AC 2010-674: A STUDY OF INQUIRY-BASED INFORMAL SCIENCE EDUCATION IN AN URBAN HIGH SCHOOL PHYSICS CLASS

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Adam received a B.S. from Purdue University and an M.S. from the Georgia Institute of Technology, both in electrical engineering. After working in industry for two and a half years as a systems engineer in the defense industry, Adam returned to Georgia Tech to pursue a Ph.D in electrical engineering. He is currently a Ph.D candidate under the direction of Dr. William Hunt with research interests in the fields of solid state acoustics, piezoelectric materials and devices (e.g. sensors and filters), and their applications to multiplexed biological and chemical detection. Adam has also performed research on electron plasmonic energy loss spectroscopy in gold thin films and nanoparticles as a Sandia National Laboratories MESA Student Intern. Adam has received significant educational experience at the high school and collegiate level as an NSF GK-12 Fellow for the 2009-2010 academic year, a graduate teaching assistant for 5 semesters at Georgia Tech during which time he received the Georgia Tech ECE Graduate Teaching Assistant Excellence Award, and as an adjunct faculty member at Southern Polytechnic State University in 2008 and 2010 in the department of Electrical and Computer Engineering Technology.

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William D. Hunt earned his B.S. from the University of Alabama in 1976, his Master's degree from the Massachusetts Institute of Technology in 1980, and his Ph.D. degree from the University of Illinois, Urbana-Champaign in 1987. All three degrees are in electrical engineering. He joined the electrical engineering faculty at Georgia Tech following completion of his Ph.D. degree and holds an Adjunct appointment with Emory University School of Medicine. Special recognitions he has received include the NSF Presidential Young Investigator Award in 1989, the DuPont Young Faculty Award in 1988, the University of Alabama Distinguished Engineering Fellowship in 1994. Dr. Hunt was a Rhodes Scholar Finalist in 1975. His "dog on a chip" invention which is a chip which can do specific molecular recognition of compounds in the vapor phase garnered world-wide press culminating in Dr. Hunt's appearance in the January 12, 2004 issue of Time Magazine in their inaugural article on Innovators. His area of expertise is in the area of Microelectronic acoustic devices for wireless applications as well as chemical and biological sensors based on this technology. He has published over 70 papers in refereed journals and conference proceedings. He has over 27 years experience with acoustic wave devices including 7 years experience with detection systems, including surface plasmon resonance devices and electron beam excited plasmonic devices. Dr. Hunt has over 70 publications in refereed journals and conference publications and 10 patents (granted and pending). He is the co-rounder, along with Pete Edmonson and Desmond Stubbs, of Zen Sensing, LLC.

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A Study Of Inquiry-based Informal Science Education In An Urban High School Physics Class

Introduction

Inquiry is a fundamental component of science, research, and learning. Inquiry-based learning in the sciences is modeled in such a way to follow the process of formal scientific practice and, as such, can be an effective educational tool in all levels of education. Allowing students to ask questions about a new topic engages them in an active learning process. Although students generally know that they do not know something about a newly introduced topic, Van der Meij has suggested that "knowing that you do not know" is not adequate for the formulation of a sufficient inquiry[1]. Edelson, Gordin, and Pea outline the five challenges associated with inquiry-based learning[2]. These include motivation, accessibility of investigation techniques, background knowledge, management of extended activities, and the practical constraints of the learning context. Our study of the effect of informal science education (ISE) on inquiry-based learning aims to tackle many of those challenges. The metric of evaluation is the level of questioning by the students on a given topic based on a modified Bloom's Taxonomy[3].

Methods

This paper studies the effects of inquiry-based informal science education on the level of questions asked by students in an urban high school physics class. This particular 99% African-American, low income, urban high school was selected to be paired with the Georgia Institute of Technology through the NSF GK-12 program to foster teaching partnerships between Atlanta area high schools and Georgia Tech. In an exercise on inquiry, the students were asked to ask questions about a science-related topic. An introduction to gravitation and astrophysics is typically taught within the formal constructs of a high school physics class, and as such was chosen as the topic of investigation for this study. A baseline of knowledge of the topic and level of questioning was taken by asking the students to write down one item about gravitation that they remember from the formal instruction and one question they have remaining about gravitation. For the items remembered, the assigned Bloom's category corresponds to the level of question for which the answer would suffice. For the students' remaining questions, the Bloom's categories were assigned as usual as if they were assessment questions by an instructor. Although there were fundamental and obvious misconceptions about the topic in several of the responses, a category was assigned assuming there was no misconception present.

