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Using iPhones to Support Student Learning in Inquiry Based Laboratory Experiments

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Abstract:

General chemistry laboratories can be a challenge for students with weak backgrounds in laboratory techniques and calculation methods. We produced brief podcast tutorials that covered essential laboratory topics for our students to access during the laboratory period as needed on iPhones® or iPod Touches®. The podcasts replaced the traditional laboratory lecture in one laboratory section. Data were collected on the types and numbers of interactions between the teaching assistants and students during each inquiry based laboratory session for five different sections. Our data indicate that students used the podcasts frequently and *t*-test results show that students in the iPhone/iPod section had to be redirected or corrected significantly fewer times than students who received the same information in a traditional lab lecture format.

Keywords: chemical education research, first-year undergraduate/general, laboratory instruction, inquiry-based/discovery learning, technology

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A 2005 report from the National Research Council concludes that traditional “verification” laboratory experiments are not the most effective teaching methodology.*(1)* The National Science Education Standards place emphasis on the essential role of inquiry based learning activities in science coursework.*(2)* These documents are indicative of the growing push in the science education community for a major shift toward discovery or inquiry based laboratory instruction. The hallmark of a discovery or inquiry based laboratory is increased student involvement in the planning and execution of the activities; some experiments are completely student generated, others are more aptly classified as “guided” inquiry activities with portions of the experiment being pre-planned. In spite of well-documented advantages to using an inquiry approach, reports indicate that only small percentage of undergraduate chemistry laboratory courses in the United States are taught using this format.*(3)*

The obstacles to implementing an inquiry-based curriculum can be daunting. Freshman level chemistry students often have had little lab experience during high school science coursework. Without basic knowledge of appropriate use of laboratory equipment and correct calculation methods for processing data, students are severely handicapped in their attempts to independently plan and execute a rigorous experimental procedure. As a result, in a inquiry based introductory lab course much time must be spent teaching measurement techniques and safety precautions as well as calculation procedures before an experiment can be planned. For this study podcast tutorials were prepared on frequently misunderstood chemistry laboratory concepts that could be accessed by students as needed on an iPhone or iPod touch. The goal was to try to provide support for students and instructors participating in inquiry based laboratories allowing more independent student work. The podcasts were used in place of a laboratory lecture that traditionally precedes each experiment.

Theoretical Basis

The Cognitive Apprenticeship Theory is a theoretical framework that has been used to provide a model of the best processes for teaching lab skills and research techniques.*(4)* Table 1 lists the dimensions of this theory with essential components as originally outlined by Collins, et al.*(5)* Focusing on the dimension of "methods", the first three components describe the functions that an instructor or teaching assistant must fulfill in teaching laboratory manipulative and cognitive skills. Ideally, an expert should be able to model an activity or procedure, coach the student in their execution and provide scaffolding until the student can independently perform the task. Unfortunately, the ratio of "experts" (instructors or TAs) to "novices" (students) in a full lab section is often 1:25. This ratio severely limits the time available for such mentoring and can leave students frustrated and without needed instruction. The dependency of students on the attention of one instructor for essential lab information discourages experimentation and independent investigation that are essential in the scientific world and in inquiry based laboratory activities.

Pre-laboratory assignments are often planned to provide modeling instruction. Some chemistry and biochemistry departments have produced in-house video series for chemistry laboratory

Table 1. Dimensions of Ideal Learning Environments (Collins,et al)*(5)*

Dimension	Component
Content -------------------------	Domain Knowledge Heuristic Strategies Control Strategies Learning Strategies
Methods-------------------------	Modeling Coaching Scaffolding Articulation Reflection Exploration
Sequence------------------------	Global Skills before Local Skills Increasing Complexity Increasing Diversity
Sociology-----------------------	Situated Learning Culture of Expert Practice Intrinsic Motivation Exploiting Cooperation Exploiting Competition

