rather than an inherent dislike for the science. This premise has been proposed in several other areas with high diversity (Adetunji et al., 2012; Blake et al., 2015). The Newark public school system, the largest in the state with 38,200 students, has a student population that is 91% from minority groups who are underrepresented in sciences, including 51% African Americans and 40% Hispanic/Latino Americans (Newark Public Schools, 2013). These students are also socioeconomically disadvantaged, with 74% qualifying for free or subsidized lunch programs. In addition, in Newark, more than 30% of the population is below the poverty level, about three times the state average. Of all the public high schools in the city, only the science magnet school has an Earth Science course for college-bound students. Such a lack of availability of geoscience education is not uncommon, as only 11%–15% of 7th and 8th-grade students nationwide attend courses in Earth Science (American Geological Institute, 2011). In the few other Newark schools that have a course in Earth Science, it is almost exclusively relegated to students who are unable to pass the college preparatory science classes. Even if these students become interested in Earth Science, it is unlikely that they will be capable of pursuing it as a profession. This greatly limits the number of students from Newark who might seriously pursue geoscience studies. The science magnet school, Science Park High School, does not cover applied aspects of Earth Science but instead focuses on classical topics such as rock and mineral identification, stratigraphy of the Grand Canyon, and others that have little bearing on the interests of the Newark students. It has been found that this lack of relevance is a major factor in why underrepresented minority students are generally not attracted to Earth Science (Levine et al., 2007; Adetunji et al., 2012).

The premise of this study is that Newark students are not necessarily disinterested in geoscience; they just have had no positive exposure to it. Most have had no exposure, and the few that have been exposed were not shown a clear pathway toward a career of any sort, much less one that could be rewarding. Interest and a positive view of geoscience is the first step in a career pathway (Levine et al., 2007). For this reason, a project was initiated to infuse applied aspects of the geosciences into 9th-grade curricula (Gates, 2015) in a university–public school partnership (Hall-Wallace and Regens, 2003) to expand student interest and ultimately pursuit of the geosciences. Such educational partnerships are a documented best practice to attract minority students to the geosciences (Huntoon and Lane, 2007). The Global Applied Projects program at Ohio State University operates on this premise and shows encouraging results (Adetunji et al., 2012). The mainstay of the Newark project was the development of enjoyable hands-on analog models using problem-based learning (PBL) that could either be used as stand-alone exercises that are not part of the curriculum or have lesson plans built around them. The areas of concentration are energy, the environment, mining, and surface processes. The exercises are incorporated not only into the Earth Science courses but also into environ-

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mental sciences and engineering sciences, depending upon the offering at the particular school. All of these courses are for college-bound students.

The first exercise introduced into the classes was the oil game within the area of energy as an additional activity, rather than having classes built around it. Fossil fuels are considered to be essential science standards by the American Association for the Advancement of Science (1993) and the National Research Council (1996), as well as according to Next Generation Science Standard ESS3.A (NGSS Lead States, 2013), yet misconceptions about their source, development, and extraction abound from elementary school through adulthood (Rule, 2005). The oil game was designed to have maximum positive impact to encourage an immediate positive response from students so that they would anticipate future exercises and ultimately consider geoscience studies and a geoscience career. This study describes (1) the development of the exercise, (2) the lesson plan for running the exercise, and (3) the student responses to the exercise. Although there is certainly a component of learning that takes place from the exercise, and although the exercise links to the science standards of energy, stratigraphy, and related concepts, it was not the direct objective of this study. Rather, the study was to determine whether targeted and innovative activities could improve underrepresented minority students' levels of enjoyment and interest in the geosciences in Newark, NJ, in an effort to ultimately increase the diversity in the geosciences. As such, no learning outcomes were measured directly.

