‘I can do chemistry’: A move towards alternative assessment in high school chemistry

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June 2011
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PURPOSE:

The purpose of my Action Research is to find learning and assessment practices that will enable my students to be more successful in their mastery of chemistry.

PROBLEM STATEMENT:

Homework continues to be a critical part of high school education. As a high school chemistry teacher, I have observed a trend in student behavior that typically appears towards the end of the first quarter. After the introductory material has been covered and the more difficult concepts start, many students begin to struggle and some resort to copying the homework of another student to maintain their grade in the class. Unfortunately, these students do not receive the intended learning benefits of the homework, and I as the teacher may receive false data regarding their learning and understanding of the concepts. A potentially ever-worsening cycle is established as a result, where future lessons are planned based on this misguided information. Initially one may question why students take the cheating risk, and what can be done to remove the cheating motivation? A further question might ask what can teachers do to encourage students to use their homework as a learning experience? With these thoughts in mind, I was led to the following research question.

RESEARCH QUESTION:

What teaching and learning methods can I implement in my classroom to best enable my students to achieve mastery of the concepts and remove the temptation to copy homework assignments in high school chemistry?
FIELD OF ACTION:

I am a Chemistry teacher at Moreau Catholic High School, a Holy Cross college preparatory school in the Bay Area of San Francisco, California, where 99% of graduates go on to attend either a two or four year college. I teach 4 classes of regular chemistry and 1 AP Chemistry class in a science department comprising 7 faculty members. We have approximately 900 students enrolled.

Moreau’s philosophy is to encourage students to be life-long learners and effective communicators. The hallmarks of a Holy Cross education are “information”, “formation”, “transformation”, as demonstrated in the mission statement:

“Moreau Catholic High School is dedicated to the legacy and values of the Congregation of Holy Cross and its founder Blessed Basil Moreau. We are a college-preparatory school committed to outstanding achievement. As a community of faith, we prepare our students through academic, social and spiritual learning experiences that form and transform them as they become responsible citizens of our global community.”

Moreau is a very technology focused school. We are in the 4th year of a 1:1 laptop program. The school founder, Blessed Basil Moreau stated "we do not want our students to be ignorant of anything" and Moreau certainly is one of the forefront High Schools regarding technology in the classroom, reflected in a partnership with ACOT
LITERATURE REVIEW:

Copying homework is not new, nor is it confined to chemistry. Students resort to a variety of measures that may be considered cheating to get their homework completed, from copying worksheets to looking up answers on the Internet (Sallee & Rigler, 2008). This raises an initial question of why students take the cheating risk, and what can be done to remove the cheating motivation. This review covers the issues of this problem, including student values, motivations to cheat, and possible solutions.

Perceived value of homework:

A survey of over 180 students at a high school in Deerfield, Illinois revealed half the students surveyed to be overcommitted with extra-curricular activities, leaving limited time for homework. The same survey also revealed that students often have different beliefs about the value of homework “21% of students said it [homework] was busywork while another 21% said it was a valuable way to prepare for class discussions and activities” (Sallee & Rigler, 2008, p.48).

Cheating – what motivates students to copy?

Opinions on the value of homework change regularly, sometimes in favor and sometimes against (Vatterott, 2009). Supporters promote the value of homework assignments that are designed to develop what they call achievement motivation where homework provides a means for students to develop good study habits and beliefs about achievement (Bempechat, 2004). Detractors of homework often also recognize these benefits but are concerned that homework happens at the expense of valuable
extracurricular or family time (Cooper, 2001). Consequently a consensus appears to exist between students, teachers and parents that homework has value, but to achieve the purpose intended by the teacher it should be of a type that is beneficial to the students’ learning. If this is not the case then homework should not be assigned (Kohn, 2007).

The rise in available technology also provides an increase in opportunities to cheat on homework assignments (Kleiner & Lloyd, 1999). Students are able to share their work via email, and may also use the Internet to look up answers. A quick internet search for ‘homework help’ reveals a plethora of easily accessible sites that contain previously asked and answered common questions as well as offers of individual tutoring. Given the motivations, and the beliefs surrounding what constitutes cheating, eliminating or even reducing the frequency of cheating in our students is not a small-scale project (Lee, 2009). Rather, we need to be working on changing the culture in our classes. Students may cheat because they feel pressured into showing that they understand when they do not. A further question then might be what can teachers do to encourage students to use their homework as a learning experience?

**On-line homework assignments – a solution?**

High school classrooms are often collaborative, cooperative learning environments that encourage social interaction, where students give and receive help from each other. Such activities often focus on students helping each other by offering explanations to construct learning (Webb, Troper & Fall, 1995). However, collaborative group-work is also employed as a shared workload situation, such as completing a class project. Yadin and Or-Bach (2010) argue that for this type of collaborative group to be successful, students need to be equally responsible for the group success, with individually assigned tasks that often require an element of individual learning. “This
collaborative environment is effective only if each student carries his/her own task and does not rely on the others. This demonstrates the importance of personal assignments and accountability even in a collaborative framework” (Yadin and Or-Bach, 2010, p. 185). In their research report, Yadin and Or-Bach agree that collaborative work benefits student learning, but they also found that individual homework assignments improved student success in assessments. Such individual, or solo homework assignments, designed to be done alone, without collaboration, have value as they reinforce the learning that has taken place in the classroom. They help to prepare students for the most common method of assessment: subject tests in which the students have to perform alone, without the help of their peer group. Well-designed solo homework assignments offer effective learning by providing feedback with positive reinforcement and offer the option to correct errors and resubmit. They encourage the student to refer to their notes, to think about the problems, and construct theories that enable them to solve the problems, rather than just mindlessly answer questions without thinking (Kohn, 2006). Online homework assignments seem to best fit these criteria. Such assignments can give valuable immediate feedback, as opposed to delayed feedback, where a student must wait for the teacher to grade and return a class assignment. They also promote active learning, and enable students to construct their own knowledge. Homework becomes a continuation of learning outside the classroom rather than just practice of what was learned in the classroom. However, it is clear that the types of questions asked or the format of the answers required may frustrate some students. For example, answers that are not given to the exact number of significant digits or decimal places, or are missing units or key words may be marked as incorrect without the student knowing why (Dillard-Eggers, Wooten, Childs, & Coker, 2008). Other research appears inconclusive on the actual pedagogical benefits to students of using technology based interactive homework assignments (Bonham, Beichner & Deardorff, 2001) and
Students have generally reported that they like the immediate feedback and interactivity provided by online homework assignments, and these types of assignments can enable better quality study time resulting in better understanding of the concepts (Dillard-Eggers & Co. 2008). Well designed assignments that give students hints and allow them to correct and resubmit answers benefit student learning and may subsequently help improve test performance (Allain & Williams, 2006). WebAssign is an example of such a program. Student's work is graded immediately. If the student submits an incorrect answer they are informed and are able to go back to their notes, correct their mistake and resubmit (WebAssign, 2010). The key seems to be in how the assignment is designed. Previous studies show that just presenting the regular book or worksheet assignments in an online format produced no benefit to the students (Bonham, Beichner & Deardorff, 2001), but online assignments that offer immediate, encouraging feedback have the potential to benefit student learning and understanding. (Butler, Pyzdrowski, Goodykoontz and Walker, 2008: Cole & Todd, 2003).