courses that are available on department web sites and may be used as a part of a required pre-lab activity.*(6,7)* The Journal of Chemical Education has a series of laboratory technique videos that describe various techniques in detail that some have used.*(8)* An example of an innovative approach is detailed in a 2003 report on an NSF supported project at Georgia Southern University.*(9)* The authors describe internet-based pre-lab tutorials that were incorporated into the general chemistry laboratory curriculum. Students were prepared for verification-style laboratories that required them to use unfamiliar equipment and techniques by completing assigned online tutorials. The tutorials included still photos accompanied by written text that described the procedure and any pertinent safety precautions. At the conclusion of the pre-lab assignment students were required to complete a quiz. This sequence was used as a replacement for the traditional “pre-lab” lecture. The authors concluded that this format allowed more time for laboratory work, because less time was used in pre-lab lecture and that students felt more confident as they began work each lab day.

The pre-lab assignment provides modeling in this case, but cannot fulfill the roles of coaching the students as they begin to work or provide scaffolding during an experiment. By necessity, pre-lab videos or lectures may include large amounts of information. The content is often so dense that students are unable to retain all of the essential information and need additional support. When planning an experiment, rather than following provided procedures, the aspects of coaching and scaffolding increase in importance. With a high expert to novice ratio limiting opportunity for one-on-one coaching, a tool that provided review of essential information as needed during lab would allow the student to “self-coach” providing the needed scaffolding and would grant greater independence and increase student confidence in performing lab functions. With this goal in mind, we prepared brief podcasts that addressed specific techniques and calculation procedures that could be used as reference tools during the laboratory period.

As a part of a mobile learning initiative at our university, all entering freshman students were issued iPhones or iPod touches to be used for academic purposes. We believed that the iPhones or iPod touches would be a convenient portable platform to deliver the podcasts that would serve the purpose of providing modeling, coaching, and scaffolding to students. We anticipated that use of the podcasts would reduce the need for instructors or TAs to redirect students working on an inquiry based experiment during General Chemistry laboratory.

Methods

We implemented a nonequivalent, control group, quasi-experimental design to measure the effects of use of the podcasts on the types and numbers of instructor- or TA-student interactions and student outcome measures. This study used quantitative methods to answer the research question: Can iPhones be used as a tool for providing self-coaching and scaffolding tools that will decrease the number of times student groups must be redirected to allow more independent student work during inquiry based experiments? Student ACT scores, GALT test scores *(10)*, and laboratory grades were collected in addition to count data on podcast usage and types of interactions between student research teams and the teaching assistants or instructor. The standard statistical methods of *t*-test comparison, calculation of Pearson's r and r^2, and linear regression, in addition to measures of central tendency were used to process data. Cohen's kappa was calculated to compare inter-rater reliability.

General Chemistry Laboratory

The five sections of General Chemistry I Laboratory offered during the fall 2008 semester were included in this study. The laboratory experiment topics were closely aligned with the General Chemistry I lecture curriculum; all students are required to be concurrently enrolled in lecture and laboratory. The chemistry courses are designed to meet the curriculum requirements for science majors. There was no correlation between particular lecture and laboratory sections. Student self-select their lab and lecture schedules. The five lecture sections, though taught by different instructors, are tightly coordinated with all sections covering the same materials at closely aligned paces. Each lecture section is taught in a traditional lecture style format using the same textbook *(11)* and the same online homework system.*(12)* Every lecture section takes identical exams on the same date. All laboratory sections were lead by the same instructor and organized and taught in the same manner. Teaching assistants were trained in the teaching methodology and were supervised during every lab by the instructor.

Participants and Procedure

To create an experimental group and a control group, one of the laboratory sections was flagged during the university registration process to limit enrollment to entering freshmen. This was necessary to ensure that all students in one section had access to an iPhone or iPod touch since the devices were only deployed to entering freshmen. Freshmen were free to register with upperclassmen for any of the lab sections and no distinction was made in terms of planned curriculum during the registration process. The other four sections were a mixture of students of various classifications.

