Teaching physics of everyday life: Project-based instruction and collaborative work in undergraduate physics course for nonscience majors

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Abstract

In the current paper, we describe a project-based physical science course for nonscience majors designed and implemented at the University of Texas at Austin during the fall semester of 1999. We focus on practical implications of project-based instruction[1]

[1] For more information on project-based instruction see:

in motivating nonscience majors in science study, as well as the challenges the students and the instructors encountered during the course. Cognitive, attitudinal and social outcomes of the project-based physical science course as reported by the students throughout the semester are also discussed.

Keywords:

Project-based instruction (PBI), physical science, motivation, collaborative learning

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http://ouray.cudenver.edu/~nflejeun/lcstrategies.htm and http://forum.swarthmore.edu/~sarah/Discussion.Sessions/Blumenfeld.html.

Full text:

> When people turn away from science in a world that is increasingly dependent on technology, it is time to take a look at the way science and technology are taught in our schools...
>
> Robert N. Little (Little 1971).

I. Introduction

Most of us will agree that minimal scientific literacy is required from every educated citizen. Not surprisingly, the issue of physics teaching to nonscience majors has become one of the hottest issues in contemporary science education[2]. Thousands of college students, regardless of their majors, are required to enroll in and pass a physical science course. The reason for this requirement is the hope that a physical science course will (a) improve student scientific literacy and critical thinking skills, and (b) serve as a conceptual base for subsequent courses taken (Dickinson and Flick 1998). However, there is ample evidence that the traditional introductory physical science course too often fails to fulfill any of these goals (McDermott 1991; Hake 1998). Two major factors may account for this

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[2] For more information see Physical Science Resource Center (PSRC) developed by the

failure (Tobias 1990; Tobias 1992). On the one hand a majority of nonscience majors exhibit very low self-efficacy toward science and mathematics. On the other hand, the students put little personal value in learning physical science (Maehr and Midgley 1991; Pajares 1996; Dickinson and Flick 1998). These factors substantially contribute to the lack of motivation for science study demonstrated by the students (Forsyth and McMillan 1991).

Our research thus focuses on designing and exploring the learning environment that promotes student motivation and supports meaningful science learning. In this paper, we describe an attempt to address the challenges described above through the incorporation of the project-based instruction (PBI) into a traditional undergraduate physical science course for nonscience majors.

The goals of the current study are:

1. to explore effective ways of implementing PBI in the undergraduate physical science hands-on laboratory course for nonscience majors;

American Association of Physics Teachers (AAPT): http://www.psrc-online.org/.

2. to gather and categorize information about possible student outcomes of the PBI;

3. to analyze student perceptions of PBI as teaching and learning environment;

4. to outline interesting directions for the future study.

II. Why project-based instruction?

> Education should be viewed "as a social enterprise in which all individuals have an opportunity to contribute and to which all feel a responsibility".
>
> John Dewey

As we pointed out earlier, the majority of nonscience majors coming to the physical science class have rather negative expectations from the course. The students rarely see how the course contributes to their future beyond being an "additional obstacle in their college career".

Keeping this in mind, our first goal in redesigning the course was making it relevant and useful to the students. However, convincing them that understanding the basic concepts of physical science will be helpful in the future is not an easy task, unless we can show that this knowledge can make a difference in students' lives. Therefore, we decided to focus on the role of science and technology in everyday life. We asked the students to investigate (a) How do the appliances we use in everyday life work? (b) What are the physical principles they are based upon? and (c) What are the most important parameters of these appliances we have to know about in order to be wise consumers on the modern market? By asking these questions, we hoped to raise student awareness and curiosity about science.

Today it is widely accepted that students do not come to the science classrooms as blank slates. They bring a wide array of common sense knowledge and beliefs that too often "successfully" interfere with the formal science instruction (Shipstone, Rhoeneck et al. 1988; Saxena 1992; Smith, diSessa et al. 1993; Wandersee, Mintzes et al. 1994). These preconceptions are very resilient to change and the strategy of a gradual replacement of student "misconceptions" with the "acceptable scientific conceptions" proposed during the 1980's was in general proven unsuccessful (Webb 1992; Chambers and Andre 1997). As it was pointed out by Andrea diSessa (diSessa 1988, p.49) "the transition to scientific understanding involves a major structural change toward systematicity, rather than simply a shift in content".

