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Basic arithmetic forms the foundation of the math courses that students will face in their undergraduate careers. It is therefore crucial that students have a solid understanding of these fundamental concepts. At an open-access university offering both two-year and four-year degrees, incoming freshmen who were identified as lacking in basic arithmetic skills were engaged in an experimental technology-enhanced workshop designed to provide them with a deeper understanding of arithmetic prior to their initial remedial coursework. Customized online content was created specifically for this experiment, and the first implementation (n=27) yielded statistically significant improvement, not only from pretest to post-test, but also in the subsequent remedial course. This paper also analyzes the accuracy of students' self-assessment from pre-test to post-test, as well as student attitudes about this experimental approach.

Keywords: developmental math; remedial math; online instruction; WeBWorK; tablet instruction

Subject classification codes: 97U50, 97D40

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A Modularized Tablet-Based Approach to Preparation for Remedial Mathematics

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1. Introduction:

There may be no greater challenge that a student faces in college than being placed into a remedial mathematics course. In general, remedial math is the most common type of remedial class that a college student may be required to take, and these remedial math courses have a higher rate of failure than their equivalents in other departments.[1] Moreover, the students who are placed into the lowest level of remedial mathematics are the least likely to make it to credit-bearing courses, with only 10% of them ever passing a credit-bearing math course.[2] In an even larger study of college transcript data from the National Educational Longitudinal Study, Attewell, et al. [3] conclude that only 30% of remedial math students complete their prescribed sequence of developmental math courses. Even more worrisome, Scott-Clayton, Crosta and Belfield [4] have found that some entrance exams may incorrectly place as many as one-quarter of incoming freshmen into remedial mathematics. They conclude that more frequently are students incorrectly placed into remediation when they do not need it than the other way around.

In spite of these obstacles to their progress, research shows that students who succeed in passing their remedial mathematics course requirements are as successful in their subsequent credit-bearing mathematics courses as their counterparts who were not placed into remediation.[5] A study conducted by American College Testing (ACT) on both two-year and four-year colleges reported similar findings.[6] Results from these studies indicate that remedial mathematics courses are effective for those students who complete them.

Alternatively, Fong, et al. [7] offer a different view of how we ought to measure students' progress through a sequence of developmental mathematics. Instead of measuring all students entering remediation against those who complete the remedial sequence, they remove students who withdraw and students who do not continue enrolling in the remedial sequence from consideration. After this adjustment, they conclude that student success at each level of remediation remains consistently high regardless of the student's initial level of remediation.

These differing perspectives on success in remedial mathematics leave us with several questions. First, why students do not stick with their remedial sequence, and if they had – what effect would that have on the overall pass rates? And the natural follow-up question, what can we do to retain these students and support their further progress through the remedial math sequence?

Epper and Baker [8] outline many varying alternative approaches to remedial mathematics, several of which utilize technology to deliver self-paced content, yielding strong positive outcomes on student success in remedial mathematics. They also draw attention to targeted remediation efforts by several community colleges to identify specific skill gaps, followed by self-paced modularized content to progress students through remediation at an accelerated rate. Furthermore, findings by Burch and Kuo [9] suggest that the use of online content can help improve retention over more traditional methods.

Context:

The location for this experiment is an open-access Hispanic-Serving Institution with students reporting more than 134 different countries of origin, ranking among the most diverse institutions of higher education in the country. 80% of incoming freshmen and 67% of returning students receive need-based financial aid, and 67% of students are the first in their families to attend college. In addition, 35% of students report working 20 or more hours per week.

This institution's statistics tell a similar story regarding student success in remedial mathematics. Students placed into the lowest level of remedial mathematics have passed remedial math courses at rates between 14.9% and 19% over the past two years, simultaneously yielding withdrawal rates ranging from 40% to 55% in the same timeframe. Summer sections have fared only slightly better, with 20% of the initially enrolled students passing the lowest level remedial class in the most recent session. With this in mind, the experiment was designed to specifically target students placed into the lowest remedial math course.

Student consistency in performing basic arithmetic computations is a regular factor in student success in remedial mathematics. Final remedial assessment at this institution comes in two forms: the first is an online multiple-choice assessment where students are permitted access to a calculator with only basic functionality, the second is an open-format written assessment without any calculator access. This written assessment is evaluated without partial credit for those students who score below 64%. As such, incorrect computations are heavily penalized, and therefore rigor in arithmetic was identified as a fundamental goal, forming the framework for the content of our experiment.

Considering the financial struggles that a large portion of the students face, it was important to choose an online content delivery system that, if successful, could be scaled up without cost to students. WeBWorK[1] was chosen as the platform for the experiment, as it is an *open-source* online homework system, supported by the Mathematical Association of America and the National Science Foundation. In order to provide flexible access to WeBWorK in the classroom for both independent and group work, each student was provided with an iPad for the duration of each class meeting.

2. Conceptual Framework and Research Questions:

When a student has already been 'taught' a topic, yet they remain unable to display mastery of that topic, a remediating instructor must take a significantly different approach or run the risk of the student tuning out once they recognize the topic at hand.

[1] http://webwork.maa.org

Most students have an inflated sense of how well they understand math, particularly our remedial students. This is completely understandable, considering that these students currently hold a high school diploma, and therefore must have passed several years of high school mathematics classes. Asking them to go back and spend time focusing on their arithmetic skills is a difficult reality for students to accept. It is only natural that when students realize that their instructor is teaching something that they consider themselves as having already mastered, they tune out. As such, one of the priorities when developing this experiment was finding creative ways to present these basic arithmetic topics so that students would feel like they were working on something *new*. Not only that, but the aim was also to introduce a more rigorous algebraic perspective on arithmetic that would hopefully serve students in their follow-up algebra-based remedial math course.