Demographic data and entrance exam scores were collected from a university database and students in all sections were given the Group Assessment of Logical Thinking test. Previous research has shown correlation between success in an entry level university chemistry course and both the ACT and GALT tests.*(10,13)* Student laboratory and lecture performance data were collected from instructors. Previous research has shown no significant difference in performance between students taught through an online format versus a face-to-face format, so a measurable difference in student achievement as a result of the use of the iPhones was not expected.*(14)*

Within a lab section, students worked in research teams of 3-4 individuals. To balance these groups, each group was assigned a student with a high GALT score (>10), a student with a low GALT score (< 8) and then one or two students with a mid-range GALT score (8,9, or 10). The

GALT test is reported to classify students according to the Piagetian categories of mental development. A GALT score of 0-5 corresponds to the concrete operational stage, a score of 6-7 corresponds to the transition between concrete and abstract stages and a score of 8-12 corresponds to the abstract operational stage.*(10)* Only 3 students spread through the five lab sections scored in the 0-5 range. Working roles within each group were assigned on a rotating basis to assure that all students participated as equivalently as possible. The assigned roles were manager, spokesperson, recorder and strategy analyst, as suggested by the POGIL organization method.*(15)* The student in each group designated as spokesperson for the day was the only student in the group permitted to communicate with the TAs or instructor. This was to encourage the research teams to thoroughly discuss material and come to the TA or instructor with well-formed questions.

Each section used the same pre-lab exercises and the inquiry-based lab format. Each lab section had access to an on-line lab resource file. These files contained the prepared podcasts, MSDS sheets for all chemicals used, and written lab procedures along with syllabi, course grading rubrics, and a copy of the required departmental safety contract. Students in every section of lab had access to the podcasts and other resources on their personal computers or on any campus computer. Students in the freshman section also had access to these files on their iPhones or iPods. As part of the required lab preparation completed before coming to class, students were instructed to watch specific podcasts that contained important information for the assigned experiment and read and summarize the experiment procedures and safety concerns. They were encouraged to take notes on the podcasts and include these notes with their procedure summaries in lab notebooks that were checked for a grade at the beginning of the lab period. An opennotebook quiz given at the conclusion of lab each day provided additional motivation for watching and understanding the podcasts and being aware of safety issues before attending lab.

The podcasts were prepared to support student learning with the intent of helping students become more independent lab workers. These podcasts can be classified according to the types of information they provide. The first type describe in detail mathematical information essential in chemistry calculations. The podcasts included in this category were titled “Significant Figures” and “Simple Statistics”. Those of the second type describe general lab procedures used in multiple labs throughout the semester. The podcasts in this category are “Mass Determination”, “Reading Liquid Levels”, “Pipet Usage”, “Using Acids Safely” and “Filtering Methods”. The third type were podcasts that contain important information for one particular lab during the semester. The podcasts in this category are “Gas Collection”, “Crucible Use”, “Vernier Equipment” and “Titration”. It should be noted that the podcasts in the third category contain information that will be essential for additional experiments during the second semester of General Chemistry lab, but we have categorized them separately for this research project due to their limited applicability during the duration of the study. A podcast review team was assembled that included instructors, TA’s, and past students. Included as part of team were two students who had been top performers in the honor’s chemistry section, two who had been B/C students in regular chemistry sections, and two students who had failed chemistry, in addition to three students who had taken chemistry at other universities. They were asked to review and critique the podcasts for clarity and completeness. Based on their input, some podcasts were modified.

We were interested in seeing whether students with iPhones or iPods would use the podcasts and other documents during the lab period in addition to viewing before class and whether this use would make a difference in student independence during inquiry-based experiments. Students in the freshman section were reminded that they could access the podcasts and other posted documents during lab using their iPhones or iPods. The information contained in the podcasts was essential to performing the experiments, so students in non-freshman sections were given 15-20 minute lectures at the beginning of lab to make sure that they remembered essential information contained in the podcasts. The podcasts were loaded in the ACU files system, which allows the instructor to view file usage. Daily reports were generated that listed every access of each posted file by time and date for each lab section.