COMPONENTS OF THE OIL GAME

The oil game is composed of two main components, introductory concept material and the game itself. The introductory material is designed to instruct students about basic science concepts that control the accumulation of petroleum and the methods for finding it. The elementary concepts include relative density of fluids and gas, porosity and permeability of rocks, and seismic reflection profiling. Each is described on a poster and illustrated with a demonstration device:

- Density is illustrated with a clear bottle containing water, oil, and gas to show their relative positions in a reservoir [Fig. 1(a)].
- Porosity and permeability of rocks is demonstrated by dripping water on shale, which flows onto the floor, and then dripping it on sandstone, which absorbs it [Fig. 1(b)].
- Seismic reflection is illustrated using a small constructed box (30 cm long × 20 cm wide × 20 cm high) made of acrylic plastic sheets with several plastic sheet shelves inside of it. A laser pointer is used to send a beam of light through the top of the box; that light is reflected off of each shelf (layer) and projected onto a white screen mounted on the back. Spots of light appear on the screen for every layer in the box, the number and spacing of which can otherwise not be determined by looking at the outside of the box [Fig. 1(c)].

The final piece of introductory material is a poster showing the four most common petroleum traps. It contains illustrations of a stratigraphic trap, an anticline trap, a fault trap, and a salt dome trap, with the locations of the petroleum accumulations and producing wells. Six page-sized versions of the poster are laminated in plastic.

The game itself consists of a large box (75 cm long × 50 cm wide × 50 cm high) with a gridded top (Fig. 2). The grid is labeled from A to Q across the width and 1 to 28 along the length for a total of 476 intersections. Each intersection is a potential location of a well (designated with a number–letter pair). The sides of the box show a three-dimensional illustration of subsurface geology with colored strata that form the shapes of petroleum traps in several places. These sides are hidden with covers made of foam core panels with knobs for removal and are held in place using Velcro fasteners. A wooden block with the picture of an old fashioned derrick may be placed on any of the potential well locations (intersections) for drilling. On the rear of the gridded top, there is a board wired with colored lights and buzzer combinations showing $10 million, $7.5 million, $5 million, $2.5 million, and dry hole (in red). The buzzer lights are operated from a switch box that is connected to the model by a wired harness.

Six small (20 cm long × 15 cm wide × 15 cm high) models of the large model are constructed from cardboard boxes. The boxes also contain laminated gridded tops, but they do not contain the illustrations on the sides. Instead, they contain Velcro fasteners that are spaced to match fasteners on laminated cards of the illustrated sides. If all four cards are attached to the box model, it matches the large oil game model (Fig. 3). All instructions to construct and run the oil game, including a new lightweight traveling version and a television news report of students playing the game, are available at the project Web site at http://andromeda.rutgers.edu/∼oedgro. The panels may be printed out on a color printer and used with small boxes, which may be purchased locally at modest cost. The large box requires more effort, but a plotter and large cardboard or foam box has been tested and works well. The panels for a larger box are also available on the Web site.

CLASSROOM ACTIVITY

Concept Presentation

The concept presentation begins with a visual and oral presentation of the basic geologic concepts that relate to petroleum accumulation and exploration and is available in video format on the project Web site. Teachers may either show this video to their class or adapt the concepts of the video to best fit their lesson plans. For the evaluated interactions, a professor (first author) presented the material and ran the game, but similar results were observed when it was run by graduate students and K–12 teachers at other times. Each concept is presented to the class as a whole. The density display is used to show that regardless of the orientation of the bottle, natural gas is always at the top, oil is in the middle, and water is at the bottom. The relative positions are emphasized to show that the best place to drill for hydrocarbons is at the top of a structure or feature. The discussion also includes the relative abundance of the three fluids or gases in the subsurface and therefore why oil is so hard to find.