Therefore, our second goal in redesigning the course was building an environment that supports student "structural change toward systematicity". We tried to achieve it by:

1. Helping the students to become aware of their learning process as well as of the informal science knowledge, they brought to the physical science classroom (Milner-Bolotin 1999).
2. Emphasizing the relations between the theoretical concepts studied during the traditional classroom activities and their applications explored during the PBI.

We also put a special emphasize on student learning outcomes, as expressed in the development of student cognitive as well as metacognitive skills. The most important of them, from our point of view, are learning how to:

1. ask meaningful questions related to science and to approach the investigation;
2. gather appropriate data and analyze it;
3. evaluate the reliability and the validity of the information, and
4. communicate about science effectively.

The PBI offered a promising framework for the goals we chose. As it was outlined by Blumenfeld et al.:

> Project-based learning is a comprehensive perspective focused on teaching by engaging students in investigation. Within this framework, students pursue solutions to nontrivial problems by asking and refining questions, debating ideas, making predictions, designing plans and/or experiments, collecting and analyzing data, drawing conclusions, communicating their ideas and finding to others, asking new questions and creating artifacts (Blumenfeld, Soloway et al. 1991, p. 371).

However, designing projects that will be relevant and interesting for the students and giving them an opportunity to become independent learners are not the only arguments in favor of PBI incorporation into science teaching to nonscience majors. We will mention here two additional reasons supporting our choice. The first one relates to the population of students participating in the physical science classes. The term "nonscience majors" refers to a very heterogeneous group of students. In addition to majoring in different fields, and being freshmen, sophomores or juniors, these students have various science and mathematics backgrounds. Teaching such a heterogeneous class is a challenging task. However, if every one of these students is given an opportunity to make a unique contribution to the project in the field of his or her expertise, the class can benefit from such diversity. This opportunity might have an invaluable impact on students' content knowledge, as well as on their self-confidence and self-efficacy toward sciences (Barron 1998).

The second reason relates to the learning environment in the project-based classes. PBI is based on the ideas of social constructivism, emphasizing the role of social environment in teaching and learning (Boaler 2000). It promotes mutual respect, support and understanding, making an impact on student-student and student-instructor relationships. The role of these relationships in the science class for nonscience majors can not be overemphasized. As it was pointed by Walsh and Maffei:

> There are a variety of theoretical grounds for suspecting that a more positive student-professor relationships will lead to increased learning. Insofar as motivation plays a critical role in learning by initiating, channeling, and sustaining student efforts to learn, theoretical linkage between the quality of the student-professor relationship and motivation to learn is very important in accounting for the relevance of the student-professor relationship to learning (Walsh and Maffei 1998, p.1).

Therefore, by incorporating PBI into a physical science course we expected to affect student affective as well as cognitive outcomes.

Our next task was to make PBI work in our classroom. In the following sections, we will describe the physical science course and the organization of the project the students were engaged in during the semester.

III. Introductory guided discovery laboratory course in physical science

In order to understand the organization of the project a brief description of the particular physical science course will be helpful.

Physical Science PS-304 class is a small-section (up to 22 students) introductory guided discovery laboratory course for nonscience majors. The course is usually taught by a graduate student and covers the topics of electricity, magnetism, sound and optics. It is a three-hour course: the second in the six-hour sequence of two physical science courses for non-science majors. The course consists of eight hands-on guided activities aiming to "discover" basic physical principles using very unsophisticated equipment. The students follow the lab manual written about three decades ago and almost unchanged since then. The manual mostly focuses on confirmation of known laws and principles, containing detailed prescriptions of what the students are supposed to do, leaving little room to student open-ended discovery (Little 1973). Although, the course does not incorporate any technology or computers, it includes a few interesting classical experiments. The textbook of the course is Paul Hewitt's "Conceptual Physics" (Hewitt 1997).

IV. Population

Current study included two sections of the physical science course (N=42). Gender and ethnic representation of the students, participating in the study, as well as student college history are given in the Table 1. Out of 42 students nine (21%) were majoring in elementary education, one student was majoring in computer sciences and all the rest were liberal arts or communication majors (77%). Each of the 42 students in the study successfully completed the PS-304 course.

Total enrollment: N = 42	Gender representation		Ethnic representation				Year at college			
	Male	Female	Afric an	Asi an	His pa	Cauc asian	Fre	Sop	Juni	Seni
Number of students	13	29	1	3	3	35	3	26	7	6
Percentage	30%	70%	2%	7%	7 %	84%	7 %	62%	17%	14%

Table 1. Gender ethnic and college history representation of the PS-304 students, participated in the study.