Bloom's taxonomy is a categorization of levels of learning. Learning at higher levels within the taxonomy is predicated on the knowledge or skills gained at the lower levels. The taxonomy is typically applied to three domains of learning: affective, cognitive, and psychomotor. We are concerned here only with the cognitive domain. The levels within the cognitive domain are knowledge (1), comprehension (2), application (3), analysis (4), synthesis (5), and evaluation (6). The Bloom's categories used to describe the entries are the modified Bloom's categories reflecting active thinking[3]: Remembering (1), Understanding (2), Applying (3), Analyzing (4), Evaluating (5), and Creating (6). For analysis, each category is ranked from 1-6 in the order of increasing complexity. Table 1 is a summary of the descriptions of each category along with examples of students' responses corresponding to the various categories.

Bloom’s Category	Description	Example item remembered	Example question remaining
Remembering	*Recall data or information.*	“Gravity is equal to 9.81”	“What is the formula for gravity?”
Understanding	*Understand the meaning, translation, interpolation, and interpretation of instructions and problems. State a problem in one's own words.*	“Gravitational force is the centripetal force that holds the planets in orbit and it is the very same force that pulls an apple towards the ground”	“Why is gravity stronger on Earth than in any other places?”
Applying	*Use a concept in a new situation or unprompted use of an abstraction. Applies what was learned in the classroom into novel situations in the work place.*	“Because Jupiter is the next largest object in our solar system, the effect of disrupting its orbit would be potentially catastrophic”	“How can a scientist determine whether gravity has increased or decreased?”
Analyzing	*Separates material or concepts into component parts so that its organizational structure may be understood. Distinguishes between facts and inferences.*	-	“Knowing that matter is not built or destroyed and black holes shrink matter within itself, how is it possible that has no mass?”
Evaluating	*Make judgments about the value of ideas or materials.*	-	“Is gravity made up of particles that help its strong pull? If so, what types of particles could obscure the structure of gravity?”
Creating	*Builds a structure or pattern from diverse elements. Put parts together to form a whole, with emphasis on creating a new meaning or structure.*	-	-

TABLE 1 – Example student responses

After the initial baseline responses were collected, the students then participated in an ISE activity involving the radio show Inside the Black Box on WREK Atlanta, 91.1 FM. The science-based radio show often incorporates expert guests on subjects ranging from the economy to nuclear energy. Listeners have the opportunity to call in with questions for the guest giving the show an interactive, yet informal, educational component. In the ISE experience, the students themselves called into the show, live, and asked questions to Professor Pablo Laguna in the school of Physics at Georgia Tech. Few people are given the opportunity to interact with such an expert outside of an academic setting.

This particular informal educational experience offers solutions to several of the challenges as described by Edelson, Gordin, and Pea. These challenges include general motivation, providing an introduction to scientific investigative techniques, background knowledge, the opportunity to manage extended activities, and general practical constraints. The opportunity to call into a live radio show offered a degree of motivation for the students and utilized the powerful, yet old, technology of live radio as an educational tool. The initial background knowledge on the topic was presented within the formal educational setting, but further knowledge from which to further formulate questions is gained during the ISE experience itself in an interactive manner. Inside the Black Box is a daytime radio show so most high school students would not be afforded the time to listen live during school unless the show is directly applicable to the subject matter at hand, and the class time and show time coincide. Since active participation in the live show itself is essential to the experience, the major practical constraint is a potential scheduling conflict between the allotted class period and the on-air time of the radio show itself. In this study, the class period and show time coincided directly so this challenge was overcome. While this experience did not directly introduce investigation techniques or allow for the management of extended activities, it could easily be modified to address both challenges in the future.

