#### Application for Approval For Research Involving Human Subjects

Project Title: Improving student understanding in STEM courses by create awareness of contextual meaning

Faculty sponsors: Dr. Graham Oberem, Physics Dr. Paul Jasien, Chemistry

#### 1. Purpose of project and background.

It is well known that students in introductory science, technology, engineering, and mathematics courses (STEM) have difficulty with learning science concepts for a variety of reasons. One of these is that the language of science is very precise and is, in fact, a different dialect from the language of everyday colloquial speech. For example, the word "power" is often associated with authority in colloquial speech. We might say, "the CEO of Ford Motor Corporation has a lot of power." In an introductory science class, the word is used exclusively to describe the amount of energy being generated by or delivered to a system in one second.

Some initial work has been done on the use of language in science classes, particularly in physics, but this has centered on the grammatical use of words and the precise meaning, rather than trying to create in students a broader awareness of the use of different use language in science. There has been no long-term systematic study of the effectiveness of developing student meta-cognition about the use of language as a means of improving student learning in the physical sciences.

In this project, we propose to work with up to 70 students per year in introductory physics and chemistry courses to investigate the question of whether creating an awareness of contextual meaning can improve student learning in physical science courses. Specifically, the goals of the proposed project are:

- i) to investigate the conceptual meaning that students associate with particular terms in physics and chemistry,
- ii) to develop and test technology-based mediation tools that will create an awareness of the different contextual meanings of scientific terms, and
- iii) to compare the learning of students who have used the mediation software with that of students who did not.

The proposed project will span a three-year period and includes the dissemination of the mediation tools in the latter part of the project.

#### 2. Participant population and recruitment procedures.

All participants in the project will be students enrolled in introductory chemistry and physics classes at Cal State San Marcos. We expect the majority of these students to be majors in biology, biochemistry, chemistry, computer science, or mathematics. Those in the targeted 100-level chemistry courses are more likely to be freshmen and sophomores. Students in the targeted 200-level physics classes are more likely to be sophomores and upper-division students. The targeted courses will not necessarily be offered every semester. There will be no participants whose ability to give voluntary informed consent would be in question.

Students in the project will be randomly and voluntarily self-selected. It is expected that the racial/ethnic and gender composition of the participants will be reflective of the overall population in these classes. Each semester, one of the project PIs will attend the first class meeting of each of the courses of interest. The PI will explain to the class that a study is being conducted that is designed to improve student learning in physical science courses. In the first semester of the first year, approximately thirty volunteers will be sought for individual interviews that will be used to investigate student understanding of particular terms. The nature and length of the interviews will be

explained, and it will be made clear that the identity of the interviewee and the data be kept confidential. A stipend will be offered to interviewees. The required consent form will be explained. Later in the semester, we will make a second classroom visit to recruit a larger group of volunteers who will use a computer-based activity designed to gather additional data about student understanding of the terms previously investigated in the interviews. In this case, the PI will explain the nature and length of the computer test, and also describe how the data will be used in the development of the mediation software. Students will again be assured of the confidentiality of the data and offered a stipend for their participation. The required consent form for this part will be explained.

In the second and third years, there will be no interviews. We will seek a group of 20 to 30 volunteers from each class to use the mediation software. In this case, the PI will explain the time commitment expected in the use of the software and the associated stipend. The PI will also explain that the software will collect usage data and that these data will be used for further development of the software. The students will be assured that all personal information and the data will be kept in the strictest confidence. The required consent form will be explained.

#### 3. Details of procedure to be used.

The first year of the project will involve researching and developing the mediation software tools. Individual interviews will be conducted with approximately 30 students. In the interviews, students will be asked to tell the interviewer about the meaning of one or more terms that have different meanings in the scientific and colloquial contexts. The interviewer will ask very few questions other than presenting a term to the student and asking the student to explain in as much detail as possible what the term means. The interviewer might occasionally ask a follow-up question which would amount to asking the student for clarification or elaboration on what he or she is

saying. Students will also be provided with a whiteboard on which to draw diagrams to support their explanations. The interviews will last 30-60 minutes and will be video-and/or audio-taped. The tape recordings will be transcribed and analyzed to provide initial data that will inform the design of the computer software.