V. The organization of the project "How things work"

> In many ways, education is a process of learning to indicate to ourselves things we hadn't seen.
>
> Julia T. Wood

The organization of the project "How things work" is schematically described in Fig.1. There were five main work-stages in the project: (I) Organization of the learning environment; (II) Question generation; (III) Project development; (IV) Artifact production; (V) Project presentation. Research shows that successful project required a lot of peer and instructor feedback and at least a few iterations (Barron 1998; Krajcik, Blumenfeld et al. 1998). Therefore, the order of the stages (Fig. 1) was important only for the first round of the instruction. As it often happens, the more students proceeded with the project, the more interrelated and interconnected the stages became. For example, while working on artifact production, stage III, students could decide that the questions they posed during stage II could be more specified, clarified or some new interesting questions could arise.

This is where Figure 1 should be

Figure 1. Schematic organization of the five stages of the project "How things work".

In the following subsections, we will outline each one of the project stages mentioned above[3].

Stage I: Organization of learning environment

Although, PBI does not necessarily imply collaborative work of a small group of students, contemporary research supports the claim that small group instruction makes PBI more powerful (Blumenfeld, Soloway et al. 1991; Cooper and Robinson 1998; Cooper and

[3] For more information about the organization of the PS-304 course and the project "How things work" see the course web site: http://www.ph.utexas.edu/~ps304.

Robinson 1998; Krajcik, Blumenfeld et al. 1998). Therefore, during the first month of the semester, we invested much effort into organization of a collaborative classroom environment. During that period, the students were working on standard classroom activities and labs, but most of the time they were encouraged to work in small groups, share responsibilities, help and support each other. We tried to help students experience different possibilities of effective collaborative work (Millis and Cottell 1998), providing them with various opportunities for small group discussions, problem solving and hands-on activities. We also encouraged them to work together on the homework assignments. Another important aspect was establishing after class communication. An electronic discussion board was useful for this purpose.

The first few weeks of the semester were found especially critical in creating an effective learning environment and investing effort in doing so at the beginning returns twofold later[4].

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[4] For more information about classroom activities, we found helpful for this purpose look in

PS-304 web site: http://www.ph.utexas.edu/~ps304.

Stage II: Question generation

As was pointed out by Blumenfeld et al. (Blumenfeld, Soloway et al. 1991), the main feature distinguishing the PBI from any other inquiry-based activity is the presence of a driving question that guides classroom activities:

> Projects are decidedly different from conventional activities that are designed to help students learn information in the absence of a driving question. Such conventional activities might relate to each other and help students learn curricular content, but without the presence of a driving question, they do not hold the same promise that learning will occur as do activities orchestrated in the service of an important intellectual purpose (Blumenfeld, Soloway et al. 1991, p. 372).

Therefore, the next step in the organization of the PBI was helping the students to formulate questions that they would be interested to pursue in the future.

A general driving question of the project was to investigate and to report in the classroom how one of the appliances we use in everyday life works. The students were given freedom to choose any appliance they wished. The only restriction on their choice was that the appliance had to use physical principles we were dealing with in the classroom.

As simple as it might look, it is not trivial to choose an appliance that

is relevant for the students' lives;

is simple enough to be explained using the basic physical principles; and

students are interested to work with.

Moreover, working on the project in small groups of four or five students, the students had to reach a group agreement on the appliance choice. Taking all this into account, we gave them up to four weeks to discuss what appliance they would like to investigate and what interesting questions they would like to ask. We also tried to put students' attention on different applications of the principles they have been learning. The course textbook (Hewitt 1997) and on-line resources about "How things work"[5] were good starting points for students' research. In order to get continuous feedback on student progress we established very close e-mail communication.

After choosing a particular appliance, each group prepared a tentative proposal of

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[5] For example, see http://www.howstuffworks.com/microwave.htm.

the research, including the research questions, possible information sources etc. Originally, the students came up with rather broad questions. Every group met with the instructor during the office hours to translate these broad questions into small subproblems that (a) could be solved more easily and (b) would lead the students to the solution of the original question. During this meeting, the instructor also emphasized what labs and hands-on activities might be especially helpful for answering the questions the students posed. This meeting gave an impetus for the process of students making connections between the concepts learned in the classroom and the driving question they wanted to answer. For example, one of the groups decided to investigate how the toaster works. After thinking about this project for a few weeks, the students became interested in understanding how it happens that the toast pops up before it gets burned. This group put special attention on the hands-on activities related to electric current and to the thermal properties of metals. The students were very surprised when they realized that the timer device they wanted to find inside the toaster was a simple bimetallic strip they had been working with in the lab.