Results

Table 2 shows the distribution of the categories in the students' responses to "list one thing you remember about gravitation and astrophysics" and "please give one remaining question you have about gravitation and astrophysics" at different times during the study (before, during, and after the ISE experience). The variation in the number of responses at each point can be attributed to the class attendance that particular day. Many of the questions collected during the ISE experience were asked by only a select few students and as such are not representative of the class as a whole, but give insight into the level of questions asked during the activity. The given responses with their assigned Bloom's categories are included in the appendix.

Bloom's Category	Items remembered before ISE	Questions before ISE	Questions during ISE	Items remembered after ISE	Items remembered after no ISE	Questions after ISE	Questions after no ISE
Remembering	17	2	-	2	4	1	1
Understanding	2	11	6	15	-	2	3
Applying	-	2	5	1	-	3	1
Analyzing	-	2	6	-	-	4	-
Evaluating	-	-	2	-	-	5	-
Creating	-	-	-	-	-	-	-
Average Level	***1.1***	***2.23***	***3.21***	***1.94***	***1***	***3.5***	***2***

TABLE 2 – Student response "scores"

The data presented in Table 2 shows some of the effects of the ISE experience on the students. For the responses regarding items remembered about the topic, there is a direct correlation between participation in the experience and the complexity of the remembered item, with the average response increasing from 1.1 to 1.94. Those students absent from the experience showed no increase in the level of the remembered item. Many of the items remembered were directly discussed during the experience and, as such, the absent students understandably learned nothing more than what was taught during their formal class periods.

Prior to the ISE experience, the average level of questioning was 2.23. During the activity, the questions asked were at an average level of 3.21 and after the activity, the level went up again to 3.5 for those who participated in the activity. The most notable point in the data, however, is that the level of questioning by those students absent from the activity remained 1.5 points lower, on average, than those who participated.

Summary

This study shows the potential of an informal science education experience as a supplement to an inquiry-based learning environment. The radio activity addressed three of the five inquiry-based learning challenges presented by Edelson, Gordin, and Pea, and incorporated a degree of technology to the learning environment. The level of questioning by the students increased dramatically after the activity and can be correlated to the participation by the students in the activity itself. While the details of many of the questions asked after the activity were directly related to the items discussed on the show, this remarkable increase in the level of questioning may be correlated to the amount of learning that took place during the activity. Although formal educational constructs are essential components to the current educational system, an inquiry-based, informal, interactive activity may be used to enhance the learning experience at all levels.

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Appendix

Items remembered before ISE experience	
Remembering	1) It's the one universal force that attracts objects together 2) Gravity is the force of attraction between two masses 3) Gravity is the force that keeps us on earth 4) Gravity – 9.81 5) Gravity is a force that "grounds" us 6) Gravity is 9.81 m/s 7) Gravity holds things down on earth 8) Gravity is -9.81 m/s 9) Gravity always equals 9.81 m/s 10) Gravity is on Earth and it holds us down 11) Newton's Law 12) What goes up must come down 13) Gravity is what goes up must come down 14) G = 9.81 15) Universal gravitation – $F = Gm1m2/r^2$ 16) Gravity is a force that pulls objects towards the Earth's surface 17) Gravity is the attraction between two objects
Understanding	1) Gravity has two forces. One pushing us down and one pushing us up to make an equal field that allows us to be balanced 2) Gravitational force is the *centripetal force* that holds the planets in orbit. It is the very same force that pulls on apple towards the ground

Questions remaining before ISE experience	
Remembering	1) What formula is used to find gravity? 2) What is the formula for gravity?
Understanding	1) Why is there no gravity in space? 2) Why is gravity stronger on other planets? 3) Why is gravity strongest on Earth? 4) Why is gravity stronger on Earth than other planets? 5) Why is there more gravity on Earth than anywhere else? 6) Why is gravity's force stronger on Earth versus other planets? 7) Why doesn't gravity work on space and on planets? 8) Why is there no gravity in outer space and is there gravity on any other planets? 9) Is gravity made up of any magnetic particles that help its strong pull? If so, what type of magnetic could obscure the structure of gravity? 10) How large does an object in space have to be in order to create a substantial magnetic pull? 11) What happens if you lose the force acting up?
Applying	1) How does gravity cause the "perfect alignment"? (The alignment of the earth, moon, sun, and the center of the milky way) 2) How can a scientist determine whether gravity has increased or decreased?
Analyzing	1) Can we produce gravity? 2) Why is gravity only confined to mass?