**Conclusion**

The purpose of my Action Research is to find assessment and learning practices that will enable my students to be more successful in their learning of chemistry without resorting to copying homework assignments. As discussed above, beliefs surrounding the value of homework are varied and research has found that many students either do not have the time, inclination, or ability to complete assigned homework. This means to maintain their grade and status, rather than asking for help from the teacher, they copy the work of peers and submit it as their own (Sallee & Rigler, 2008). Research into the benefits of online versus traditional worksheet style homework assignments has been inconclusive and further research is needed in this area (Dillard-Eggers et al, 2008: Allain & Williams, 2006). The use of individual homework assignments may make it
more difficult for students to copy the work of others, something that hopefully will encourage student learning and provide more accurate learning data for instructors (Yadin and Or-Bach, 2010). My initial research question is to find out if offering online homework that provides immediate, encouraging feedback and which the student can correct and resubmit will enable mastery of the concepts and reduce the occurrence of copying homework in high school chemistry.

**CYCLE ZERO:**

Since the issue highlighted in my problem statement above initially manifests as occurrences of students copying homework assignments, a logical place to start was to look more closely at the homework assigned. I see value in well-designed homework with purpose, so my initial thoughts about the problem were that the homework I was assigning may not be serving the purpose intended, that is to help students towards mastery of a particular concept, and to inform me of the level of understanding achieved.

**Research Question For Cycle Zero:**

Will the use of on-line homework that is specifically designed to provide immediate encouraging feedback and which students are able to resubmit, enable high school chemistry students to obtain mastery of the concepts and reduce the occurrence of copying homework?

**Action:**

The literature found prior research into the benefits of online homework to be inconclusive, with many reports suggesting the need for further work, so before I set up a full cycle based around online homework I wanted to try the procedure with my

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Advanced Placement chemistry students since I knew they would all do the assignment, and I knew they would evaluate the process for me without compromising their own learning.

I created a multiple choice Moodle quiz that allowed students to resubmit their answer without affecting their overall grade. If the student got the answer incorrect, I was able to provide some automatic electronic feedback, such as ‘try looking at your notes from chapter 23 again’, but I wasn’t able to make the process interactive, or show how to build up step by step to the correct answer.

**Evaluation Of The Action:**

Using Moodle for this assignment allowed me to see how long the students had the quiz open, which for most students was several hours. Discussion with the students revealed this was because they knew they had the opportunity to resubmit so they wanted to make sure their answers were correct even though they knew I would take the best grade. Students told me they had their notes and the textbook open, and were also using other internet resources to carefully research each question before submitting an answer – and they did this over a long period of time, returning later but leaving the quiz open. Most students also shared that they had collaborated on solving problems. While creating the assignment I quickly realized that Moodle is not the tool for doing these kinds of assignments due to its limitations in providing an interactive experience, and technical difficulties regarding creating the problems. I am unable to compile this kind of
package with my current resources (one of which is time constraints) and without funding to purchase one of the already written packages such as Web-Assign I am doubtful that I can continue with this method. The students liked the format, but became frustrated when their answer was marked as incorrect, which may have been due to typing or wording errors rather than an actual incorrect answer. Some other key points from discussions with the students was their openness to admitting collaborating on the problems, and that they cared so much about their grade that they spent longer than I had intended on the problems to ensure their grade was not compromised, even though they knew they could resubmit at no penalty.

**Reworking The Problem Statement:**

All 25 students completed the homework, and all 25 students told me that they felt the experience helped them to learn, or rather forced them to learn. I see this as somewhat successful but the discussions and results made me wonder if the actual problem might be more about how the work is assessed, rather than the work itself. In the time period of cycle zero starting and ending, I had also seen ‘Race to Nowhere’ (Maimone Attia, 2009), a documentary film about the homework and achievement culture in education and the affect it has on students. My views on homework began to shift after watching, with specific thoughts on not overloading students. Students nonetheless seem to be focused on grades and ‘what will be in the test’. I found myself beginning to ask how can I change their focus from ‘what is my grade in the class?’ to ‘I can do Chemistry!’ These thoughts led me to think more about alternative assessments. What if I removed homework altogether and assessed the students differently in class? One of my focus points throughout the year had been on creating problem-based learning – trying to encourage my students to work together to solve problems, rather
than rote learn to pass tests. I wondered if perhaps I needed to reconsider my problem statement and try some alternative assessment methods.

**CYCLE ONE**

**Research Question For Cycle One:**

If I remove teacher assigned homework and make group members responsible for each other’s learning, will my students be able to demonstrate mastery of a chemistry concept?

**Additional Review of Literature for Cycle One:**

Guided Inquiry activities are activities that enable student-centered learning, where students are engaged in activities that prompt them to investigate and research rather than be instructed or lectured to. This method of teaching also fosters learning-to-learn and cooperative learning methods (Kuhlthau, 2007). POGIL, which is Process-Oriented Guided Inquiry Learning, a student-centered learning pedagogy where the teacher takes the role of facilitator and students work in small, self-managed groups on guided, exploratory activities (Pogil, 2010), has been employed successfully in science education at both college and high school levels (Eberlein, Kampmeler, Minderhout, Moog, Platt, Varma-Nelson, & White, 2008), and studies have shown that this method has led to an increase in grades for college chemistry students, in particular the students who normally have lower grades (Spencer, 2006). Students work on POGIL activities in the classroom with the teacher moving between the groups, making assessments of progress and understanding through observation and questioning. Inquiry learning has its roots in Bruner’s Constructivist theory of learning, and cooperative learning stems from Vygotsky’s Social Development theory (Kearsey, 1994). The benefits of learning
cooperatively in chemistry classes have been extensively researched (Felder & Brent, 2001; Hamby Towns & Grant, 1997; Kreke, Fields, & Hamby Towns, 1998; Tlusty, McIntyre, & Eierman, 1993; Webb, Troper, & Fall, 1995; Yang & Tuan, 1997). Research that compares teacher-directed and student-directed homework assignments is less extensive but a study carried out by Kogan & Ruedda on students with learning disabilities at a Los Angeles High School found that when students are able to decide for themselves if homework is appropriate for learning a particular concept, the rate of participation increases (Kogen & Ruedda, 1997). Consequently, students need to feel the value in a teacher-directed homework assignment, but students are seldom given the opportunity to have their opinion heard (Warton, 2001).