Another group decided to build binoculars, using simple laboratory equipment. This group became so engaged in the project that they decided to investigate a few additional devices: a kaleidoscope, a telescope and even night vision binoculars.

Stage III: Project development

The development stage was the central stage of the project. In addition to student-instructor classroom communication, every group had to e-mail on biweekly basis a progress report as well as to describe the problems they encountered. The students got a prompt constructive feedback from the instructor. Sometimes, the electronic communication was not sufficient and then the instructor met with the students during the office hours and discussed possible solution to the existing problems. Moreover, in order to provide every student with an opportunity to express his or her opinion without a fear of "being punished for it", we incorporated the classroom assessment technique called a minute paper

(Angelo and Cross 1993, p. 149). It consisted of asking the students to provide anonymous three-sentence response on the following questions: (a) What were the best/worst things about the project they encountered during the last week? (b) What is the most important thing related to the project they learned during the last week? (c) What important questions still remain unanswered?"

This simple but very effective technique gave us the opportunity to adjust and improve the group work as well as to help the students to formulate and answer their research questions.

Stage IV: Artifact production

Although we included artifact production in a separate stage, the students started creating, recording and gathering artifacts from the very beginning of the project. By "artifacts" we mean all the products the students created, found and analyzed during the project.

Creating interesting and effective artifacts requires critical thinking abilities as well as observational skills. Writing component played an important role during the project, since in addition to gathering and analyzing the information, necessary to answer the research question, the students were asked to reflect on their project. During this stage, the students focused on learning (a) How to report their findings to other students; (b) How to incorporate technology in their research (Power Point, video, etc.); (c) How to communicate information effectively.

Learning these important skills is necessary for contemporary undergraduate students. However, only a few students in the physical science course felt confident about them.

Stage V: Project presentation

Toward the end of the semester, each group wrote a report, based on their investigations, including all the artifacts they created during the semester. After discussing their findings with the instructor, the students presented them to the classmates. The goal of the presentation was to communicate science via teaching other students what they had learned during the project. Students were encouraged to bring the appliances they were researching to their presentation. The presentations were evaluated by the instructor and by their classmates, using the criteria developed together with the students. After the presentation every group met with the instructor in order to reflect on the presentation and on the group work. Seven out of nine student teams' presentations were videotaped and analyzed. Three groups out of seven asked to watch the video in order to reflect on their presentations.

VI. Student cognitive, affective and social outcomes

> While learning has many ends, teaching has only one: to enable or cause learning.
>
> K. Patricia Cross

Data collection procedures

In order to evaluate the project "How things work" and to find out what were the outcomes of the PBI we continuously gathered and analyzed course information throughout the semester. Trying to uncover students' understanding of basic physics concepts, we conducted, videotaped and analyzed multiple interviews focused on student understanding of electricity and waves (Milner-Bolotin 1999; Milner-Bolotin, Lane et al. 1999). Minute papers, student reflections and e-mail communication also served us an invaluable source of information about the project. Moreover, every test included at least one open-ended question about the science applications in everyday life. In addition to that, at the end of the semester we asked the students to reflect on their project experience, writing a three-page essay. We asked them to answer four questions: (a/b) What did/didn't you like about the project? (c) What did you learn from participating in the project? (d) How the project can be improved? We did not ask specific questions about different cognitive or affective outcomes, since we did not want to influence student responses.

All the outcomes described in this section were reported independently by a large number of students. The outcomes mentioned by the students and caused, in their opinion, by the PBI fall into three interrelated categories: cognitive/metacognitive, affective and social outcomes. In the next paragraphs, we will describe them, illustrating each one with students' quotes.

a) Cognitive and metacognitive outcomes:

The majority of the students mentioned how much they learned while participating in the project, not only learning the content of the course, but also making connections between different course related activities. Not surprisingly, the students emphasized that the project helped them to relate scientific concepts learned in the classroom to everyday life:

> The things I learned in this physical science class came into play when doing research on the toaster.
>
> L.C.

The students also pointed out that teaching the ideas they had learned to other students helped them to deepen their understanding. Science teaching experience was very unusual for the majority of the students.