As is the case with learning any new skill, improvement is largely the product of practice. And just as any sort of practice can be made more effective by receiving immediate feedback, math homework is no different. However, with the traditional pencil-and-paper homework approach, students attempt the assigned problems, turning them in to the instructor (if homework is even collected) for what is usually completion-based credit. If the students are fortunate enough to receive their homework back with feedback, it cannot be realistically expected to come back sooner than two weeks after the problems were originally assigned (assuming one week to complete the assignment, and another week to evaluate and provide feedback). In the meantime, any misconceptions remain, making further progress even more difficult. Ultimately, the task of providing individual homework feedback is very time-consuming and the delays inherent to this approach drive its effectiveness down to the point where most instructors reasonably conclude that it is not worth the effort.[10] Confronted with this unavoidable and almost certainly fatal flaw, the natural conclusion is to shift to online homework. Many studies have already shown that online homework is at least as good, if not more effective than traditional homework in math classes ranging from College Algebra through Calculus. [11-15]

While online homework resolves many of the issues that plague the pencil-and-paper approach, it is not without its own concerns. A common complaint of students adjusting to the stringent requirements of an online homework system is correctly parsing out mathematical expressions via keyboard. [16,17] The WeBWorK content created specifically for this experiment was scaffolded in such a way as to try to simplify the required responses throughout the solution process for most problems. While the final answers to the problems could not be made any simpler themselves, the intermediate scaffolding questions about the solution process attempted to bridge the gap between conceptual knowledge of an answer and technical competency in typing out that answer.

With only 15 total hours set aside for the arithmetic intervention workshop, it was important to make use of every available minute of instructional time. The initial idea was to engage students with modularized online content, accessed via tablet computer. Implementing self-directed learning helps to address students' individual needs while avoiding the natural disengagement that happens when a student is forced to spend extra time on a topic they have already mastered due to the struggles of their peers. However, having an entire classroom of students working independently is its own challenge because students tend to seek out assistance from the instructor, rather than from their peers.

The approach to address this potential issue was two-fold. First, each workshop classroom was supplemented by the inclusion of two peer leaders[2]. Furthermore, students were placed in small groups (2-3 students per group) depending on which modules they were currently attempting. The combination of these two strategies intended to make manageable the amount of attention required by students. Students were encouraged to make use of the online feedback first, their group members second, and then if they still had questions, to ask the instructor or peer leaders as a final resort.

Traditionally, with a fixed set of problems for the entire group, often students may rely on the 'smart kid' in the group to do the work, from whom everyone else simply copies.[18] Now, *following someone else's method* of solution can easily be misconstrued as *understanding the material* to the student who is doing the copying. Instructors know better, and as such, must employ creative measures to ensure equal participation and understanding when implementing group work. With the randomization inherent in WeBWorK providing different versions of each problem to each group member, students could collaboratively discuss the *method* of solution for any given problem without letting any individual student off the hook for solving their own version.

Research Questions:

With the shocking statistics outlined in the introduction, it was only natural to wonder if the placement exams at this institution were properly assigning students to the lowest remedial course. Could students be successfully 'bumped up' to a faster-paced remedial course with a quick review of arithmetic topics? Retention, engagement and self-assessment were identified as key aspects of success in remedial courses, and as such, it was important to look for potential improvement in these areas stemming from participation in the workshop.

- Does a digital arithmetic intervention have an effect on students' perceptions of their own mastery of topics?
- Does a digital arithmetic intervention increase student engagement and retention?
- Does a digital arithmetic intervention have a lasting effect on student performance in subsequent remedial courses?

[2] Peer leaders are undergraduates who have been trained in providing students with helpful feedback and problem-solving strategies. http://pltlis.org

Strategies and Instruments:

In order to address the problem of students tuning out topics that they perceive themselves as having already mastered instructional content was designed that offered alternative methods for approaching arithmetic problems. The general philosophy behind the structure of each module was to first hook students with one or two 'real-world' problems that could be solved using simple techniques, followed by instruction that eventually concludes with shorter, more efficient methods of solution. Generally speaking, 'real-world' problems are messy and time-consuming, and as such, they are an excellent source of motivation for learning advanced techniques that handle the solution process more elegantly. Moreover, showing students the relevance of the material that they are learning and contrasting the slow, basic solutions with the faster more advanced solutions combine to create a highly engaging lesson. If we, as math educators, stick to simple, integer-based problems, students will often shun advanced techniques for more rudimentary ones because they are more comfortable. We must give them a compelling reason to employ these advanced techniques.

With this in mind, the content created for this workshop intentionally required student interaction during the solution of simple problems – forcing students to input intermediate results throughout the solution process. These intermediate requirements were maintained as the difficulty of the problems increased, with the intent of reconciling students to the consistency of the solution process despite the intentionally 'scary' nature of the increasingly difficult problems. Over the course of the concluding practice problems in each module, the intermediate requirements were gradually reduced, until the final problems for each module contained no intermediate questions at all.