In order to track the types of questions being asked during a lab period as a measure of how independently students were working, TAs were trained to categorize student interactions by type. The category types used were adapted from a recent publication standardizing evaluation of inquiry-based instruction.*(16)* We counted each interaction and parsed the interactions as "Clarifying Procedures or Techniques/Redirection Needed", "Conceptual Misunderstanding/Redirection Needed", "Conceptual Understanding/Confirmation", or "Summarizing and/or Connecting with Previous Knowledge". A thorough description of the categories with examples is provided with supplementary materials. To assure validity of the categorization process, the researcher silently observed each TA during a four-hour lab period and independently recorded type of interactions observed. The researcher's tally was compared to the TA's and in each case differences were minimal. Cohen's kappa for the three teaching assistants were in the range 0.82-0.87.

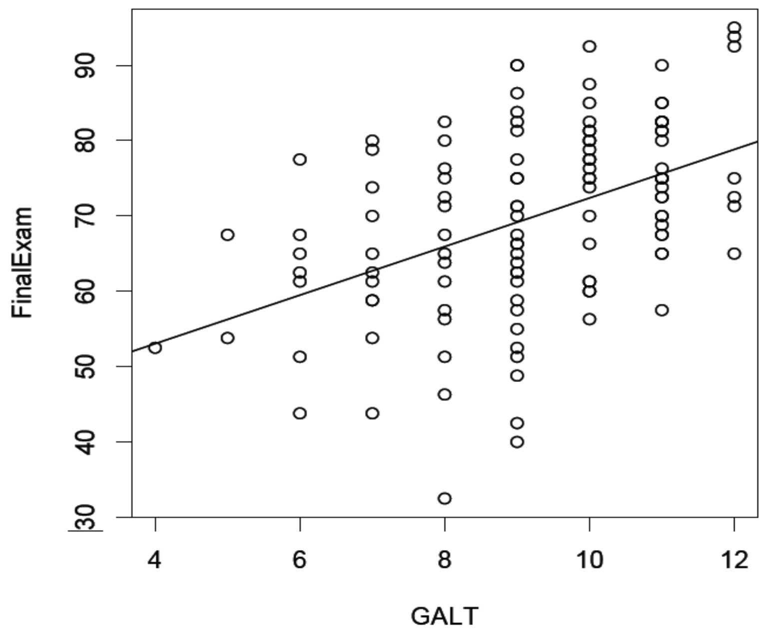
Data on student group performance on lab reports and individual performance on quizzes, notebooks, and the final exam were collected. To reduce the possibility of prejudice in the data collection process that might be caused by “inside” information on developing data trends, no data was compared, totaled or analyzed until the completion of all data collection.

Results

To evaluate differences between the iPhone and non-iPhone student groups that might affect the outcomes in this project, demographic data and GALT and ACT scores were compared. The mean GALT score for students in the iPhone section was 9.00 ± 1.96 and the mean GALT for students in a non-iPhone section was 9.02 ±1.83. A *t*-test indicates that there is no statistically significant difference between these mean values at the alpha=0.05 level (p=0.7286). The graph in figure 1 compares GALT score to mean grade on the lab final exam for all lab students. The regression line shows a positive correlation. Pearson’s r is 0.4554, making r^2 equal to 0.207. This is comparable to the correlation between the GALT test and general chemistry lecture grades reported in earlier research and shows that the GALT test explains about 21% of the variation in the final exam grades.*(13)*

Mean ACT scores for students in the iPhone section and the non-iPhone section show no statistical difference at the alpha=0.05 level (p=0.9583). The iPhone section had a mean value of 26.30 ± 4.12 and the non-iPhone section had a mean value of 26.26 ± 3.48. Figure 2 shows the plot of ACT score versus lab final exam score for all students enrolled in lab. The correlation between ACT score and final exam score is expressed by the Pearson’s r value of 0.5264. The r^2 value is 0.277. The student ACT and the GALT scores show small to medium range correlation