**Action:**

Cycle one took place during the stoichiometry topic, a six-lesson topic on calculating ratios that occurs at the end of the first semester. To facilitate my research question I made two changes. The first was a change to the way I taught the topic. This involved removing myself from the central role to more of a coaching role and having the students work collaboratively throughout five of the six lessons; with the sixth lesson being a topic test that students took solo. This was not a new concept to my students since they had been working this way through all of the prior topics this year, but it is new to the way that I have historically taught stoichiometry. Students worked in their already established lab groups of four people per group where they assumed roles adapted slightly from POGIL groups, POGIL activities are also not new to students in my class; we have been working in the POGIL style since the beginning of the school year.

Each student in a group assumed one of the following roles and responsibilities:
Manager: Responsible for making sure everyone understands at each stage and at the end of the topic. Is not responsible for teaching but works with the Strategy Analyst to formulate a plan. Resolves any disputes.

Spokesperson: Keeps Ms Couling informed regarding the progress of the group, and of any issues they may be having. May also ‘travel’ to other groups to ask questions.

Timekeeper: Responsible for keeping the group on target. Has to look ahead to see what needs to be done, and by when. Sets the work pace. Can arrange out of class meetings if they think it is necessary and is able to set homework.

Strategy Analyst: Comes up with strategies to keep the manager, and/or the timekeeper happy.

Students were permitted to self-assign roles, so long as they were different to the roles they had assumed last time, then they worked together to solve the problem – completion of the ‘stoichiometry workbook’ which is a guided inquiry assignment that enables the students to teach themselves how to solve stoichiometry problems, and which I had carefully written and designed to fit into four class periods.

The second change that I administered was that I would not assign homework of any kind during this topic. Instead, the Timekeeper in each group was able to assign homework if they thought their group needed to do work outside of class to meet the deadline for the assignment. Other group members could suggest homework but the overall decision was that of the Timekeeper who also made the decision on what activity was to be done for homework if it were assigned.

Evaluation Of The Action:

Cycle one was evaluated in the following ways:

- Assessment results. Throughout the activity students were required to check their work with me before proceeding to the next stage. At this time I looked at
their written work and asked questions (see below). The students also took a solo topic test in the sixth class meeting.

- The assessment results for a group of struggling students from my 5˚ class were monitored and compared to grades from prior topics. I refer to this group as the ‘focus group’.

- Directed questioning throughout the topic about their progress and about how students were feeling about their learning and understanding. I also asked questions about homework and how they felt about their timing.

- Observations based on the level of engagement and progress I saw in the classroom. I recorded these observations in a journal.

- Student questionnaire.

Summative assessment was in the form of their final completed document, and the solo topic test. The test was not multiple-choice instead it involved application of the concepts learned to solve stoichiometry problems. The literature had shown that student’s grades increase when they learn collaboratively so I was expecting the test grades to be around the same as they have been in previous topic tests this year, but I was hoping that making the students responsible for each others learning would lead to higher grades particularly for the students who usually score lower. I also looked at each student’s overall grade for the stoichiometry topic, and compared this to earlier topics where assessment has included grades from homework, labs and quizzes as well as class activities and topic tests.
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Data Analysis and Cycle Observations:

Student Questionnaire:

Of the 30 student groups that make up 4 classes, 24 groups self-assigned homework in this topic. Groups that assigned homework were asked what work was assigned, the responses included:

- complete the current section
- 1-2 problems
- finish the page
- get to a certain point

The groups were also asked if the homework assigned was completed alone or collaboratively. This data is shown in the chart below.

![Chart showing how homework was completed]

Interestingly 62.5% of groups carried out solo work on a collaborative assignment. In discussions and observations during class I found out that after working alone students would check in with each other at the next class meeting to see if they got the same
answers. The questionnaire that the students completed after the topic was anonymous because I had hoped it would encourage students to be more honest in their responses but the anonymity meant that I was unable to compare grades of students who completed their homework alone with those who worked collaboratively. The survey did however ask students who collaborated how they had done so. Three of the four groups reported that they collaborated electronically through i-chat while at home and one group met up during a school collaboration period (a time allocated by the school every other day to quiet study).

The student questionnaire asked students how they felt about student directed homework versus teacher directed homework. Many students commented that they felt less stressed about their workload without teacher assigned homework, even though 24 groups still assigned and completed homework. 63% of students said they preferred student directed homework. Of the 27% of students who prefer teacher directed homework the most common reason given was that they felt teacher directed homework gave more importance to the task and they were less likely to complete the homework if another student had directed it. The chart below summarizes the survey responses regarding preferences over who issues the homework.
Assessment Results

For one of my classes I compared the overall stoichiometry topic grades of students to grades obtained in earlier topics of similar difficulty. The results were better than I had expected and are represented in the following chart. The average grade for the stoichiometry topic was 89.6%, compared to average grades obtained in earlier topics:

- Periodic table – 80%
- Moles – 84%
- Reactions - 81.4%

The concepts from these earlier topics are revisited in the stoichiometry topic so that could be a contributing factor to the increased grade average for stoichiometry and discussions after the topic test confirmed that some students thought this was true.
The following chart shows a comparison of the topic grade scores for the students from my ‘focus group’. These students struggled during first semester chemistry and have grades that are towards the lower end of the class. The data clearly shows that most of the struggling students did better in the stoichiometry topic than in any of the previous topics, and all but one of these students achieved a topic grade of above 75%.
Throughout the topic I moved among the student groups to check their work at specific points through the workbook and to ask them questions about their progress and how they were checking understanding. I also spoke with the timekeepers to ask how they felt about their group’s progress in terms of completing the assignment. It was interesting to me that almost all groups stopped at the same point after the first lesson, which was at the end of a section and understandably seemed a natural place to stop. However, this is not where I would have stopped the class if I had been teaching it in a more traditional way. I did not want to influence any of the groups with my thoughts so I noted in my journal that I thought they had all stopped a little early and I was concerned if they would now be able to complete the assignment solely in class time. In the questionnaire I did not ask specifically on which days homework was assigned so I do not know which groups assigned homework after the first class.