Using WeBWorK allowed us to address several of the previously mentioned obstacles. First of all, WeBWorK is designed to randomize problems for students, meaning that each student receives a different version of the same fundamental problem. For example, Student A might be asked to multiply 25.6 times 5.15 while Student B is asked to multiply 62.3 times 7.16. While the method of solution and the intermediate questions are the same for both students, the answers are not. As a result, students can work together and benefit from an abstract conversation about *how* to solve the problem without the risk of students simply 'borrowing' the answers from the first student to complete the problem. This feature of WeBWorK greatly facilitated the effectiveness of group learning as a strategy.

In addition, WeBWorK provides students with immediate feedback on their responses. While the feedback mechanisms of any computerized system will never be as helpful as getting feedback from a human expert, this feature greatly reduced the amount of individual assistance that students required during the workshop. At the very least, WeBWorK's immediate right/wrong evaluation of students' responses saved the instructors and peer leaders from the "am I on the right track?" line of questioning that is so prevalent whenever students are asked to work on problems in class. And at best, students are able to discover their own mistakes with the feedback provided by the WeBWorK system, allowing the instructors and peer leaders to focus on deeper conceptual issues plaguing other students around the room. Development of customized error messages in WeBWorK is possible, and was attempted in several problems. However, this potential needs to be more fully implemented before attempting to gather and analyze any associated data.

Faculty at all levels of instruction were asked for their input on the arithmetic topics to be covered in the experimental workshop. Of course the basic topics of addition, subtraction, multiplication, division, exponents and the order of operations were necessary; but the final list also included common factors and multiples, square roots, decimals, percents, and fractions. For each of these 11 topics, a custom instructional module was then developed for the WeBWorK online homework system.

3. Implementation:

Initially, 40 students were recruited for the workshop from the pool of incoming first-year students whose placement scores identified them as deficient in arithmetic. Students were told during advisement that they had the option of participating in an "Arithmetic Immersion Workshop" prior to their summer remedial math course. In this way, our sample was self-selected by students opting-in to additional instructional time. The overall limitation of 40 students was necessitated by the amount of equipment available to run the experiment.

Participation in the full amount of time allotted for the workshop was mandatory. Our study suffered from attrition due to attendance, as nine students failed to appear for the first day and three more students were absent on subsequent days. This left us with a sample size of 28 students who completed the full 15-hour workshop.

On the first day of class, students started by taking a pre-test (appendix A), followed by a survey asking them to identify arithmetic topics that they felt they already understood. They were informed that the pre-test did not count for a grade, and that it was merely to gauge their strengths and weaknesses in arithmetic. Following the one hour assessment, everyone engaged in an 'icebreaker'[3] designed to get the students comfortable with each other in preparation for working collaboratively. Because the pre-test could not be immediately scored, students were then assigned to begin the first four modules[4], regardless of their (then undetermined) performance on the pre-test. Also, as students were all starting on the same module, groups were determined primarily based on the rapport observed during the icebreaker. At the conclusion of the first day, students were strongly encouraged to make sure that they had completed the first four modules before coming to class the following day.

For the next three days, the instructor prepared student groups immediately prior to class, based on student progress through the modules. Students were then grouped together accordingly, and the instructor announced a target module for completion by the

[3] An 'icebreaker' is an activity, game, or event that is used to welcome and warm up the conversation among participants prior to collaborative exercises.
[4] Addition, Subtraction, Multiplication and Division

end of class. Even from the second day, it became apparent that some students were not progressing quickly enough to complete all the modules by the end of the workshop. The peer leaders were instructed to make sure that these students were closely monitored, kept on task, and that their questions were made a priority.

A considerable number of both on-track and struggling students alike continued their work outside of class, leading to some students having completed all the modules a day early. For these students, WeBWorK has a feature that allows students to re-visit previously completed problems and request a new version of that problem. Because WeBWorK is designed to randomize problems, these students were able to continue practicing difficult problems with fresh numbers and new answers.

On the final day of class, students who completed 100% of the modules worked with the instructor to review the material and prepare for the post-test. Students who were still behind in terms of completing the modules were grouped again as usual in order to make as much progress as possible. The final hour of the workshop was devoted to the post-test. Students knew that the post-test would be scored, and that their scores would determine which remedial math class they would be assigned to after the workshop.

The post-test consisted of 25 problems (appendix B), with each problem scored with three possible results: full-credit was given for problems that had a complete solution with a correct final answer; partial-credit was given only if the student showed mastery of the topic under which the problem was classified and had just one single technical error stemming from a different topic; and no credit was given if the student failed to show mastery of the classifying topic or if their solution contained more than one technical error in calculation.

Following the workshop, students who scored below 75% on the post-test (a total of 20 students) were assigned to the remedial course into which they would have been placed without the workshop. Those students who scored 75% or higher on the post-test were instead assigned to a faster-paced remedial course that covered the same content with 30 fewer instructional hours. Both follow-up remedial courses require that students pass two final exams, one of which is multiple choice and offers no partial credit. The CUNY Elementary Algebra Final Exam[5] (CEAFE) was chosen as a measurement of continued student success primarily because of the straightforward nature of the exam and impartiality due to its lack of partial credit.

Data Collected:

28 students completed the workshop. One student arrived late on the first day and did not take the pre-test or the pre-test self-assessment. As this student participated in the full treatment effect, their data is only considered towards retention and the summary of student opinions regarding the workshop.