The porosity–permeability illustration is used to discuss the storage and migration of gas, oil, and water. The porous

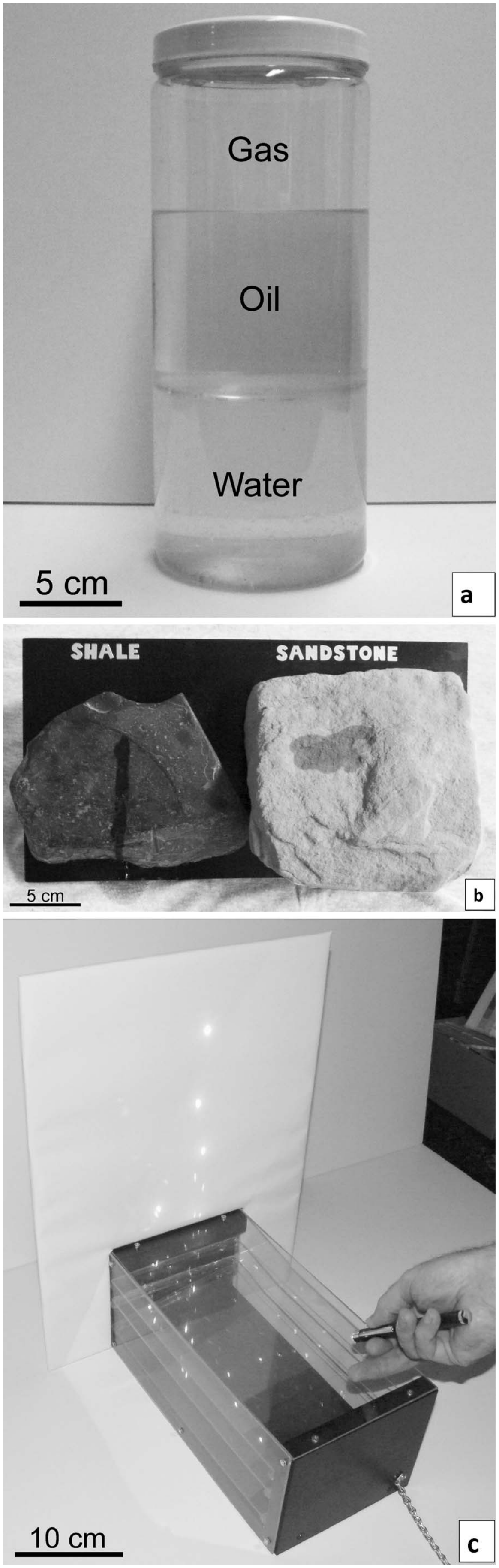

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FIGURE 1: Devices for the concept presentation. (a) Sealed container with gas on top, oil in the middle, and water on the bottom as a function of density. (b) Rock samples of shale (cap rock) and sandstone (reservoir rock) with water dripped on them to show that the sandstone is porous and permeable (absorbs water) and the shale is not (runs off). (c) Box with shelves made of clear sheet plastic. The beam from a laser pointer reflects off each of the layers and projects onto the screen, one dot per layer.

and permeable sandstone is classified as reservoir rock, and the impermeable shale is classified as cap rock and source rock. The need for both reservoir rock to store the fluids and gas and cap rock to seal the accumulation and prevent the fluids and gas from escaping is also discussed.

The seismic reflection poster and demonstration include both a description of the process and its necessity, because there is a high cost for drilling wells. The concept of reflection imaging is linked to medical procedures, using ultrasound and the sonograms they produce, with which all students were familiar. It is emphasized that the process only shows shapes, not compositions, but that it is the most powerful method to image a trap and constrain the location to drill a well. The sheet plastic–shelved box best illustrates the concept of reflecting waves off of interfaces to image the subsurface structure from a surface location. Students can readily determine the number of shelves without seeing them individually, and it makes the strongest impact.

The three concepts are combined to discuss the four types of hydrocarbon traps. Seismic reflection imaging determines the subsurface shape of the strata or feature. The trap must be composed of reservoir rock sealed by cap rock, and the fluids and gas contained in the reservoir rock will always be in the following order: gas on top, oil in the middle, and water on the bottom. The stratigraphic trap and anticline trap clearly show the hydrocarbon accumulations are at the top of the structures. All traps show where the wells should be drilled, and the relative sizes of accumulations for each trap type are discussed.