Later in the semester, during the first year, a computer-based activity will be used in which students will be asked to compare the usage of various terms in the scientific and/or colloquial context. This will involve graphical manipulation of objects on the computer screen, selection of textual items, and the typing of short explanations. Details of the student interactions with the computer will be captured and analyzed to provide additional information for the development and refinement of the mediation software.

In the second and third years, pretest and posttest data will be collected from all students in the targeted courses. These pretests and posttests will be in the form of written or computer-based tests such as are normally used in these classes. The pretests and posttests will be a part of the regular requirements for the class. The posttest is likely to be a part of the final exam. The data from the pretests and posttests will be used to determine the overall effectiveness of the mediation software. This will be done by making a comparison between performance of students who used the mediation software and those who did not. Only the overall learning gains will be used in the study. The mediation software will also collect data, which will be used primarily for the on-going refinement of the mediation software.

# 4. Include a detailed description of the debrief/feedback that will be provided to the subjects.

The interview and test data collected in the first year will be used to guide the development of the software. There are thus no reports or outcomes that could be

provided to the participants in the first year. In the remaining years, the study will assess the effectiveness of using the mediation software. The outcome will not be known until after the end of the course, which will make it difficult to provide students with feedback about the study. To overcome this difficulty, we will set up a website that summarizes the results of the study. At the end of the course, students who participated in the study will be given the URL of the website and told that they will be able to see the results of the study on that site when they become available.

# 5. Describe any potential risks to the dignity, rights, health or welfare of the human subjects.

No study involving human subjects is without its potential risks. In studies of this kind the chief areas of risk are: i) confidentiality/privacy rights, ii) anxiety, and iii) dignity.

- i) In our study, we will be looking at participants' understanding of the meaning of certain scientific terms and we will be tracking their performance on examinations including pretests and posttests. Most people are not comfortable with others knowing their grades or their specific responses on exams. In addition, many people are sensitive about opinions that they might be asked to express on a in an interview or on a test. While students' rights are protected in this area by FERPA, the class records will be examined and processed in more detail than usual, and great care will need to be exercised to preserve the anonymity of the participants.
- ii) Many people experience a certain degree of anxiety during an interview or during test-taking. If they know that their responses are being used not just for their grade but also as a part of a broader study, it is possible that their anxiety level could be

increased. It will be important to put the interviewees at ease by letting them know that their data will not be made public.

iii) If specific interview of test question responses are made known, this could be a source of embarrassment for participants in this study. In our case, it is likely that several of the participants could be friends and this further increases the importance of being sensitive to this potential problem.

### 6. Describe the safeguards (including confidentiality safeguards) you will use to minimize the risks.

The key issues of potential risk in our work will be confidentiality, sensitivity to the potential for embarrassment, and participant anxiety. Specific measures will be taken to ensure confidentiality, voluntary participation, and the right to withdraw from the study at any time. The provision of information about the nature of the study and the safeguards will help minimize these risks.

At no point will the identity of individual students be important to us in our study. In the first year, when we will be recording interview data, the data will be used to guide the software development. Care will be taken not to record the names of the students on the interview tapes. The tapes will be identified only by a serial number associated with the interview date and time. Transcripts will likewise be identified only by this number. The tapes themselves will be kept under lock and key to avoid unauthorized use. Similarly, students' names will not be recorded in or associated directly with any of the computer data files.

In the second and third year of the study, students will be taking pretests and posttests as a part of their normal in-class activities, and the learning gains will be computed from the class grade book. Once the learning gains have been obtained from

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the grade book, they will be analyzed only in terms of the group (experimental or control) to which they belong.

If the data lead to scientific publications, case studies might be used, but the confidentiality of the participants will be strictly observed. If verbatim excerpts from tests are used, they will be transcribed. Thus no opportunity will exist for handwriting recognition or other such violations of privacy.

Regarding the potential for increased anxiety during interviews and examinations, there is a burden of responsibility on the interviewers and the course instructors to ensure that the participants are put at ease and made aware of the precautions being taken to minimize the risk of embarrassment. We will do everything we can to alleviate any potential for increased anxiety associated with interviews and tests.

### 7. Assess the potential benefits to be gained by the subjects, as well as to society in general as a result of this project.

The study of how learning in STEM courses can be improved is on-going. Many innovative pedagogical approaches have been tried and incremental gains have been achieved. However, the question that we are addressing is one that offers some additional opportunities for the improvement of student learning. We therefore chosen pursue it.