[5] http://www.cuny.edu/academics/testing.html

- Pre-test (n=27): 28 questions covering the 11 topics
- Pre-test self-assessment (n=27): 11 topics – students answered “yes” or “no” with regards to their confidence in the stated topic.
- WeBWorK participation data (n=28): 11 modules – correct responses, number of incorrect attempts per problem.
- Post-test (n=28): 25 questions
- Post-test self-assessment (n=28): 11 topics – students answered “yes” or “no” with regards to their confidence in the stated topic.
- Attitude survey (n=28): 6 free-response questions
- CEAFE exam (n=24): one of the two final exams required of students who completed the subsequent remedial math course

Methods of Data Analysis:

All tests assume 95% confidence level ($p<0.05$) to reject the null hypothesis.
All samples were tested for normal distribution according to the Shapiro-Wilk test for normality.
Pearson’s product-moment test was used to measure correlation for normally distributed samples.
Kendall’s tau-b rank correlation was used for non-normally distributed samples. For instance, WeBWorK completion data was heavily skewed towards the top-end, with 16 of 28 students fully completing the online material. As such, any analysis involving this data requires a nonparametric correlation measure that can handle ties.

4. Results:

Performance-related Results:

Table 1. Normality Tests.

	Shapiro-Wilk p-value	Assumed normal
Pre-test (n=27)	0.468	Y
WeBWorK (n=27)	2.9e-05	N
Post-test (n=27)	0.691	Y
Raw improvement (n=27)	0.356	Y
Normalized gain (n=27)	0.389	Y
CEAFE Exam (n=24)	0.660	Y
Pre-test (n=24)	0.144	Y
WeBWorK (n=24)	2.6e-05	N
Post-test (n=24)	0.519	Y

A paired t-test shows that we can be very confident that there was an improvement between pre-test and post-test scores, with p-value = 2.436e-08, and an average raw improvement per student of roughly 26 percentage points. Even with limited time for instruction, it seems that students made substantial improvement.

As suggested by Safer and Segalla [12], the 'normalized gain' from pre-test to post-test is emphasized over raw improvement. Normalized gain is computed by dividing the raw improvement by the maximum improvement possible based on the student's pre-test score. With this measure, the relative gains made by students who scored well on the pre-test are not at a disadvantage with respect to those who had more room for improvement.

$$\text{Normalized Gain} = \frac{\text{Posttest score} - \text{Pretest score}}{100 - \text{Pretest score}}$$

Table 2. Workshop Correlation Measures.

	Pre-test	WeBWorK	Normalized Gain
WeBWorK	$0.34^{\dagger}$ (*)	--	--
Post-test	0.57 (**)	$0.39^{\dagger}$ (**)	N/A
Raw improvement	X	$0.30^{\dagger}$ (*)	N/A
Normalized gain	X	$0.35^{\dagger}$ (*)	--
Confidence count	N/A	$0.49^{\dagger}$ (**)	0.38 (**)
Accuracy count	N/A	X	0.56 (***)

N/A: not relevant, X: not significant, (*): 0.95 significance, (**): 0.99 significance, (***): 0.999 significance
†: correlation measure is Kendall's tau_b

First, students' pre-test scores were not significantly correlated to either their raw improvement scores or their normalized gain from pre-test to post-test (p=0.54 and p=0.094, respectively; table 1). This suggests that students benefited from the workshop with little regard to their skill-level when they entered. The relatively low p-value when comparing pre-test scores to raw improvement suggests that lower-performing students saw higher raw gains than their initially higher-performing peers. But when we adjust these improvement scores according to how much room for improvement each student had, we see that the p-value comes much closer to significance, suggesting that overall, this workshop may have benefited the initially-stronger students a bit more. However, considering that there was a significant correlation (p=0.023; table 1) between students' pre-test scores and their degree of WeBWorK completion, it might be reasonable to conclude that the potentially significant edge seen in the initially-stronger students having higher normalized gain might be due to their ease in covering the WeBWorK material more completely.

Overall, WeBWorK completion scores correlated strongly (p=0.0020; table 1) to the total number of topics for which students reported confidence on the post-test. Even more so, the WeBWorK completion scores did not significantly correspond (p=0.10; table 1) to the number of topics for which students *accurately* reported confidence on the post-test. These combined results suggest that students may be gauging their confidence in the topic based on the success they saw in practicing via WeBWorK. Due to the fact that several topics had multiple problems on either the pre-test or post-test, it is possible that students improved in a topic from the pre-test and yet were still measured to be "inaccurate" in their self-assessment on the post-test. In fact, the correlation between the total number of topics for which a student was confident and the normalized gain from pre-test to post-test was significant (p=0.0086; table 1). Putting these pieces together, it is reasonable to conclude that students gauged their confidence, at least somewhat, on the amount of online work they had completed, and furthermore they saw a corresponding benefit from this work on the post-test, though it may not have been enough to be considered "mastery."

WeBWorK scores were also significantly correlated (p=0.0093; table 1) to the post-test scores achieved by students. Even if we consider the normalized gains instead of the raw post-test score, there is still a significant correlation (p=0.019; table 1). It is unsurprising that the correlation is stronger between WeBWorK scores and the post-test, given the aforementioned likelihood of students who entered with stronger skills having had an easier time completing the WeBWorK, resulting in a stronger likelihood of scoring well on the post-test by virtue of their stronger initial skills (correlation between pre-test and post-test scores was significant, p=0.0018, with coefficient 0.57; table 1). However, the correlation between WeBWorK scores and normalized gain gives us reason to believe that the WeBWorK was an effective intervention in effecting students' relative improvement.

Table 3. Follow-up Data.