Oil Game

To play the game, the class is divided into four or five groups of four to six students, depending upon the size of the class. Each group represents an oil company, and each student in the company is an executive with equal decision-making power. Each company receives one of the cardboard box models and one of the laminated sheets showing the various petroleum traps. Each company also starts with $5 million, which is accounted on a chart on the board or a large sheet of paper in the front of the classroom. Companies may do one of three things with their money: drill a well for $1 million apiece, see one of the sides of the model (seismic section) for $1 million apiece, or obtain a stratigraphic log for $500,000 to determine the rock types corresponding to the colors on the seismic sections.

One by one, the companies, including all participating students, come to the front of the classroom to the big model with their box replica and purchase one of the options. The goal is to drill a successful well that strikes oil and gas. Each of the intersections on the grid on top of the model is a

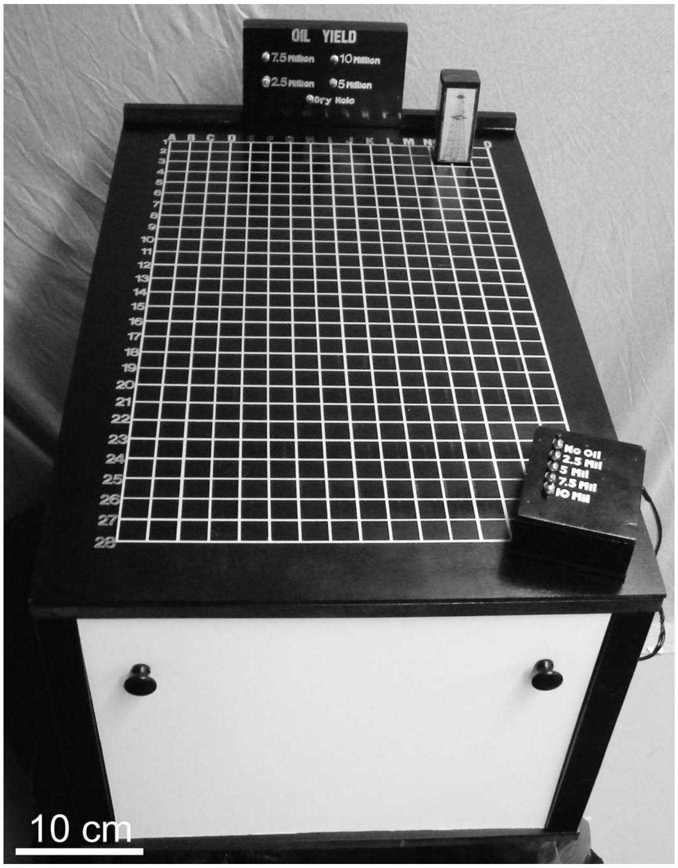

FIGURE 2: The oil game model showing a gridded top for drill locations, a derrick to mark well locations, and a light–buzzer board on the rear (oil yield), with the control box in front. The white panel with knobs conceals the geology.