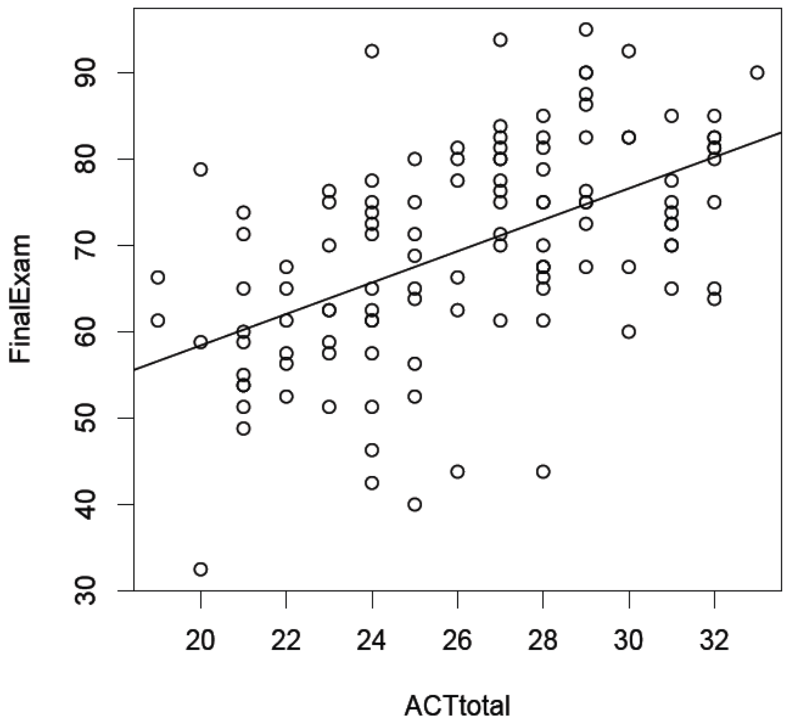
Figure 1: Final Exam Grades versus GALT Score for all students



with the final exam grades, but do give some indication of the "threshold values" of each required to perform at least at the 75% level on the final exam. Examination of the scatter plots show that students who scored below a 7 on the GALT test or below a 23 on the ACT did not perform at or above the 75% level. (There is one outlier who scored 6 on the GALT test and 78% on the final exam.)

Basic demographic data for students enrolled in each type of section is shown in table 2. The iPhone section, by design, was comprised of all freshmen students. The other sections were a mixture of students of various classifications, the largest groups being the 39% freshman student component and the 38% sophomore student component. The difference in composition by student classification is reflected in the percentages of students declaring various majors in the lab sections. Freshman chemistry or biochemistry students usually enroll in general chemistry

Figure 2: Final Exam Grades versus ACT total score for All Lab Students



during their freshman year, while students in other majors often wait to take the course during subsequent years. The major of an entering freshman is probably not a valid or useful predictor of aptitude for the major subject; many freshman change majors after a single semester in their originally chosen field after discovering their lack of aptitude or interest in that area.

Outcome measures for students in all non-iPhone sections and the iPhone section are shown in Table 3. A *t*-test was used to test the difference between the means of each outcome measure. The results indicate that there is no statistically significant difference between the mean lab quiz grades (p=0.5653), mean lab notebook grades (p=0.4749), mean lab final exam grades (p=0.6436), and mean lab course grades (p=0.2417) at the alpha= .05 level

for the iPhone lab section and non-iPhone lab sections. Interestingly, the mean

Table 2. Demographic Data for Students in the iPhone and non-iPhone Sections

	iPhone section n=25	Non-iPhone sections n=109
Declared Majors	48% Chemistry or Biochemistry	16% Chemistry or Biochemistry
	28% Biology	28% Biology
	12% Other Science/Math	17% Other Science/Math
	0% Undeclared	1% Undeclared
	12% Other	39% Other
Classifications	100% Freshmen	39% Freshmen
		38% Sophomores
		16% Juniors
		7% Seniors
Gender	68% Male	45% Male
	32% Female	55% Female

lab report grades do show statistically significant difference (p=0.03191), though the numerical difference is still small; the iPhone section mean was 95.96 ± 3.34 and the non-iPhone section mean was 94.55 ± 4.26. All quizzes and the final exam were graded using a prepared key and were objective tests. The lab notebooks and lab reports were graded using a detailed rubric and were all graded by the same TA. Lab reports were written and turned in as group reports at the end of each lab period. The assigned group role included an assignment for the portion of the lab report that was to be written by the individual.