	CEAFE Exam	
	p-value	Correlation
Pre-test	0.060	X
WeBWorK†	0.0087	0.42
Post-test	0.00023	0.68

†: correlation measure is Kendall's tau_b

When looking to students who completed the remedial course following the workshop, we see continued correlations with the workshop data. The content of this workshop was designed to help students reconcile algebraic concepts to corresponding notions from arithmetic. One of the strongest correlations coming from the data we collected occurs between post-test scores and the CEAFE exam scores (the standardized exam students took at the end of the follow-up remedial course). With a p-value of 0.00023 and a coefficient of correlation of 0.68 (table 2), it is reasonable to conclude that the workshop accurately identified and prepared students in prerequisite topics, which then had a strong impact on their performance in the follow-up remedial course. In student interviews, after the follow-up course was completed, many of the interviewed students further supported this interpretation by pointing out different techniques from the workshop that continued to be helpful in the next course.

Furthermore, there was a significant correlation (p=0.0087; table 2) between WeBWorK completion and CEAFE exam scores. This correlation could be explained by the likelihood of correlation between the initially stronger students completing more WeBWorK, scoring higher on the post-test, and finally outperforming their initially-weaker peers on the CEAFE exam as well. Although this may be a potential factor, it is worth considering that the WeBWorK content was not completed exclusively by those students scoring among highest on the pre-test. It seems more reasonable to conclude that WeBWorK completion rates indicate those students who are more likely to dedicate the necessary time to complete supplied practice materials, especially for those students scoring poorly on the pre-test. If this is indeed the case, it also seems reasonable that these students would correspond to those scoring higher on a final exam such as the CEAFE.

Self-Assessment Results:

As is often the case in the math classroom, problems are rarely restricted to only one concept in order to solve. Problems on both the pre-test and post-test were categorized according to the primary topic of their content. Student results for the problems in each topic were divided into two groups based on whether the student had answered “yes” or “no” to the question of whether they felt confident in the given topic. Each group was then averaged to give a percentage of problems for which students in each category scored full credit.

An overwhelming number[6] of students responded confidently to the topics of addition, subtraction and multiplication in both the pre-test and post-test self-assessment surveys. As a result, the corresponding data for these topics was not interesting.

[6] 85-100% reported confidence in their addition, subtraction and multiplication skills on both pre- and post-tests.

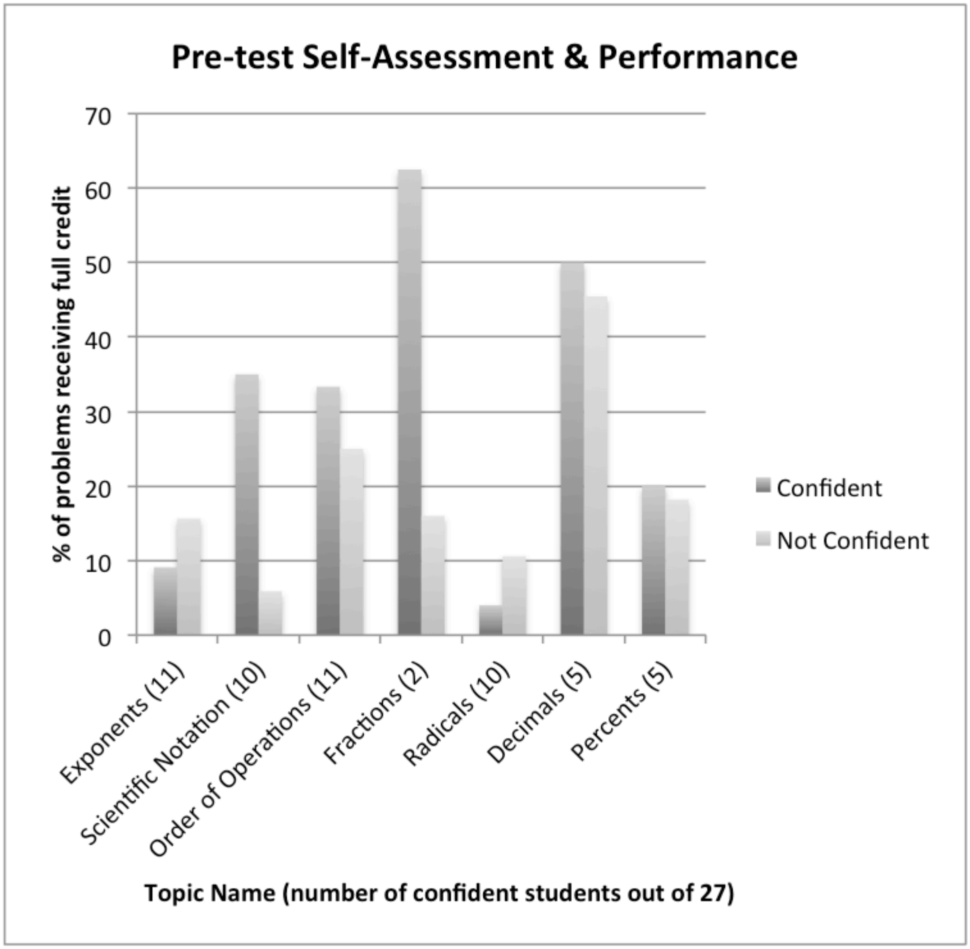

Figure 1 compares the average number of pre-test problems scored completely correct by "confident" and "not confident" students. The number in parenthesis for each topic provides the number of "confident" students out of 27 total.