> The part I liked most about the project was presenting the material we had learned, and being able to teach it to others. I also thoroughly enjoyed watching everyone else's final product being presented to the class.
>
> A.W.

Another student wrote:

> This project was much more interesting than the labs. I felt like we had discovered something unique instead of given the labs easy format. I liked that we had to find information. However, because we had all worked together before, it was easy to work together on this project.
>
> K.M.

More than 50% of the students mentioned that the project helped them to learn how to learn and become more responsible for their learning. Taking responsibility for the group learning was a difficult step for the students. However, a lot of them emphasized that it was a very positive learning experience. More than 25% of the students mentioned that working on the project helped them to learn how to read popular science articles and books and be critical about what they have read. A few students mentioned how surprised and sometimes disappointed they were to find out that not all the information published on the web is trustworthy and they should not believe every written word. A few of them pointed out that working in small groups on a systematic basis helped them to become more critical of their own learning habits. Some of the students acknowledged that they learned to monitor their learning and to manage their time.

b) Affective outcomes:

Affective outcomes were the most frequently mentioned outcomes in students' reflections. The majority of the students emphasized that the project helped them to look at science and at themselves doing science in a different way. More than 70% of the students emphasized gaining an appreciation of science. This outcome relates to the gain in self-confidence and self-efficacy toward science, as mentioned by more than 60% of the students. A lot of students reflected that they were surprised to find they could do science and even teach other people science concepts they understand.

> I also liked the project because we got to apply physical science to our everyday life. That aspect is not common in most classes. I think it helped me respect physical science more, because I realize how crucial it is to all of our lives.
>
> M.R.

> I think that as far as physics goes, this project made me look around and think more carefully about the way things work instead of just taking them for granted. I don't know why I had never contemplated how a toaster worked, for example, but I hadn't, so this gave me the opportunity to see things in a different light.
>
> E.H.

c) Social outcomes:

More than 50% of the students pointed out that during the project they learned some social skills. They acknowledged that learning to compromise, to listen to other people, to work collaboratively, to respect other students and the instructor were very important.

> I learned much about the telescope and new scientific terms, but this project also taught me how to compromise and to work better with other people.

A.W.

There were many things that I thoroughly enjoyed about our group project, but one thing stands above all of the others. At the university level, many professors have forgotten the importance of the group work. Working well with others is a vital skill necessary for success in today's society; and this idea is often lost in institutions of higher learning. Group members attempt to combine their skills for attaining a common goal. Compatibility is uncertain and groups do not always agree. Even though dissention often teachers a better lesson when working with others, I was fortunate to be a part of a work-efficient foursome, whose skills combined for a phenomenal project.

D.F.

A few students mentioned that making friends was one of the very important personal outcomes of the course.

What I liked most about the group project was the group efforts. I feel that I became much closer to my group and may even have some lasting friendships after the class is over. We worked well together, and taught each other the things that we were researching. We had good discussions over the subject matter that helped to give me a better understanding of the course content at that time.

V.B.

VII. Addressing the challenges of the PBI

In this section, we will outline possible strategies that might be useful in overcoming the common challenges to successful implementation of the PBI, based on our observations.

These challenges can be roughly divided into three groups: (a) conceptual challenges, (b) challenges related to project management, (c) communication challenges related to student difficulties in communicating project findings.

a) Conceptual challenges

Conceptual or cognitive challenges relate to choosing a topic of the investigation, gathering data or analyzing the information. Sometimes students insist on a topic that is much more complex than it seems. For example, one group decided to investigate how the cellular phone works. With the background they had it was a great challenge to pursue this question in depth. Too often, the students do not have enough knowledge and experience to comprehend the complexity of the issue. They need good advice from the instructor to help them decide if it is feasible to investigate the topic in the available time. Frequent student feedback and formative assessment are necessary components of the successful PBI. In our case, the minute papers mentioned above, personal meetings and e-mail communication were very useful in solving this problem.

There is one more reason why continuous student feedback is so important in PBI. Too often students find some on-line information and without testing its reliability base all their work on it. Sometimes the students find different contradictory sources and they don't know "which one to believe". By establishing close student-instructor communication the instructor can help the students to become critical consumers of on-line information. This very important skill will save the students a lot of time and might be very helpful in the future.

Very often the interaction with the instructor and getting immediate feedback are crucial (Walsh and Maffei 1998). Obviously, not all problems can be solved immediately using an electronic mail or any other type of communication software. However, the students have to know that the instructor is available for them and they can rely on his/her help and support. The worst situation occurs when students have problems and do not ask for help. In order to avoid this a variety of various formative assessment techniques might be useful[6].