The subjects in the second and third year of our project will have an opportunity to benefit directly from the use of the mediation software. Also in the third year of the project, we will be offering workshops for STEM instructors at other institutions to introduce them to our work and the mediation software. It is our hope that, if students are introduced at an earlier point to the idea that terms have different meanings in different settings, they will be able to cope better with college-level science when they enter the university.

#### 8. Briefly assess the risk-benefit ratio.

Although there are risks associated with any study like this one (See Section 5.), we believe that they can be controlled effectively (See Section 6.). Our previous experience with studies of this kind (See Section 9.) appears to confirm that these risks can be controlled effectively. It is therefore our belief that the potential for benefiting learning of science concepts in STEM courses far outweighs the potential risks we have identified.

# 9. Describe the qualifications and experience of the experimenters (including student experimenters).

a. Dr. Graham E. Oberem has been at CSUSM since Fall 1996 is a tenured Professor of Physics. He has been involved in physics education research for more than 15 years. In 1998, he and Dr. Jasien were awarded an NSF grant to start IOP (Inquiry-Oriented Physics, a four-year project that included many of the research elements being proposed for the present study. Before coming to CSUSM, Dr, Oberem was a Research Associate Professor in the Physics Education Group (PEG) in the Department of Physics at the University of Washington, Seattle. In the PEG, he worked with other faculty, post-doctoral associates, and several graduate students on several studies similar to the one proposed here. He has designed pretests, posttests, and examination questions to probe the conceptual understanding of physics students. He has collected and analyzed large amounts of data from computer tutorial programs. He has participated in in-depth one-on-one interviews of physics students, a method being proposed here. He has worked on the analysis and publication of the data and has used the results of his research in curriculum and software development.

- b. **Dr. Paul G. Jasien** is a tenured Full Professor of Chemistry who has been at CSUSM since 1991. He has played a major role in the development of the curriculum for the Department of Chemistry and Biochemistry at CSUSM. Since coming to CSUSM, he has published seven articles (plus one pending) in the chemical education literature and has published over 40 articles in scholarly journals since 1980. He has contributed to the development of curricular materials for introductory chemistry under the NSF sponsored ModularCHEM Consortium project. Dr. Jasien has previously been involved in other IRB-approved survey activities of the type described here. Specifically, these have included investigations of: (1) a three-year study of in-service teachers' attitudes and content knowledge, (2) a five-year study on student background and how it is correlated with performance in organic chemistry, and (3) two separate multi-year projects on student content knowledge in the areas of Heat & Temperature and Acids & Bases.
- c. No student experimenters will be involved in this study.

# 10. Describe the procedures you will use to obtain informed consent. (If applicable, attach your proposed consent form to this protocol. See sample consent on next page.)

The following steps will be taken to ensure that participants in our course are fully aware of the data we are collecting and the steps we are taking to avoid potential risk to them.

a. A brief verbal overview of the nature of our study and the data that we will be collecting will be given at the start of each semester.

- Participants who volunteer to participate in the individual student interviews and to use the computer mediation software will be asked to complete a written consent form (attached).
- c. Whenever data are being collected, participants will be reminded that their responses will form a part of a data pool. They will again be assured that we are taking steps to protect their rights and minimize risk to them. In the case of the computer software, the statement will be provided on a separate screen.

Because the pretest and the final exam (posttest) are an integral part of the course, no consent forms will be needed for these.

### **List of Appendices**

- A. Consent form for the interviewees
- B. Consent form for on-line test takers
- C. Consent form for the mediation group



### CONSENT TO PARTICIPATE IN RESEARCH

Researchers at California State University San Marcos (CSUSM) are conducting a study on the use of terms in everyday language and the science classroom. You are invited to participate in this study because you are enrolled in an introductory chemistry or physics course.

This study has two objectives:

- 1. To better understand the issues students face in learning introductory chemistry and physics.
- 2. To develop a series of computer-based activities that can improve learning for students in introductory science courses.

In this part of the study, you will be interviewed individually about your understanding of one or more scientific terms. The conversational style interview will take 30 – 60 minutes and, with your permission, will be audio and/or videotaped. The interviews will take place in a private conference room located on the Cal State San Marcos campus.