Looking at the students' self-assessment in the topics of figure 1, we can see that students more accurately self-assessed themselves in the categories of scientific notation and fractions. In each of these categories, confident students' performance on problems dealing with that particular topic far exceeds the performance of their "not confident" counterparts. This suggests that students had a more accurate understanding of their own skills in the topics of scientific notation and fractions from the beginning of the workshop.

On the other hand, in topics such as exponents and radicals, "not confident" students outperformed students who identified as confident with the topic – suggesting that not only did students inaccurately judge their own skills, but they were more frequently the opposite of what they should have been. For example, the 11 students responding as "confident" in exponents scored worse than the remaining 16 students who identified as "not confident" with exponents. However, it is worth noting that the overall percentage of students answering any of these questions correctly is quite low regardless of confidence.

The remaining three topics: order of operations, decimals, and percents show little distinction between students who are confident and those who are not. This also suggests that students have not adequately gauged their own skills in these topics. Especially with the topic of decimals, there were 22 students who identified themselves as "not confident" with decimals; however, collectively they scored full credit on nearly half of their attempts.

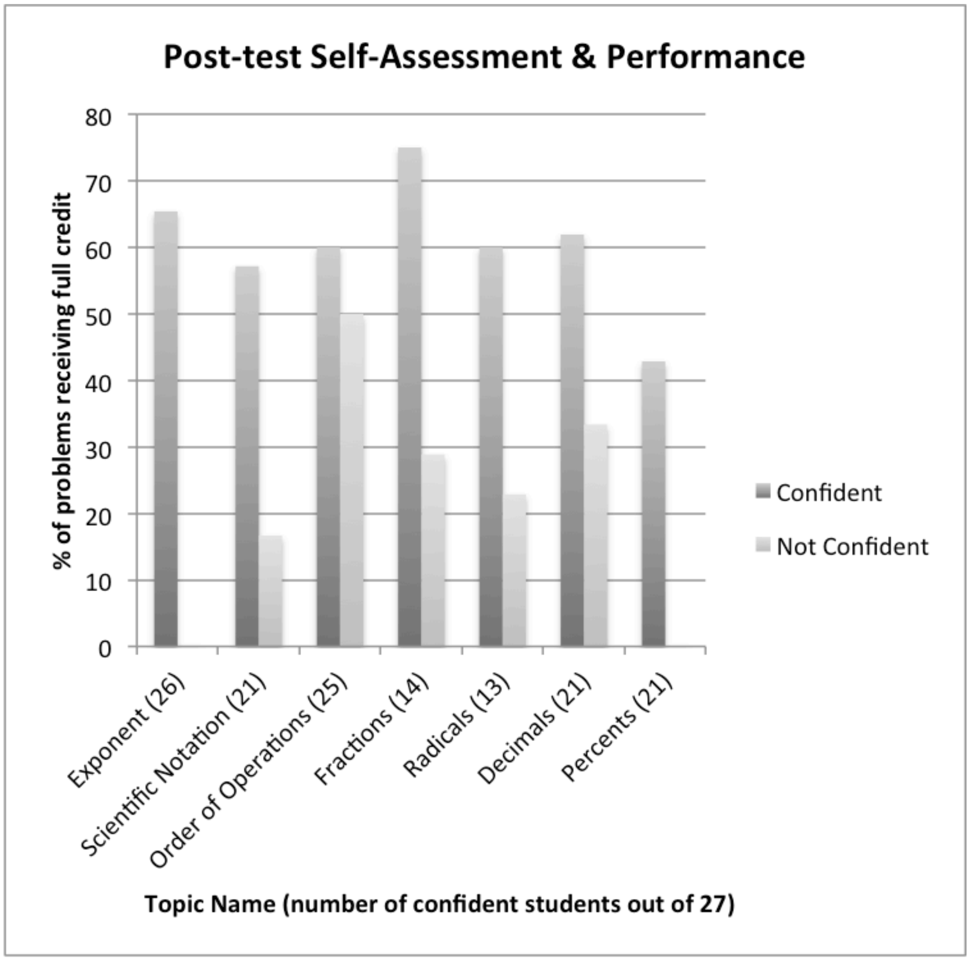

Figure 2 compares the average number of post-test problems scored completely correct by "confident" and "not confident" students. The number in parenthesis for each topic provides the number of "confident" students out of 27 total.

Following the post-test, students were again asked to report their confidence in the topics covered by the workshop. The same measurement was repeated, and the findings are displayed in figure 2.

There are several differences to notice about the data from the post-test self-assessment. First, the number of students reporting confidence in each topic has more than doubled in each topic; with the exception of radicals, whose "confident" group grew by three students. Second, the overall average number of completely correct responses has also increased in every topic, particularly for the "confident" groups. Finally, there are no longer any inversions of self-assessment and performance. In each category, with the possible exception of order of operations, students have appropriately distinguished themselves in terms of performance on each topic.

In the topics of scientific notation and fractions, students have retained their accuracy in assessing their own skill levels, even as the skill level for each group improved. Not only did the overall percentage of problems receiving full-credit improve, but each category gained newly confident students as well.

Using McNemar's test for marginal homogeneity, both order of operations and decimals exhibited statistically significant ($p=0.021$ and $p=0.0027$, respectively) improvement in the distribution of students' accurate assessment of their skills in these topics. There were four other topics showing non-significant improvement in self-assessment accuracy: multiplication, exponents, radicals, and percents.