Only data on the number of times podcasts were used during lab were collected during the lab period for the first two weeks. It was important to allow adjustment time so that students and TAs could acclimate to the teaching methods, organization of the student research teams, and

Table 3: Mean Values of Outcome Measures for Students in the iPhone Section and non-iPhone Sections

Laboratory Measures	iPhone Lab Section mean score n= 25	non-iPhone Lab Section mean score n=109
Lab reports	95.96 ± 3.34	94.55 ± 4.26
Lab quizzes	81.52 ± 11.71	79.69 ± 10.65
Lab notebook	93.04 ± 9.47	91.89 ± 13.65
Lab final exam	70.02 ± 13.58	67.34 ± 13.81
Lab course grade	88.89 ± 6.07	87.26 ± 6.01

physical organization of the laboratory. Complete data sets for lab experiments including all outcome measures and interaction data were collected for nine additional weeks.

Table 4 lists the podcast usage totals by podcast category type during lab time for the iPhone section. The data in the first column shows number of times the podcasts were accessed by the lab section over a seven experiment window. The second column shows number of accesses per research team. There were seven experiments for which podcasts were prepared. The section was comprised of 26 students divided into 7 research teams. Often three or four students within a team would view a podcast on a single device during lab, so numerical data collected by counting the number of times a file was accessed during lab does not accurately reflect the number of students watching the podcasts, but simply the number of devices used to play the podcast during the lab period. The second column shows a mean value of number of times a podcast in the category was accessed per group. Occasionally a particular device was used to access a podcast more than once during a lab period. If access times for a single device were more than 30 minutes apart each access was counted.

Table 4: Number of Times Podcasts Were Viewed by Podcast Category

Podcast category	Times accessed	Mean number of times accessed per group n=7
Chemistry Calculation Methods	45	6.4
General Laboratory Techniques	75	10.7
Experiment Specific Information	41	5.9

Table 5 summarizes mean student interaction data collected for nine experiments beginning with the lab session during week 3. This data includes interactions during weeks when podcasts were and were not used. Interaction data was not included for the first two weeks of the semester to allow students and TAs to adjust to the instruction style. The total interactions are listed first, and the interaction/student group ratio is listed in parentheses. Within student research groups, each student is assigned a role. One student is the "spokesperson" whose role includes all verbal communication with the teaching assistant or instructor. This group structure encourages students to communicate within the group before asking for assistance. The ratio of type of interactions to number of student groups should allow for best comparison of data between types of lab sections. The mean number of interactions per week is higher in every category for the non-iPhone research teams, though the number of interactions in the category labeled "connecting with previous knowledge" is so low, that this data is not very meaningful. In table 6, the total interaction data for the weeks during which podcasts were available is listed (weeks 4,5,6,9, and 11). When comparing the means interaction rates for podcast-supported experiments using a *t*-test, the "Clarifying Procedures or Techniques" category is statistically significant at the 95% confidence level (p=0.03973), as is the difference in means for the "Conceptual Misunderstanding" category (p=0.02692). The difference in means for the categories "Conceptual Understanding" (p=0.3081) and "Connecting with Previous Knowledge" (p=0.5785) are not statistically significant.

Table 5: Type of Interaction by iPhone and non-iPhone Lab for All Experiments

Category	Total Interactions for iPhone Section (per research team, n=7)	Total Interactions for non-iPhone Sections (per research team, n=30)
Clarifying Procedures or Techniques: Redirection Needed	82(11.7)	495(16.5)
Conceptual Misunderstanding: Redirection Needed	28(4.0)	189(6.1)
Conceptual Understanding: Confirmation	33(4.7)	155(5.2)
Connecting with Previous Knowledge	5(.71)	30(1)

Table 6: Type of Interaction by iPhone and non-iPhone Lab for Podcast Supported Experiments