By the end of the second class I could clearly tell that many groups would not get to the end of the assignment in the allocated class time. I did not want to force students into a homework situation nor did I want them to rush through the assignment without making sure that all members were able to solve the problems so I extended the time period available by one extra class. Some groups reported at the end that they were grateful for the extension, as even with homework they would not have made it to the end in the original time frame. Other groups commented that they did not need the extension.

Other observations I noted were that some students were really getting into their roles and I observed coaching within groups to get all members to the same point. I also noticed how the majority of the timekeepers really enjoyed the power of being able to decide on homework. Listening to students discuss their progress towards the end of each class was very interesting. For the timekeeper to make a decision on homework each student had to explain how confident he or she was with the concepts covered,
they were forced to reflect and then make an action based on their understanding. Finally, I was happy to observe a high level of student engagement throughout and the atmosphere in every class period felt happy and relaxed. Indeed there were periods of time where I could have been bored if I were not making notes!

**Cycle Reflections:**

I was amazed at the number of student groups who assigned homework that they completed alone. Interestingly some groups assigned a couple of problems to each student, which they then 'shared' when back in class. I asked the Managers of these groups if they thought this was the best way to make sure that everyone was mastering the concepts as this meant that not every student was doing every type of problem, all of them agreed that it was not but said that they had not thought of that at the time, the objective to the group was just to complete the assignment. This led me to the observation that many of my students do not seem to know what is appropriate homework, and if they do not know how or what to set for homework in this topic then perhaps they do not know how or what to study in any topic.

As I was analyzing the data I realized that my questionnaire could have been better designed. The anonymity mentioned earlier has prevented me from finding valuable information to help me investigate the benefits of working collaboratively on work completed out of class. Although the assessment data has shown a great success in this method of learning I feel that if I had included more specific questions about the homework that was assigned each day I would have received better data about how the students learned. The purpose was to remove homework and make group members responsible for each other’s learning so that all students can demonstrate mastery of stoichiometry. I feel this was successful, certainly the test results show that it was but I suspect that I perhaps missed some important information regarding homework.
In the time period between cycle one ending and cycle two beginning I experienced a copying of homework incident among my students. The work copied was a lab report and the student who copied said that they had done so because of time and work pressure and because the opportunity was too easy to resist. This brings me back to my original problem statement of removing the need for students to copy homework assignments in order to be successful in the class. It also reinforces the data from cycle one where students were successful in showing mastery of a topic without teacher directed homework and makes me question once again the purpose of homework, especially if the homework that is turned in contributes to my forward planning.

Action Research has led me to change my practice and I am amazed at the transition I have made in such a short period of time. During my teaching experiences prior to teaching in the United States homework did not play a significant part in my curriculum. However, it soon became evident to me that here in the States homework has a much bigger role than I was used to and I was quick to make use of this extra resource. Unfortunately, almost as quickly I became frustrated with the copying and policing procedures that seem to go hand in hand with it. Thankfully the Action Research process has led me to totally change my opinions and thoughts on homework. I began my Action Research by looking at ways to stop students from copying homework assignments and the results so far have led me to take a complete u-turn in my practice in that I have now almost completely removed teacher assigned homework from my class. This is a change I never would have anticipated.
CYCLE TWO

Inspired by the success of cycle one and also by the occurrence of cheating, my plan for cycle two was to continue to incorporate the cycle one method of not assigning homework that contributes to assessment. Also, given the successful use of collaborative learning employed in cycle one, and keeping in mind both the purpose of my Action Research which is ‘to find assessment and learning practices that will enable my students to be more successful in their learning of chemistry’ and of my original problem statement which is ‘remove the need for students to copy homework assignments in order to be successful’ I prepared the next chemistry topic ‘solutions’ to be almost entirely laboratory based. Students worked in their cycle one groups to carry out inquiry laboratory activities intended to help them develop their understanding of chemical solutions. Since chemistry is a laboratory based subject and students need to create laboratory reports that reflect their findings I asked my students to collect individual data but encouraged them to work collaboratively to help each other analyze their collected data. Students submitted individual laboratory reports that were assessed as part of their topic grade.

Research Question For Cycle Two:

Can students demonstrate learning of a chemistry concept by carrying out a lab where they collect individual data but collaborate on the methods of analysis of their data?

Action:

Cycle two took place during the solutions topic in which students study the properties of solutions and learn how to prepare and dilute solutions. There are many
possible laboratory investigations that students could carry out in this topic, all of which are very good at supporting the learning of the concepts covered. I usually incorporate three labs in this topic, an introductory lab, a formal lab, and a fun ice-cream making lab. To facilitate my research, I introduced a new formal lab, which took place over two class periods. Throughout the topic the amount of homework assigned was minimal but necessary for safe laboratory practice. With regards to the lab, students were asked to read through the lab details and procedures ahead of time and to answer some pre-lab questions as homework. I assessed this homework by looking at their calculations and asking questions about the risks involved in the lab. It was possible for students to copy the pre-lab answers from another student but they needed to have read the lab to be able to answer my direct questions. As with all labs, students could not begin the lab work until they had satisfied me that they were prepared and able to work safely.

The objectives of the lab were:

- Prepare a series of solutions of known concentration using molarity and dilution equations.
- Investigate the relationship between the concentration and the absorbance of a solution.
- Determine the accuracy of the laboratory procedures carried out.

Students worked at their usual lab tables (comprising the same group members from cycle one) and were encouraged to collaborate on procedures. They shared equipment and materials as usual but each student individually made their own series of solutions and carried out their own analysis. This meant that each student had original data to analyze.
**Evaluation Of The Action:**

Cycle two was evaluated in the following ways:

- **Formative assessment.** Students were required to check their work with me at key stages throughout the lab. At each stage I looked at their calculations and asked them questions about their progress and about their plans and expectations for the next section.

- **Summative assessment.** Students submitted individual, hand written, lab reports at the end of the topic. These reports followed a grading rubric issued at the beginning of the lab. I have also included the topic test grades in the cycle evaluation.

- **Journal entry.** At the end of the topic students were asked to assess their own learning through this lab in their learning journals.

**Data Analysis and Cycle Observations:**

For this cycle I focused on two classes for the most part; the same class that I focused on in cycle one and I also included some data on my second period class since this is often the class with the lowest average test grade. The chart that follows shows the grades achieved for the formal lab by students in these two classes.
n=32 students in each class.