Retention:

Of the 28 students completing the workshop, 25 of them completed the subsequent remedial math course, yielding an 89.3% retention rate. In follow-up interviews, students commonly remarked on the social ties formed during the workshop as beneficial to their continued studies.

Of the other 186 incoming first-year remedial math students similarly placed into the lowest level remedial math class, 144 of them completed the course, yielding a retention rate of 77.4%. In the previous summer, 110 of 159 incoming remedial math students completed the lowest level remedial class, for a retention rate of 69.2%.

When comparing these retention statistics to the broader mixed-group of new and returning students during the school year, the difference is even starker. Spring 2015 had a completion rate of only 45.1% in the lowest remedial course; 56.7% completed in Fall 2014; and 54.9% in the Spring 2014 semester.

Survey Results:

The 28 students who completed the workshop were surveyed about 6 different aspects of the workshop: meeting on consecutive days, the attention they received, the feedback provided by the online system, relearning topics, whether they prefer the approach of this workshop or a traditional class, and how much time they were engaged in learning during the workshop. All survey questions were free-response and some students left some questions blank.

All 27 of the students who answered the question about meeting on consecutive days responded positively. When explaining their preference for meeting on consecutive days, several common themes emerged: retaining what they had learned (18%), getting their questions about the material answered without having to wait (15%), and keeping the material "fresh" (37%).

As might be expected, students responded very positively to the amount of attention that they received during the workshop. 21 of the 27 responses to this question included the word 'help' or 'helpful'. For example, *"I received adequate attention during the workshop. It was very helpful because they helped me understand the problem and not just give me the answer."*

Student responses to the question about the feedback they received from the online homework system were largely positive, however a fair number of students were mixed between finding it 'somewhat' or 'not' helpful. Several adjustments have already been made to the customized feedback system of several problems in response to student suggestions – however, this is a good place to point out that online systems will *never* be able to fully replace the classroom experience. Additionally, student pushback to the strict requirements of a system such as WeBWorK is not at all unexpected. Part of the strength of implementing such a system is that it requires students to be detail-focused; they must read instructions completely and be careful about formatting their responses. For every student comment like, *"Sometimes [helpful,] but sometimes confuse me because they want the correct form,"* there is a corresponding comment, *"Although it was very picky with answers, that really helped me understand."* And quite frankly, one of the skills these students need to develop is precisely this notion of responding not just with a 'correct' answer, but formatting it appropriately for the context.

Students were also asked whether they felt like they had to relearn any topics during the workshop. Of the 27 students who answered this question, 22 of them affirmed that they had to completely relearn at least one topic. Of those who provided specific examples, 10 of them mentioned at least one of the basic operations (addition, subtraction, multiplication and division) with signed numbers. Other specific topics mentioned included: fractions (4), order of operations (2), and scientific notation (2).

All 28 students answered the question about whether they would prefer to keep using the workshop model or return to a traditional classroom. 86% of student said they preferred the workshop model, with an additional 11% saying they would like to see a hybrid of workshop techniques and traditional lectures. Students offered a variety of reasons for preferring the workshop model, describing the combination of iPads and WeBWorK as: *interesting, intuitive, helpful, modern, "easier to follow", "hands on", "helps students work at their own pace",* and "*it hooks students into the class."*

And finally, one of the things that impressed us the most: student engagement. From the first day, both the instructors and the peer leaders recognized the incredible amount of student engagement in the material. Students began each class promptly, getting their iPads and setting to work on the material immediately. Their level of engagement did not begin to wane until roughly the last 5-10 minutes of class each day. Students were not even asking for breaks during the 3-hour class, which is unheard of for such a long period of instructional time. Both professors took the approach of letting students determine their own short breaks throughout each day's class – but these breaks were observed to be infrequent and usually lasted only a couple minutes before the student returned to their studies without needing to be prompted.

Student responses to the question "What percent of the time would you say that you were actively learning during the workshop?" bore out these observations as well. Of the 27 students who answered this question, 14 responded with 100% and another 7 indicated 90% or more.

This question also asked students to compare their experience in the workshop to that of the traditional classroom. When describing the traditional classroom, students used phrases like: *talking, sleeping, lost, bored, confused, tiring, dazed, "not actually learning", "looking around to entertain myself",* and "*teachers do not stop for questions"*. But when describing the workshop model, they used phrases like: "*easier to focus", engaged, "more fun", "easier to learn", "really think about what to do", "working at my own pace", "there's always a new topic", rewarding, fast, challenging, "more helpful", interesting,* and "*actually learning something"*.

5. Conclusion and Discussion:

In the original design of this 15-hour intervention, student completion of material was a primary concern. With 11 topics and less than 13 hours available to devote to active learning, it was clear from the beginning that student engagement was going to make a huge difference in the effectiveness of this workshop. Both observations from students and instructors and the statistical results bore out the effectiveness of this intervention.

This high level of engagement was supported by technology in several ways. First, each student was provided with their own device, ensuring equal access to all students - the importance of which cannot be overstated. Second, the randomization of the content required every student to fully participate in completing each required task, while still providing enough similarity to allow for collaboration with his or her peers. Furthermore, the content itself was scaffolded so as to help students bridge the conceptual gaps in proceeding from simple concepts to more complex applications.

There were a lot of significant correlations in the analysis of student data. Understandably, students who scored higher on the pre-test were more likely to complete all 11 online modules; presumably because they had fewer conceptual gaps to fill. Being able to move through a few modules quickly would free up instructional time for them to spend on the topics where they needed more review.