Questions asked during ISE experience	
Understanding	1) Is it true when there's a new moon that the gravity affects peoples' emotions and actions? 2) Is it possible to use a device from Earth to knock a big planet like Jupiter out of its orbit? 3) What causes stars to die out? 4) Why is gravity stronger on Earth than in any other places? 5) If every planet has its own gravity, how is there none in space? 6) Is there a predicted time when the sun will die?
Applying	1) How can a scientist determine whether gravity has increased or decreased? 2) What makes stars be able to travel across time and space? 3) Exactly how are black holes created? 4) I heard in the news about a star "breathing" (referring to the death of a star). I was wondering if stars could "breathe" and what are they actually doing? 5) Can one black hole collide with another black hole and what would happen?
Analyzing	1) Can we produce gravity? 2) Has any scientist ever figured out what is in a black hole? 3) In the movie "2012", are the floods more likely than the sun exploding? 4) Although a black hole has no mass, does that mean it actually does not have a gravitational pull? 5) Can all of the stars explode at one time, or can scientists assume what will happen if all of the stars in the universe explode? 6) Knowing that matter is not built or destroyed and black holes shrink matter within itself, how is it possible that has no mass?
Evaluating	1) Is gravity made up of particles that help its strong pull? If so, what types of particles could obscure the structure of gravity? 2) Can a community of black holes exist, and if so, can the force become so strong that it can suck in a planet?

Items remembered after participation in ISE experience	
Remembering	1) Gravity is the force that keeps you on Earth 2) I learned that black holes are located in the center of galaxies
Understanding	1) Gravitational pulls cause things to be sucked into a black hole 2) Black holes are actually smaller than others make it seem 3) Gravity is much heavier on Earth than on any other planet 4) It is not likely for one planet to knock another planet out of its orbit 5) When 2 black holes come together, they make 1 huge black hole and no one has yet found out what's inside 6) Stars can die out 7) A black hole has no mass, yet is made up of small pieces of matter 8) I learned that galaxies have a gravitational pull between one another 9) I learned that when two black holes collide, their gravity atmosphere rips each other apart therefore destroying everything around 10) There's more gravity on larger massed planets, such as Jupiter, than on Earth. 11) Gravity depends on the density of an object 12) I learned that stars can die out in outer space 13) It's possible for two black holes to swallow each other 14) I learned that when one black hole collides with another black hole, it creates one big black hole 15) I learned why stars fade out
Applying	1) I learned that it is possible to knock a large planet, like Jupiter, out of orbit. Because Jupiter is the next largest object in our solar system, the effect would be potentially catastrophic

Items remembered after no participation in ISE experience	
Remembering	1) Gravity is “G” and G = 9.81 m/s 2) Gravity’s pull is -9.81 m/s 3) Gravity will equal 9.81 m/s 4) Gravity is the pull on Earth and it’s 9.81

Questions remaining after participation in ISE experience	
Remembering	1) When will the sun die out?
Understanding	1) Does gravity have a magnetic field? 2) Why is the sun going to explode?
Applying	1) When a star dies, can we feel it? 2) How are stars created? 3) Where is gravity the strongest?
Analyzing	1) Does time vary between galaxies? 2) How does a black hole form from the focusing of a density at one point in space and how does an object shrink to form that focus point? 3) Is it possible for large planets to become black holes? 4) Will a black hole affect the Earth in the future?
Evaluating	1) Do the scientists know what is actually in a black hole? 2) Is a black hole really black? 3) What are some significant differences between the stars in our solar system and stars in other solar systems? 4) One question I would like to know further is if a chain of stars implode, could it rupture the space it occupies and create a black hole? 5) When a star is sucked into a black hole, is the light created by the star destroyed?

Items remembered after no participation in ISE experience	
Remembering	1) What is the gravity on Earth's moon?
Understanding	1) How does gravity affect an objects weight? 2) Why is there no gravity in space? 3) Why is there no gravity in space?
Applying	1) How do you measure gravity?