A grade of 18/30 gives a percentage grade of 60%. Grades below this are considered an F grade. A total of 3 students across both classes ‘failed’ the assignment. In all three cases the F grade was awarded because the student work was submitted with large chunks missing. The following chart shows where points were lost for all students.

n=32 in each class
Almost a quarter of students in both classes lost points for misreporting their data. This could be either an incorrect number of significant figures, incorrect units or both. This information is quite disappointing to me. We cover significant figures early in the first semester so students have been working with significant figures since the beginning of the year. The importance of units has also been stressed since early in the first semester, but particularly in this topic where there are so many units for measuring concentration. Students lost one point for significant figure errors and one point for missing or incorrect units in their data table. There was only one point deducted no matter how many times the error occurred.

The most alarming information to me was the number of students who could not draw on their graph or correctly use the graph to analyze their results. Students used a data-logging software system to collect their data and the system produced a graph for them. They were then asked to draw a line of best fit through the data points by hand and to use that graph to predict a value within the range of their graph.

Twenty-eight of the thirty two students in period 2 class lost points either because they didn’t draw the graph correctly or they didn’t correctly use the graph to make the prediction of the unknown, or both. In period 5 this number was twenty-five out of thirty two students. This means that around 88% of my chemistry students do not know how to create or use graphical data. I discussed this finding with the math department in my school and was appalled to discover that students generally do not learn graphical analysis until junior or senior year, yet my students are mostly a mix of sophomores and juniors. I had made the assumption that since graphing is such an important skill for processing laboratory data that students would have learned this prior to high school, or at the very least as a freshman. With this new knowledge I then began to analyze my cycle two data with a different focus. I looked at historical math grades and placement into chemistry. I found that for the students in my focus group all but student N had
completed their prior math classes with an average year grade in the D to C+ range (student N achieved an average of B- in both prior math classes). For their current math classes all of the group members have grades in the C- to C+ range. In my second period class I looked at the historical data for the three students who failed to pass the lab and found that these are all male sophomores with prior math grades of C or C- and current math grades of B-. I then began to look at students in all of my classes who had not been able to make use of their graphs and I found that 18 students (3 sophomores and 15 juniors) had achieved grades of C- or below in their previous math class. Five of those juniors had also achieved grades of C- or below in their freshman math class. The chart below shows the percentage of students in each of my classes who came to chemistry with a prior math grade of C- or below.

Processing this math data reinforced to me the diversity in ability of students coming into my class. The data above show that in total just over 14% of my chemistry students are coming to a heavily math based science class with already recognized poor math skills. Since the qualification and setting of prerequisites to get into chemistry are
out of my control I have set aside this part of my cycle analysis for further discussion with my school administration and counseling departments. For the purpose of my Action Research I feel the discoveries surrounding math ability have certainly helped to provide me with more accurate planning information, which was a goal of cycle two. However, I had also hoped to discover if students could produce individual laboratory reports that reflect their own knowledge of the concepts covered. Looking back at the chart that shows the grade out of 30 points one can see that the majority of students successfully completed the assignment with a passing grade. To support this statement I have included test grade data from this topic. There is a correlation between a successful lab assignment and the test grade. In the test students were asked questions that tested their understanding and application of the important concepts of solutions that were learned and reinforced throughout the topic and applied during the lab. The chart below shows lab and test grades for my focus group students. Student R is the only student who did not score a passing grade on the test; all other students from this group were clearly able to demonstrate good understanding and application of the necessary concepts to be successful. In fact two students, student N and student C scored higher in the test than they did in the lab.
The following chart shows the grades achieved in all of my classes for the lab, the test and the overall topic grade. What is clear from this data is the success of the lab. Students in all classes seemed to do really well being assessed in this way. The lab grades stand out as much higher than the test and the overall topic grades where there is a greater correlation between scores. The rest of the topic was made up of a quiz, creating a study guide, the ‘fun’ ice-cream making lab without a formal write-up, and a journal entry. It is important to note that some of these other grades include zeros because students did not complete or submit their work for grading.

My final evaluation of the action was from student learning journal entries. At the end of the topic students were asked the following question “What did you learn in the making and diluting solutions lab?” I purposely asked a very open-ended question because I wanted to find out how the students had viewed the activity. The learning journal is fairly new to students. They have been making reflective entries at the end of each topic since January so this was their fifth entry. All of the entries were positive and most were very detailed, quoting new equations and terminology. I have included below
a selection from each class that clearly show how positive students felt after completing the solutions lab.

“This lab helped me a lot more in finding Molarity in a solution and also finding out what is the dilution of a solution."

Molarity is a way of measuring the concentration of a solution, and an objective of the lab was to make a series of dilutions of different concentrations.

“In the making and diluting solutions lab I learned that how little a substance could change a solution and how to correctly calculate different concentrations of substances in the solution. Also I learned how to correctly use the colorimeter and how to graph that data into a post lab. I think truthfully this was one of the more interesting labs because of how in depth it was and how it forced us to use critical thinking and different skills to carry out the lab”

A colorimeter is a piece of lab equipment that determines the concentration of a solution by measuring the absorbance of different wavelengths of light. The colorimeter was connected to the data-logging equipment.

“In the 'making and diluting solutions' lab I learned... a lot about concentration and absorption. Although I never asked this from class, when a juice box said not from concentrate does that have anything to relate to the concentration in the juice. I think I will Google that. The equations we learned for dilutions, molarity, and molality were pretty easy. But why would we need to find those calculations in solutions? I remember when we were doing the making and diluting solutions lab to help mix the solvent into the water, we had to heat it up, because sometimes stirring isn't enough, and you need heat to cause more frequent
collisions between solvent and solute. It was pretty interesting; I learned a lot that concentration and absorbency go hand in hand really. It was fun using the colorimeter thing! Made me feel like a real chemist. Just another question [sic], though I think I will have Google answer or maybe I’ll find it in my chemistry textbook, is it made of a solution has a high concentration of something, or does it just depend on what the concentration is? I will try to figure this out! But this was a fun lesson! Even though this does involve math it isn't so bad. (:”

“In the 'making & diluting solutions' lab, I learned how to properly make diluted solutions of copper (II) sulfate according to concentration formulas I had worked out. This lab felt like a real chemistry lab. There was so much work and data that it was fulfilling in the end to see you end results. This lab also set a great foundation for the ice cream lab we would later do, which by the way, I have to admit had been my favorite lab of the year. 😊”

**Cycle Reflections:**

Cycle two brought much more than I had bargained for. First, my students demonstrated some excellent lab skills and spoke about their enjoyment of the lab activities in the topic, and some of my lower achieving students were able to improve their grade. So in answer to my cycle-two research question, I can happily say, yes, students can demonstrate learning of a chemistry concept by carrying out a lab where they collect individual data but collaborate on the methods of analysis of their data. Secondly, I found out that I had made some naïve assumptions about student’s prior learning and in the process I received confirmation of a previously suspected issue regarding placement of students into chemistry. This has resulted in an arranged follow
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up meeting with the counseling department. Thirdly, as I graded student work and analyzed the cycle data, I found myself thinking more deeply about assessment methods in high school science, and asking questions about the effectiveness of quizzes and topic tests as the major source of assessment and points that are available for students. This thinking process led me to return to the literature ahead of my third cycle to investigate what has been written about the merits of alternative assessment methods.