There are no physical risks attached to this study. Your interview responses will be kept confidential; available only to the research team for analysis purposes. The tape recordings will be identified only by a serial number and will be kept under lock and key. If the length of the interview is inconvenient for you, you may terminate the interview at any time.

Although there is no direct benefit to you personally for participating in this study, we will use the data from this interview in designing mediation tools that will help students learn concepts in introductory physical science in the future.

You will receive a stipend for participating in the interview.

All interview tapes will be locked in a safe place. Only the research team will listen and transcribe the information. The tapes will be erased or destroyed once this study is completed.

Interview responses will not be linked to your name, address, or personal ID #, and there will be no follow-up sessions. You should know that CSUSM Institutional Review Board (IRB) may inspect study records as part of its auditing program, but these reviews only focus on the researchers and the study, not on your responses or involvement. The IRB is a group of people who review research studies to make sure they are safe for participants.

You do not have to participate in this interview if you do not want to. Your grade in this course will not be affected and there will be no penalties or consequences of any kind, if you decide not to participate in this interview, or if you terminate the interview because it is taking too long. If you have any questions about this study I will be happy to answer them now. If you have any questions in the future, please contact one of the principal investigators listed

below. If you have any questions about your rights as a research participant, you may contact our Institutional Review Board at 760.750.4028.

Principal Investigators:

Dr. Graham Oberem Department of Physics Room 233, Science Hall 2 Telephone (760) 750-8034

Dr. Paul Jasien Department of Chemistry & Biochemistry Room 331, Science Hall 2 Telephone (760) 750-4135

Principal Investigators:

Dr. Graham Oberem Department of Physics Room 233, Science Hall 2 Telephone (760) 750-8034

Dr. Paul Jasien Department of Chemistry Room XXX, Science Hall 2 Telephone (760) 750-4135

I agree to participate in this research study. The experimenter has answered any questions I had.

Participant's Name

Date

Participant's Signature

Researcher's Signature



### CONSENT TO PARTICIPATE IN RESEARCH

Researchers at California State University San Marcos (CSUSM) are conducting a study on methods to improve student learning in introductory chemistry and physics courses. You are invited to participate in this study because you are enrolled in one of these courses.

This study has two objectives:

1. To better understand the issues students face in learning introductory chemistry and physics.

2. To develop a series of computer-based activities that can improve learning for students in introductory science courses.

In this part of the study, you will be asked to use a series of computer-based activities that are designed to help you introductory chemistry or physics. You will be expected to work on these activities for 30 minutes per week throughout the semester and your interaction with the computer will be recorded in a data file.

There are no physical risks attached to this study. Your responses on the computer will be kept confidential; available only to the research team for analysis purposes. The data files will be identified only by a serial number and will not be available to persons outside of the research team. If participation in this study becomes inconvenient for you, you may terminate your involvement at any time.

By participating in this study, we believe that you will improve your learning in this course. This could directly benefit your end-of-course grade. While we believe the software you use will be effective, we cannot guarantee the outcomes we have described.

You will receive a stipend for completing these activities over a period of 12 weeks.

All data files will be kept secure and made accessible only to the research team. Only the research team will analyze the information. The data files will be erased once this study is completed.

Data files and the responses in them will not be linked to your name or address, and there will be no follow-up sessions. You should know that CSUSM Institutional Review Board (IRB) may inspect study records as part of its auditing program, but these reviews only focus on the researchers and the study, not on your responses or involvement. The IRB is a group of people who review research studies to make sure they are safe for participants.

You do not have to participate in this study if you do not want to. If you agree to be in this study, but later change your mind, you may drop out at any time. Your grade in this course will not be affected and there will be no penalties or consequences of any kind, if you do not want to participate, or if you decide to drop out of the study.

If you have any questions about this study I will be happy to answer them now. If you have any questions in the future, please contact one of the principal investigators listed below. If you have any questions about your rights as a research participant, you may contact our Institutional Review Board at 760.750.4127.

Principal Investigators:

Dr. Graham Oberem Department of Physics Room 233, Science Hall 2 Telephone (760) 750-8034

Dr. Paul Jasien Department of Chemistry Room XXX, Science Hall 2 Telephone (760) 750-4135

I agree to participate in this research study. The experimenter has answered any questions I had.

Participant's Name

Date

Participant's Signature

Researcher's Signature