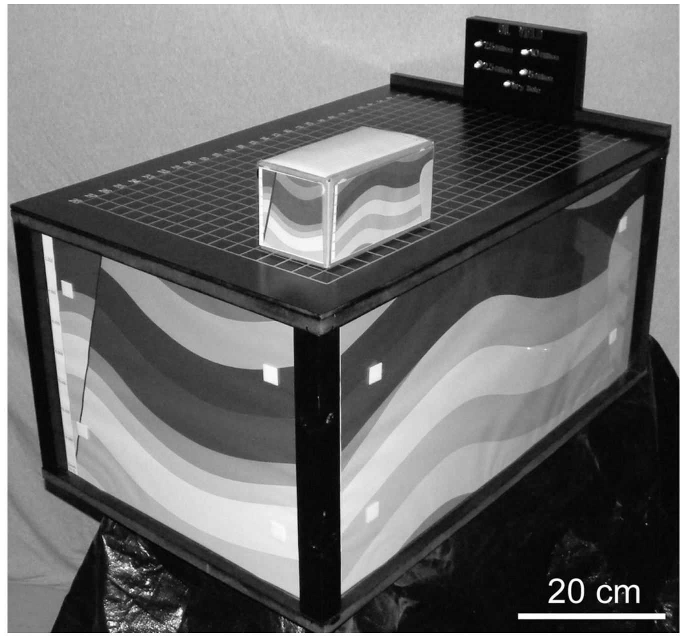

FIGURE 3: The oil game model from Fig. 2 with the cover panels removed and showing the subsurface strata. The small, scale model on top is used by the individual student groups (oil companies). Cards showing the subsurface geology are held on with Velcro strips.

possible drilling location, and the wells can yield $2.5 million, $5 million, $7.5 million, or $10 million in oil profits, as indicated on the light board. Once a successful well is drilled, that location cannot be drilled again by that or any other company. Unsuccessful wells are dry holes, and students are told that 75% of the drill locations will yield dry holes at the beginning of the game. If a company drills enough dry holes to exhaust its financial resources, it goes bankrupt.

However, the companies can buy and analyze data to constrain the location of drilling the wells. If a company buys a seismic section, the model, which is on a cart, is spun out of the view of the class and the cover of the desired side is removed so that the company can observe it. A card of the same section is attached to the small box with Velcro to model the large box so that the students can study it at their table, where they compare the features with the traps shown on the laminated page. Students keep the cards covered so that the other groups (companies) cannot see them without purchasing them. Each company is permitted only one transaction per visit to the front of the room and the large box.

The normal progression of the game is for companies to purchase seismic lines initially. Some purchase the stratigraphic log as well. Once companies have enough data to determine well locations, they drill a well. When they approach the large model, they give the letter–number location to the teacher. That position is then compared to a key for that particular subsurface configuration, without the students seeing the outcome. The teacher then presses the indicated button on the light box. Using an assistant to press the buttons while the teacher interacts with the students adds excitement to the game, because no one knows the outcome. If the company strikes oil, students react enthusiastically by cheering, screaming, clapping, and even dancing, depending upon the class. The financial status of each company is tracked on the blackboard or posted paper at the front of the room, which ensures competition among the companies. The company with the most money at the end of the class wins the game. In some classes, teachers give one-quarter point extra credit on an exam for each million dollars earned. Students can typically earn 5 to 12 points as a result.

Some groups of students are risk takers, and their companies drill before they purchase any data. Normally, these companies drill dry holes and learn quickly that the data are necessary. However, some may be lucky and strike oil, or they may have been tipped off by a student from an earlier class to a particular location. This can encourage the entire class to drill without enough data. In virtually all cases, companies with early strikes continue to drill with too little data and do not make additional money. Consequently, companies that start strong by luck or information leak often wind up losing the game.

The entire description of the oil game, including construction specifications, posters, handouts, and a video introduction of the topics and how the game is played is available on the Web site. It is ideally played in a single class session, with introduction for the first half and playing of the game for the second, though two single-period sessions on

TABLE I: Student responses to oil game evaluation survey (N = 305).

	Strongly Agree	Agree	Disagree	Strongly Disagree	Not Sure	No Response
Helped understand how people find oil	63.30%	31.50%	1.00%	1.00%	3.30%	<1.0%
Helped understand the role science plays in oil exploration	55.40%	38.70%	2.60%	1.00%	2.60%	<1.0%
Help better understand what was learned about oil exploration in class	48.50%	43.00%	2.00%	1.00%	3.30%	2.30%
Increased interest in learning more about oil exploration and the petroleum industry	47.20%	33.80%	6.20%	3.60%	8.50%	1.00%
Helped understand the relationship between science learned in school and the petroleum industry	40.70%	41.60%	4.60%	2.00%	10.20%	1.00%
Increased interest in geology and geosciences	40.70%	35.40%	9.50%	3.00%	8.60%	3.00%
Helped to learn about the petroleum industry	34.40%	44.60%	6.20%	1.30%	12.10%	1.30%
Made interested in the possibility of a career in geosciences in general	33.10%	32.80%	14.10%	5.90%	11.50%	2.60%

consecutive days works as well. The game is not available commercially, but the entire introduction can be viewed online and the panels may be printed from the Web site and mounted to cardboard boxes to construct an operating version of the game in a few hours.