CYCLE THREE

Additional Literature Review for Cycle Three

When one searches for prior work on alternative assessment one is mostly led to alternative methods of assessment for students who are unable to participate in the general assessment system. However, for the purposes of my action research my interpretation of alternative assessment is focused on assessment strategies other than a topic test that may be used for students who are taking general chemistry in my high school class and who are able to participate in the general assessment system with or without accommodations. Relevant literature with this focus was a little harder to find.

Classroom grading policies usually measure different constructs, ranging from test performance to creation and presentation of a project. The knowledge and skills required for such a range of constructs are very different but are often treated as though they are the same when being graded. While it is evident that teachers do use multiple methods of assessment, e.g. quizzes, topic tests, labs, essays, research papers, etc, what is not evident is the meaningfulness of the measures of assessment. There needs to be purpose in combining multiple measures, and teachers should give consideration
to the intended learning and the measure, or rather multiple measures, of assessment of that learning (Brookhart, 2009).

From the student’s point of view, allowing other forms of assessment to have equal weighting to test points or even offering an alternative to a topic test may reduce the anxiety that some students feel towards tests. In her study of five students through a year of high school, Pope (2001) observed how test anxiety affects students:

I understand it as much as everybody understands it…When it comes to the test, it’s like oh my God I just don’t, you know, I just forget.........it just like puts me down more…Maybe teachers shouldn’t base everything on [test] grades…. because people learn in their own ways (p130).

Pope (2001) goes on to discuss what she calls the ‘grade trap’, where students are caught in a system that does not require them to engage with the curriculum material, but rather encourages them to manipulate the system by taking easy classes to raise a GPA, and to complete assignments and tests without learning or understanding the material. It seems then if we are all signed up to this system called education, that if we are assessing our students on completing the curriculum rather than on demonstration of their learning, shouldn’t they be allowed to choose which method of assessment works best for them? Perhaps we teachers need to be as creative in our assessment methods as many of us are in our lesson planning.

Good alternative assessments allow the teacher to determine the level of learning and understanding of their students. They should also allow students to demonstrate their understanding in a way that works for them, and perhaps allow more than one right answer. Herman, Aschbacher, and Winters (1992) suggest:

Common characteristics in alternative assessments include asking students to perform, create, produce, or do something; tap higher-level thinking and problem solving
skills; use tasks that represent meaningful instructional activities; invoke real world applications, and people, not machines, do the scoring, using human judgment (p13).

Corcoran, Dershimer, and Tichenor (2004) recommend formative assessments such as journal entries, interviews, and checklists that can be used as summative measures as these allow teachers to better forward plan (p214). They also suggest allowing students “the option of crossing out five of the twenty-five short answer questions on a test and inserting five similar questions about material they learned while studying for the test but was not included on the exam” (Corcoran et al, 2004, p215).

**Conclusion:**

Alternative assessment means more than one way to assess the same construct. Allowing students more choice in which method of assessment works best for them may reduce anxiety for poor test takers and provide better planning information for teachers. However allowing students to choose their own method of assessment may be a difficult adaptation for some teachers (Corcoran et al, 2004). All of the literature I read encouraged a change towards the author’s own suggested recommendations for alternative assessment methods but as a whole were lacking in supporting evidence. I remain mindful of our grade-focused school society and am encouraged by the suggested methods of assessing students in an alternative manner. While not quite ready to move to total student choice in assessment methods, I am hoping that the following research question and action cycle will allow me to provide some supporting evidence of my own.
Research Question For Cycle Three:

If I assess my students on their laboratory and data analysis skills rather than a topic test, will some of my lower achievers be able to increase their topic grade while still demonstrating mastery of the subject?

Action:

Cycle three took place during the acids and bases topic where students study the properties of acids and bases and learn how to carry out a classic piece of laboratory analysis, the titration. An acid base titration allows the unknown concentration of either an acid or a base to be determined by titrating it with the opposite solution of known concentration. For example, one can calculate the unknown concentration of a sample of hydrochloric acid by titrating it with a sample of sodium hydroxide (base) of known concentration. The procedure involves some laboratory measurements followed by calculations using equations that were learned in the previous topic. The topic was spaced over seven class periods followed by one class period in which the topic assessment took place. Most of the seven class periods were spent carrying out lab activities. After learning the introductory material and reviewing calculations from the previous topic students watched a podcast for homework that demonstrated how to set up the titration equipment and how to correctly take the required measurements. In the next class meeting students practiced all steps working at their own pace. The titration process was practiced many times in the following classes and students worked collaboratively on analyzing their data and processing calculations.

An assessed lab was used in place of a topic test. I adapted the format and rubric for an A’ level coursework lab that I had used previously in the UK. Students were randomly assigned a new lab partner for the assessment. Each pair worked together for
45 minutes in which they set up their equipment, carried out their titrations, and collected data. During this 45-minute period students also had to thoroughly clean up their work area when the titrations were complete. For the remaining 40 minutes students worked independently using their collected data to calculate the unknown concentration of their acid sample. They also had to write a short risk assessment and evaluate their evidence.

**Evaluation Of The Action:**

This cycle was evaluated by comparing the results of the assessed lab to traditional test scores, and by comparing results from the calculation section of the lab to how students processed titration data in the spring final exam. At the end of the topic students were also asked to complete a questionnaire on their views of assessment methods. During the assessed lab, a grading rubric was issued to the students ahead of time. Seventy points were available for the lab distributed as shown in the following table:

<table>
<thead>
<tr>
<th>Points available</th>
<th>Skill</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 points</td>
<td>Implementing skills</td>
<td>Includes creating a data table and accuracy of titration results</td>
</tr>
<tr>
<td>11 points</td>
<td>Analyzing data</td>
<td>Processing titration results to calculate the unknown concentration</td>
</tr>
<tr>
<td>8 points</td>
<td>Evaluating evidence</td>
<td>Comments on the sources of error and suggests improvements to the experimental procedures</td>
</tr>
<tr>
<td>36 points</td>
<td>Observation</td>
<td>Teacher observations of safety, procedures, techniques, participation, confidence, clean up.</td>
</tr>
</tbody>
</table>

**Data Analysis and Cycle Observations:**

To be consistent I focused my detailed analysis on the same two classes that I have concentrated on previously, however I begin by looking at the grades obtained in

Couling 2011
all of my classes. The chart below shows the average grade achieved in the assessed lab by each class. Periods 2, 3, and 5 each have 32 students, and period 9 has 29 students.