In another case, the instructor might not be an expert in the topic the students want to pursue. PBI opens doors for learning for the students as well as for the instructors. Moreover, in the ideal case, the students will become experts in the chosen field and then they will know the specific topic in more depth than may be the instructor does. Therefore, it might be useful to connect students with other experts in the field of their interest. For example, in our case, the students who were interested in building a telescope found it very helpful and exciting to use the solar telescope of the Department of Astronomy at the

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[6] The book "Classroom Assessment Techniques" by Thomas A. Angelo and K. Patricia Cross can serve as a very helpful reference on the ways of incorporating formative assessment into classroom practice (Angelo and Cross 1993).

University of TX at Austin[7].

b) Project management

The second type of difficulty relates to project management. PBI requires students to work outside of the classroom and to take responsibility for their learning. Helping students to organize their meetings and to find out other ways of communicating is a part of this challenge. As we mentioned earlier, electronic communication amongst the students and between the students and the instructor might be very helpful in solving this problem. Students also have to be given time to discuss these issues during the class time. A clear outline of deadlines of different stages of the project will also help the students and the instructor to manage their time more effectively. Dr. JoyLynn Reed's (Reed 2000) idea to organize students' groups around their schedules might be another way to solve this problem.

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[7] Our thanks to Prof. Bob Robbins and the Department of Astronomy staff member Lara Eakins for supporting the students and helping them to operate the solar telescope.

Another important issue in project work management is helping the students to find the information more effectively. Providing students with hints about the library or on-line web search and some useful references might be very important and can save them a lot of time and unnecessary frustrations. For example, one group of students wanted to investigate how the microwave oven works. However, the results of their on-line search, using the key-words "microwave oven" were not helpful, since they were getting a lot of sales information and obviously not what they wanted. One of the group members e-mailed the instructor and got a prompt response to use a search using a different combination of key words: "How stuff works" (Brain 2000).

The organization of effective collaborative work can also be very challenging. This problem relates to the time management, but it is even more complex. Barbara Millis and Philip Cottell in their book "Cooperative Learning for Higher Education Faculty" (Millis and Cottell 1998) addressed a few important issues in cooperative group management. The key-issue is being flexible and responsive to students' feedback helping them to organize their work more effectively.

c) Communication of project findings

The third type of challenge relates to teaching students to communicate their findings. We found that the majority of the freshmen and many sophomores had never given a twenty-minute presentation, especially communicating scientific findings. Therefore modeling a good presentation, emphasizing important points and supporting the students was necessary to help them in preparation of a successful presentation.

In order to reduce student presentation anxiety we modeled the final presentation during the semester, by assigning students to make a five-minute report about one of the topics or experiments discussed in the classroom. We also spent some times discussing the criteria of a good presentation and preparing an outline of the criteria students had to keep in mind while preparing to the presentation.

A few groups also consulted the instructor regarding the visual aides they could use in order to make a presentation more attractive to the audience. It is important to mention that during the presentation stage students majoring in communication, theater, photography and other related fields were especially helpful to their classmates and made invaluable contributions to the group project.

VIII. Project evaluation and conclusions

The project-based physical science course described above was our first, and we hope a successful, attempt to incorporate the PBI into a traditional physical science course for nonscience majors. We have no doubts that the design can be and should be improved, and we are currently working on incorporating student reflections and suggestions into a new version of the project (Milner-Bolotin 2000). In order to be able to make some statistical inferences and generalizations about the population of nonscience majors we are also planning to incorporate rigorous experimental design in the future study.

However, this pilot study made it clear for us that nonscience majors are capable of science learning and can be very motivated, productive and creative. The key-issue is letting the students ask questions they want to answer supporting their endeavor through meaningful science learning.

The current study also posed a few important questions for further investigation: What are the other key-issues in the PBI that are responsible for cognitive and attitudinal outcomes of the nonscience majors? What effect does PBI have on student conceptual understanding of physical science? Does PBI have an impact on student "misconceptions" about physical science? What are the long-term outcomes of the PBI? What is the impact of PBI on student metacognitive skills? How does PBI impact student problem-solving abilities? What is the impact of PBI on instructor's attitudes toward teaching nonscience majors?

In conclusion, we believe that the field of teaching sciences to non-science majors will experience an extensive growth during the next decade, and PBI will have a special place in this process.

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