OUTCOMES

The evaluation of the oil game was completed by Partnerships for Creative Action, Jersey City, NJ, using the discussions of Osbourne (2003) and Kind et al. (2007) to guide the development and vetting of the questions. The surveys were on paper; they were distributed and collected during the class period and analyzed later. All questions were in multiple-choice format and used a Likert scale wherever possible. In order to measure the effects of the oil game on participants, 305 students were asked to complete surveys before and after they played. These included 196 ninth graders at Science Park High School, the Newark Public Schools' science magnet school, and 109 ninth, tenth, and eleventh graders in two comprehensive high schools: Barringer Success Academy (83 ninth graders) and Barringer High School (26 tenth and eleventh graders). Science Park accepts only strong students based upon grades, an entrance exam, and faculty recommendations, whereas Barringer accepts all students within their designated geographic area.

Baseline survey questions were designed as part of a broad study for the entire project to determine the general view and interest in the geosciences in Newark schools. In particular, the questions aimed to determine the students' (1) general understanding of the content of the geosciences; (2) knowledge of geoscience-related professions and ways in which the geosciences are applied to improve the environment, both locally and in general; (3) attitudes toward the professions; and (4) their interest in pursuing professions in geoscience fields. Therefore, the baseline surveys included many questions that had no relation to petroleum exploration or the oil game and had no relation to the postgame evaluation (or summative) survey. The baseline surveys showed that most respondents were either unsure or uninformed regarding basic facts of geoscience or its applications. Fewer than 50% of the respondents understood that special training is required to become a geologist, and 23.2% thought that geologists only do things like study fossils, rocks, and volcanoes. While 76.2% thought that the work geologists do can affect the future of the world, 13.5% agreed with the statement that geology has nothing to do with their life in Newark and another 13.5% were not sure. Only 9.7% of the baseline survey respondents agreed that they would consider a career as a geologist, 50.6% disagreed with that statement, and 39.8% were not sure.

After they completed the oil game, participating students were asked to complete evaluation surveys designed to measure the extent to which they enjoyed the game and the way in which it had affected their understanding of its content and their attitudes toward the field (Table I). Of the 305 students who participated in the oil game, 68.9% enjoyed it a great deal, 19.3% indicated that they enjoyed it somewhat, 4.9% enjoyed it a little, and 2.3% did not like it at all. The remaining 4.6% did not respond to the question.

The other results of this survey are shown in Table I. The data clearly show that large percentages of participating students agreed or strongly agreed that they learned a great deal about the petroleum industry through playing the oil game. About 95% of respondents felt that it helped them to understand how people find oil, as well as the role that science plays in oil exploration. Between 80% and 91% felt that it helped them understand the relationship between the science they learned in school and that applied in the petroleum industry. In all of these cases, more than 80% of the students agreed or strongly agreed with the statements.

More than 80% of the students also agreed with the statement that it had increased their interest in learning more about the petroleum industry. Large numbers of the students also indicated that it had increased their interest in geology and the geosciences (76.1%) and piqued their interest in the possibility of a career in the geosciences (65.9%). This is a marked difference from the 9.7% in the benchmark survey.

DISCUSSION

The evaluation data confirm anecdotal evidence from teachers, administrators, and the authors that the oil game succeeded in piquing the interest of the students from Newark. They found it enjoyable and gave them a new outlook on the geosciences. The game show format kept the activity interesting to the entire class through the entire class. Students were excited about competing with one another and earning money. The desire to win the game, especially in front of their friends, drove the students to learn more about the scientific principles than they otherwise would have done.