All students scored well with this alternative assessment method. At first glance, there seems to be a large gap between period 3 and period 5 but actually this is gap represents only 6.6% and all classes fall into the B grade range. The period 5 results are interesting since this is the class period that contains my focus group of students who have been struggling with chemistry this year.

The following chart compares the average grade in each of the end of topic assessments (tests) during second semester for each class. This chart shows that the assessed lab grade was the highest scoring ‘test’ grade for all classes.
All students scored better in the assessed lab, the question is, did it allow them to show mastery? In an attempt to answer this question, I looked at how students scored in each of the lab sections.
The chart compares grades achieved in the four assessment areas of the lab from the two classes that I have been monitoring and from the focus group. It is very clear from this chart that on average, all classes were unsuccessful in the analysis section, but this of course does not mean that all students were unsuccessful. The analysis section required multi-step mathematical calculations. Since the focus group scored so much lower in the analysis section the data above reinforces the results of cycle two where I looked closely at the math skills of this group prior to coming to my chemistry class. These lower ability math students are struggling to master the math required to be successful in chemistry. Overall the data highlights the difficulty of the required calculations since the average grade of all students was so poor in this area. It is interesting to note that all members of the focus student group are students in period 5, who as a class scored higher than period 2 in the implementing and evaluating sections. This widely ranging data again highlights the diversity of student ability in that class.

The following chart shows the analysis section grade for each of the focus group students and again the low achievements in this math-focused area of the lab support the data from cycle two.
Scoring poorly in the analysis section did not result in a failing grade for the overall assessment. However, being able to process data collected in a titration experiment is an essential part of the chemistry curriculum. For this reason, I felt it was important to re-evaluate this skill so we covered it again in our review week and it was included in the semester final exam. The following chart shows the individual analysis grade for each of the focus group students in both the assessed lab and in the final exam. I’m happy to note that for all but one student the chart clearly indicates improvement in this area, although the improvement is not enough to show mastery except for student N, who is now demonstrating mastery of this concept.

The overall grades achieved by the focus group students in the assessed lab are shown in the next chart. By evaluating the lab as a whole the grades achieved indicate that all of the students have mastery of titrations. The next question I need to ask is have I misguided myself by assessing the students in this way? Can students really have mastery of titrations without being able to carry out the necessary calculations?

Couling 2011
To answer this question I turned to my reflections and observations that I had made during the topic. When we do labs we collect data, record it and answer some questions. The rubric for the assessed lab focused on all of the skills required to be able to carry out a titration. The assessment was asking are students able to set up and carry out the lab, do they know what to do without instruction, can they make decisions about numbers of trials and what data to collect, do they work safely, can they evaluate their evidence and recognize sources of error and limitations, are they able to suggest improvement, and are they able to carry out the titration calculations? My cycle question asked: “If I assess my students on their laboratory and data analysis skills rather than a topic test, will some of my lower achievers be able to increase their topic grade while still demonstrating mastery of the subject?” Did the grades increase, yes; do the students have mastery, no. The mastery came later for one, when the calculations were covered again before the final exam. What is evident is that students were able to be successful and confident in carrying out the lab and they demonstrated all of the skills listed above,
except for one skill. Without that final skill then I do not believe that mastery has been achieved.

At the end of the topic I asked students to complete a questionnaire about assessment methods. The questions came with a choice of answer options that hopefully encouraged the students to reflect on what they had learned in the topic. Only 82 of my 128 students took the survey. Some of the questions in the survey were related to other areas of the recent topic but the following charts summarize their responses that are relevant to this cycle.

**Question: Did you answer the calculation section in the assessed lab?**

<table>
<thead>
<tr>
<th>Response</th>
<th>Number of students</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: No</td>
<td>5</td>
</tr>
<tr>
<td>2: Yes, but I don’t think I did very well</td>
<td>30</td>
</tr>
<tr>
<td>3: Yes, I am confident in my answers</td>
<td>25</td>
</tr>
<tr>
<td>4: I answered the ones I knew how to solve but I couldn’t answer them all</td>
<td>15</td>
</tr>
</tbody>
</table>

n=82
The following chart shows how students responded when they were asked to comment on their preferred method of assessment. The question asked them to consider the best and worst ways for them to demonstrate their learning, and the responses have been grouped by increasing popularity.

![Assessment Methods chart]

n=82

The ‘Homework problems’ option included a statement that the work would be turned-in for a grade, and the ‘Inquiry labs’ option included the statement ‘where you create and test your own hypothesis’. For the ‘other’ category students were invited to include any other form of assessment not on the list. Student responses included “any form of application of the material”, “conversing about what was learned”, and “conversing about questions asked by the teacher”.

Couling 2011
It seems clear from the data that students prefer to be assessed by practice questions and calculations, and by graded homework. They also much prefer collaborative assessment to solo assessments. Which in my classroom this year meant that lab partners could turn in one lab report between them, or the table group (four students) could work collaboratively to answer a problem, but only one of them writes down the answer and submits that one copy for all four students.

Cycle Reflections:

After two successful cycles, this third one troubles me somewhat. I know that I have changed as an educator during this action research process and I believe this is part of what is troubling me. I know that this cycle has not been totally successful, but it is not because of the students, it’s because of me. I am beginning to feel that perhaps I hadn’t changed in the way that I thought I had. At the end of the topic I asked my students “what method of assessment works best for you?” I really wish that I had asked this question at the beginning of the topic instead. While writing my cycle three report I looked closely at student’s grades in the assessed lab, the good overall grades that they achieved despite the poor analysis section grades has made me realize that I must think that in some instances it is OK to not be able to do the calculations that go along with an acid base titration. None of my students failed this assignment, but most of them failed that one section. I am troubled because I think deep down that I don’t believe my previous statement at all, and this means I may have made an error how I organized the assignment. What if students without instruction are able to set up, complete, and successfully collect data for a titration lab but to do the calculations they look up the method and work through it step by step? Now that would be demonstrating mastery! I think I assessed my students wrongly and that is what troubles me most. Without even realizing that I had done it, I’d expected them to memorize how to do those
calculations. What is wrong with students looking up a method in a textbook, or on-line and then just plugging in their own data? Why am I thinking about this now instead of before? I feel I have failed my students, I spent so much time throughout the topic prior to the assessment helping my students to feel confident in actually carrying out the lab activity that I overlooked their confidence on performing the calculations, I expected them to memorize how to do calculations and only now, after analyzing data for my cycle have I realized what happened. I was hoping for mastery, but what is mastery? Is it memorizing and regurgitating facts, or is it being able to apply knowledge to solve a problem?