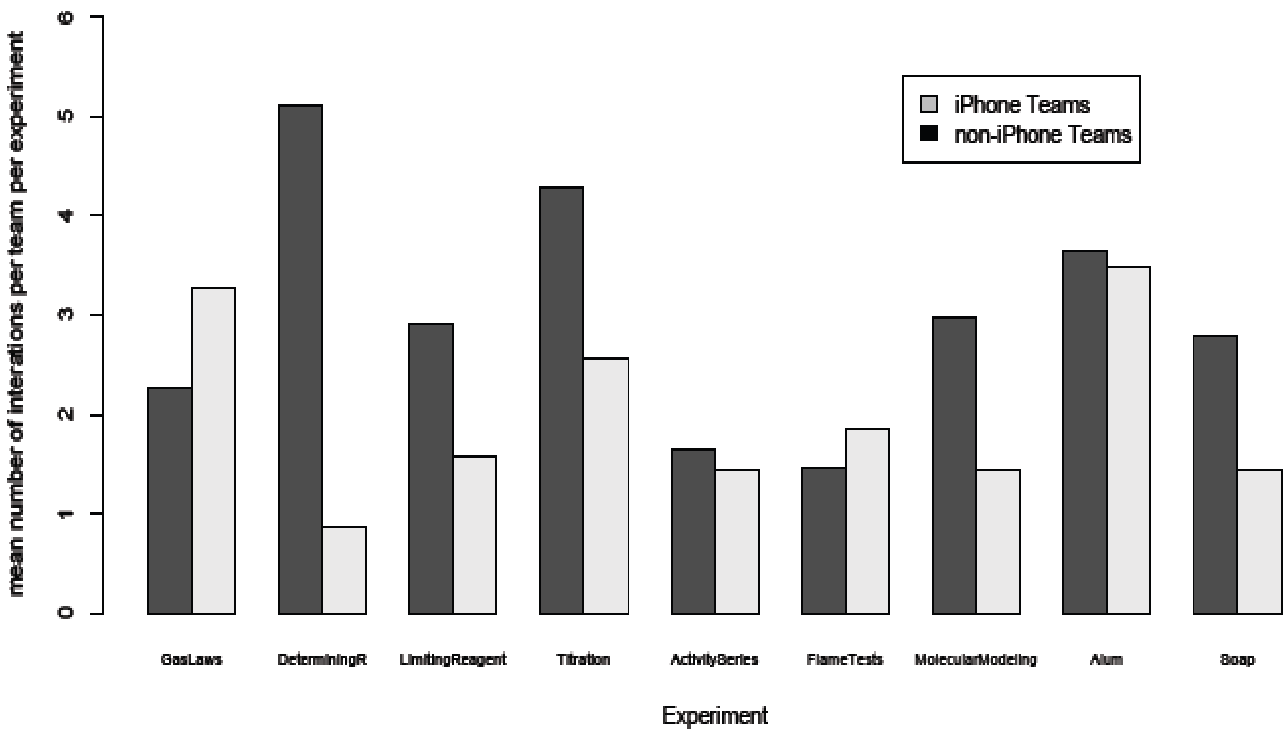
Category	Total Interactions for iPhone Section (per research team, n=7)	Total Interactions for non-iPhone Sections (per research team, n=30)
Clarifying Procedures or Techniques: Redirection Needed	55(**7.9**)	204(13.6)
Conceptual Misunderstanding: Redirection Needed	14(**2.0**)	77(5.13)
Conceptual Understanding: Confirmation	18(2.6)	61(4.1)
Connecting with Previous Knowledge	3(.43)	11(.73)

Values displayed in bold type indicate a statistically significant result at the 95% confidence level