There was a distinct transformation in the attitude of the students from respectfully, but apprehensively, giving their attention to a professor to demonstrating unbridled interest while the game was being played. On an anecdotal level, the transformation was astounding in several cases. Students who claimed that they hated the class and did not understand why they were required to take it were actively seeking information on how to participate in additional enrichment experiences after the game.

Considering that these classes were composed of upward of 90%–95% underrepresented minority students, the oil game provides great promise as a first step in adding desperately needed diversity to the geosciences. Although interest is only the beginning of a career pathway (Levine et al., 2007) and more attention is required to increase diversity in college majors and professionals, it is essential for the rest of the pathway to be realized. There is a clear link to potential careers, and it enables students to see how the geosciences can be lucrative (Huntoon and Lane, 2007; Adetunji et al., 2012). In this way, the oil game can additionally be a great tool toward increasing enrollments in the geosciences and helping to avert a potential shortage of personnel (American Geological Institute, 2011).

The format of the game is a modified and guided PBL exercise (Boud and Feletti, 2001; Kahn and O'Rourke, 2004). Such exercises have been successfully applied in the geosciences at a higher academic level (Dadd, 2009). The guided inquiry–based format has been found to be enticing to urban students (Harnik and Ross, 2004) in other areas, and it was clearly the case here. The guided nature of the game, in that all solutions, or oil discoveries, were restricted by the format of the game and the data provided, is essential to successful application to PBL at this level (Kirschner et al., 2006).

Most questions in the evaluation survey (Table I) asked the students to judge whether they had learned about oil exploration by playing the oil game. The students felt that they had learned quite a bit. In some cases, more than 95% of students agreed or strongly agreed that they had learned geoscience concepts. If these opinions are any indication, then learning took place by playing the oil game, and it may be applied to other populations to enhance learning. That, however, was not the goal of this project, nor was it statistically measured against a control group, so further application and testing would be required to evaluate the students' perceptions.

The goal of the oil game was to expose students to practical applications of geoscience and to change their attitude from negative or disinterested to one of appreciation and perhaps interest. It was certainly successful in this regard. It was also designed to help students understand the importance of knowing the basic geoscience concepts that they learn in their regular classes. The game is designed to be purely motivational and contextual to support the general premise of the project: that positive exposure might change the view of these students who are underrepresented in science, technology, engineering, and mathematics (STEM) and especially the geosciences. In terms of affective domain, the enthusiasm and emotional state generated by the game indicate motivation for learning (McConnell and van Der Hoeven Kraft, 2011; van Der Hoeven Kraft et al., 2011). This motivation has the potential to be extended into the classroom and improve overall performance in geoscience classes, further improving the success of these students.

Although it is unlikely that 65.9% of these students will pursue geoscience careers, the oil game clearly provided them with a positive experience, resulting in them regarding it as a possible field of endeavor. Their positive response is a potential first step in a model for attracting urban youth to the geosciences and ultimately enhancing the diversity of the geosciences.

CONCLUSIONS

A new hands-on analog game, applying basic geologic principles to drill for oil, has real potential to provide an initial attraction to the geosciences for urban youth from underrepresented minority groups in a cradle to career pathway. The game is a modified PBL exercise, in that students learn in groups as a joint effort to solve an applied problem: find oil and make as much money as possible. The applied nature of the exercise means that it follows prescribed best practices to attract minority students into the geosciences. It also addresses several state and federal science standards for Earth Science. This exercise can be a drop-in type or integrated into the curriculum. Clearly, it would preferably integrate into lessons in order to place the academic subjects into an applied perspective. This is especially important for students from areas and communities that are not exposed to opportunities in the geosciences, such as most urban areas, and for first-generation college students, who may not have the family support to pursue nonmainstream careers. The oil game results in the students being open to other opportunities in the geosciences, which is the first step toward pursuing an interest in the field. Ideally, it and other exercises that place academic geoscience topics into practical application would be integrated into lessons to enhance the interest of urban minority students from groups that are underrepresented in STEM.

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