The most surprising revelation for me from this final cycle is how deflated I felt when I realized that I had unknowingly expected memorization while thinking I was trying out an alternative assessment method. As an educator, one does not like to feel they have been unsuccessful, after all if I am unsuccessful, then 120+ students are likely to be unsuccessful too. Yes, Action Research has changed me as an educator, but for this cycle the change that I really needed to happen came too late.

Looking at the positive outcomes of this cycle, I am happy to note how good the students all felt about themselves after this assessment. Their overall assessment grades were good and they felt that they had stepped up to a new challenge and been successful, they feel like ‘real chemists’. Hearing this from my students encourages me to repeat this type of assessment next year but of course next time I will need to introduce it into the topic in a slightly different way and make sure that it does not require students to memorize difficult calculations.

I can see now why I struggled to find evidence of the success of alternative assessment from the literature. I think as educators, too many of us are still not quite there when it comes to assessment. We may be implementing the suggested measures but are we assessing learning or are we still assessing memorization? I still have a lot to
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learn about how to assess my students, and also, I think students still have a lot to learn about which method of assessment is best for them. Students are used to being tested and quizzed on their memory of facts. If we encourage students to have a voice, an option, in how they demonstrate what they have learned I am confident that more students, no matter their math background, or their ability will be able to say “I can do chemistry”.

FINAL REFLECTIONS AND THE NEXT STEPS...

The British physicist Sir William Bragg once said: “The important thing [in science] is not so much to obtain new facts as to discover new ways of thinking about them”. Action Research has helped me to do just that; it has helped me to explore my own values and to develop new ways of thinking about my practice. I began by wanting to improve the homework procedure in my classes because I was irritated when students copied their assignments. I said “I see value in well-designed homework with purpose” (p9 of this report) and I planned to introduce an on-line homework system that would discourage cheating. Little did I know that I would embark on a journey that included a complete u-turn in my practice leading me to almost completely remove teacher assigned homework.

Cycle zero investigated changing the format of homework assignments to encourage learning while discouraging copying. Cycle one removed teacher assigned homework completely and instead put the focus on collaborative learning in the classroom with the responsibility for learning, and of assigning homework, firmly in the hands of the students. In cycle two, with the focus still on encouraging collaboration on methods, students became ‘real chemists’ and produced individual, and I’m happy to note unique lab reports, and enthused about how much they had learned. Cycle three took the previous cycle successes another step further with a jump right into alternative
assessment in the hope for demonstration of mastery. I still hold the value that homework should be purposeful but instead of enforcing rules over homework completion I have empowered my students to feel able to decide when homework is necessary.

**Personal change**

On a personal level I have become more open minded and less controlling of student learning behavior. What on earth was I thinking about, jumping on the homework bandwagon like that, shame on me! I am glad that through reflecting on data collected during mini cycle zero I was able to realize the implications of assessed homework on my students and jumping off of that homework bandwagon is one of the best things I have done as an educator. What is even more rewarding about this is that others in the science department have followed suit and have also began to move away from teacher directed homework.

Action Research has encouraged me to look differently at how I reflect on my practice. Previously I had focused on qualitative reflections, thinking about how I felt each lesson had gone, was the timing right, did the students understand what I was asking them to do, was I pitching at the right level, and I would plan changes for the next time I taught that lesson. Now I have learned how to analyze data in a way that really informs me about student learning, providing me with quantitative data that helps me to make much better planning decisions.

**Organizational change**

Cycle two proved to be the key cycle to bring about organizational change. This was a surprise to me as I had thought that since I was focusing my research in my own classroom and not involving my colleagues directly that there would not be any
organizational change to consider. But I was wrong! While analyzing the data collected in cycle two a previously suspected issue of the diversity in math capabilities of students who come to chemistry was reinforced. At first I was a little worried by this observation and the potential conflicts that it may bring. Prior to Action Research I had raised this suspected issue with the administration and counseling departments at my school but I was not successful in making myself heard. Or rather, not successful enough to make changes happen. Cycle two data however, provided me with some hard evidence that my initial suspicions were correct, and as a result I have been able to begin some positive steps towards addressing these issues. So the immediate future brings meetings between the science and counseling departments to collaborate on improved routes through science for our students. This is exciting because it was not an intended part of my research, but by evaluating data collected for a different purpose, this ongoing, and clearly critical, issue has re-surfaced and will now be addressed. What surprised me most about this is that when choosing my problem statement I had consciously decided not to focus on placement of under-qualified students into chemistry classes, believing it to be something that I had tried to tackle already and which may be too sensitive for me to attempt to change through Action Research. Yet as I carried out my chosen research it became highlighted anyway and as a consequence is now back on the agenda. I really could not have hoped for a better outcome.

As I proceeded through my research project and discussed each cycle report with my science department colleagues they became increasingly involved in discussions about how students progress through four years of science at Moreau. This led to continued dialogues and a collaborative decision to investigate a new route for all students through science, something that we hope will be implemented for the students who begin their Moreau high school career in 2012.
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**Changes still to come**

Action Research has helped me to develop my understanding of the words ‘purposeful’ and ‘meaningful’ in my chemistry curriculum. I began by thinking about homework with purpose and I have developed to have greater consideration of my students’ needs with a move towards meaningful alternative assessments. I have been reminded to keep asking ‘why?’ and ‘what if?’ questions. I am sure I will continue to make changes to my curriculum in the hope of enabling all of my students to achieve mastery of chemistry. I have expanded from seeing myself as the ‘teacher’ to being the ‘learning enabler’, but I know that I face a bigger challenge with my AP classes whose ultimate assessment is out of my hands and instead in the hands of The College Board and the AP exam. This I am sure will be an increasing conflict for me as I move my general chemistry class towards alternative assessments and away from recall tests.

For the immediate future, as I reflect on the results of cycle three and consider a new problem statement and research cycle for my incoming classes I am drawn to the recommendation from Corcoran et al of ‘crossing out of test questions and replacing with similar ones’. The last question I asked my general chemistry students this year was ‘what is the best method of assessment for you to demonstrate your learning?’ I am absolutely certain that instead of this being the last question I ask my incoming students in August, it will be the very first question that I ask them.
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