Figure 3 is a bar graph depicting the mean of the total of the two categories that require student team redirection for the iPhone and non-iPhone labs. These categories of interaction are most important in assessing independence, because each of these interactions involves correcting student errors or assisting students with a procedure or technique, both aspects of the coaching and scaffolding functions that the podcasts are designed to support. The other two categories require no redirection of student activity and are the types of interactions that ideally should increase with student understanding and engagement. The bars graphs illustrate that during week 4: Determining R, week 5: Limiting Reagent, week 6: Titration, week 9: Molecular Modeling, and week 11: Soap the mean of interactions requiring redirection was significantly higher for the student teams in the non-iPhone sections (p=0.01668). These were the weeks for which podcasts were prepared and interaction data was collected. During week 3: Gas Laws, the podcast prepared for the iPhone section was judged to be incomplete in supplying the information that students needed to properly use an experimental set up. In response to the difficulties the students encountered during the iPhone section that met before any of the non-iPhone sections, the instructor included more information in the lecture given for the non-iPhone group. The non-iPhone lab's better preparation is reflected in the lower number of interactions requiring redirection during the experiment. More interestingly, week 7: Activity Series, week 8: Flame Tests and week 10: Alum did not have new podcasts that supported the experimental procedures. During these weeks all sections whether designated iPhone or non-iPhone received a 15-20 minute pre-lab lecture before the experiment. The bar graph shows that the mean number of interactions requiring redirection are very similar for the iPhone and non-iPhone sections and t-tests show that they are not statistically significantly different at the 95% confidence level

(p=0.994). This is an indication that when students in both types of sections were presented information in the same format, they interacted with the TAs in similar ways.

Figure 3. Mean Ratio of Interaction Types "Clarifying of Technique or Procedure" AND "Conceptual Misunderstanding" to Number of Student Teams for the iPhone Section and non-iPhone Sections.



Conclusions

The data presented supports our hypothesis that iPhones can be used to provide self-coaching and scaffolding tools that will decrease the number of times student groups must be redirected to allow more independent work during inquiry based experiments. The data indicates that students in the iPhone section used the podcasts regularly during the lab periods and that podcasts in the category "General Lab Techniques" were most heavily used. The differences in the total mean student interactions requiring redirection between the iPhone lab section and the non-iPhone sections were statistically significant and were greatest for the weeks that new lab techniques were introduced. (Week 4: Determining R, Week 5: Limiting Reagent, and Week 6: Titration.) The fact that the greatest difference in mean student interactions occur during the weeks when the most heavily used podcasts are applicable to the experiment suggests that podcast usage is correlated to more independent work.

During three weeks when all of the lab sections were instructed by pre-lab lecture and no new podcasts were available (Week 7: Metal Activity Series, Week 8: Flame Tests, Week 10:Alum), the section interaction rates requiring redirection were very similar and show no statistical difference. This supports the conclusion that student research teams in the iPhone and non-iPhone sections interacted with instructors and TAs at similar rates when provided with instruction by the same method and further supports the probability that the fewer number of interactions requiring redirection in iPhone groups during other experiment weeks were a result of podcast usage.

During one week, Week 3: Gas Laws, the interaction data does not fit the general trend. The information provided via pre-lab lecture for the Gas Laws experiment was modified for the non-iPhone sections after discovering that the information in the prepared podcast was not adequate preparation for successfully using the equipment. It is not surprising that research teams in the non-iPhone sections asked fewer questions requiring redirection, because they were supplied with more complete supporting information.

As we continue to develop the inquiry-based curriculum using the iPhone as a support, we will redirect some of our TA training to help TAs improve their interaction and engagement skills. It was disappointing to see the few number of interactions in the category “Connecting with Previous Knowledge”. TAs have usually filled the role of “redirector” and have been consumed by this responsibility and TA training has focused on preparing the TA to keep students “on track”. As this role diminishes because of the availability of information in podcasts, a new style of “assisting in teaching” needs to emerge which should include engaging student research teams in many more interactions in the “Connecting with Previous Knowledge” category.

It is interesting to note that in addition to using files posted by the instructors as sources of information during lab, students also used their iPhones in other ways. During one experiment, students were directed to use a search engine to find hydrogen emission spectra and emission spectra of other elements. Easy access to a search engine during class allowed greater flexibility in the existing data students could gather for analysis during problem sessions. Without prompting, students would use a search engine to help with nomenclature uncertainties and would do a search on topics related to the experiment to learn more about how what they had learned might be applied in the “real world”. Students used their devices as timers during parts of experiments that needed to be timed and as calculators on a weekly basis. Our experiences using iPhones in the lab have been positive. We will continue to develop podcasts to support experiments and work on ways that we can use the availability of a search engine to incorporate more recent chemical research in our lab curriculum.

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