Completing the WeBWorK modules significantly correlated to students' increased confidence, while not significantly corresponding to their accuracy in matching their confidence with performance. While the data did not fully capture the gains made by each student per topic, overall improvement in performance indicates that students' confidence may reflect their effort in completing the modules combined with an improved score – though that improvement may not have been enough to display full competency.

Neither the raw improvement nor the normalized gain from pre-test to post-test correlated with students' pre-test scores, indicating that this workshop was successful at reaching students regardless of their incoming skill level. Moreover, both of these measures of student improvement were significantly correlated to the degree of completion of the online material – further suggesting the efficacy of the content that was created for this workshop.

Furthermore, the strongly significant correlation between post-test scores and the CEAFE exam scores from the course immediately following the workshop also attests to the lasting impact of the workshop. And again, the lack of significant correlation from students' pre-test scores to CEAFE exam shows that the impact of this workshop was not necessarily limited by students' incoming skills.

Measuring a much smaller sample, this study still found retention improvement similar to Burch & Kuo[9]; an overwhelmingly positive student response Zerr[14] and Jacobson[16], even including nearly identical student complaints about answer formatting; improved engagement measures along the lines of those found by Zerr[14]; and outcomes where exam improvement did not necessarily match students' perception of learning, as did Jacobson[16].

As indicated by Scott-Clayton, Crosta and Belfield [4], incoming students are more likely to be incorrectly placed when their entrance exam scores are near test cutoffs. The success achieved by students placed according to their workshop performance suggests that this workshop could be useful as an optional secondary assessment for students with potentially ambiguous placement scores.

Additionally, with the amount of improvement on arithmetic topics shown by students participating in this study and the relatively short amount of time it required, the materials developed for this study might prove beneficial as an intervention for students in remediation who exhibit early warning signs of failure along the lines of what was implemented by Wladis, Offenholley and George.[19]

Directions for Future Study:

This study should be repeated with the inclusion of a control group receiving traditional lecture-style instruction of the same topics. This would control for the nature of students who opt-in to additional instruction. It would be even better if the control group could be matched by gender and other demographical data such as first-generation college students and English Language Learner students (both of these demographics were present in this study). With this additional data, the degree of effectiveness could be compared between instructional styles both in terms of normalized gain from pre-test to post-test during the workshop as well as CEAFE exam scores in the follow-up remedial course.

Analyzing students' self-assessment data might have been more illuminating if instead of asking students to simply respond "confident" or "not confident" in each topic, they had rather been asked to indicate their confidence on a Likert scale, akin to the self-efficacy measurements used by Wadsworth, Hudsman, Duggan & St. Pennington.[20] Having scaled confidence values could also potentially make use of collected partial-credit data that was not useful in the current analysis.

In order to investigate the effects of the workshop on practicing assigned homework, homework data should be collected from the follow-up remedial course for workshop students. This way, it could be assessed whether or not the dedication that students show in completing WeBWorK assignments during the workshop translates into completing homework in their next class.

This study would also benefit from an increase in sample size; however, due to the constraints imposed by the limited number of tablets available, an increased sample size is not likely at this institution for the foreseeable future. If this experiment is repeated, students who opt-in to the experiment should be contacted well in advance of the workshop and warned of the consequences of showing up late or skipping the first day. This could help to marginally increase the sample size by reducing the attrition that was experienced here due to lack of first-day attendance.

Bibliography:

[1] Bonham, Barbara S., and Hunter R. Boylan. "Developmental Mathematics: Challenges, Promising Practices, and Recent Initiatives." *Journal of Developmental Education* 34.3 (2011): 2.

[2] Bailey, Thomas, Dong Wook Jeong, and Sung-Woo Cho. "Referral, enrollment, and completion in developmental education sequences in community colleges."*Economics of Education Review* 29.2 (2010): 255-270.

[3] Attewell, Paul, et al. "New evidence on college remediation." *Journal of Higher Education* (2006): 886-924.

[4] Scott-Clayton, J., Crosta, P. M., & Belfield, C. R. (2014). Improving the Targeting of Treatment: Evidence From College Remediation. *Educational Evaluation and Policy Analysis*, 36(3), 371-393.

[5] Bahr, Peter Riley. "Does mathematics remediation work?: A comparative analysis of academic attainment among community college students." *Research in Higher Education* 49.5 (2008): 420-450.

[6] Schiel, J., & Sawyer, R. (2002). Using posttesting to show the effectiveness of developmental/remedial courses (ACT Research Report No. 2000-3). Iowa City, IA: ACT, Inc. Retrieved from http:// www.act.org/research/briefs/2002-3.html

[7] Fong, K., et al. "A different view on how we understand progression through the developmental math trajectory." *Los Angeles: Rossier School of Education, University of Southern California. Retrieved June* 6 (2013): 2013

[8] Epper, Rhonda M., and Elaine D. Baker. "Technology solutions for developmental math: An overview of current and emerging practices." *Journal of Developmental Education* 26.2 (2009): 4-23.

[9] Burch, Kimberly Jordan, and Yu-Ju Kuo. "Traditional vs. online homework in college algebra." *Mathematics and computer education* 44.1 (2010): 53.

[10] Brewer, David Shane, "The Effects of Online Homework on Achievement and Self-efficacy of College Algebra Students" (2009). All Graduate Theses and Dissertations. Paper 407. http://digitalcommons.usu.edu/etd/407

[11] Hauk, Shandy, and Angelo Segalla. "Student perceptions of the web-based homework program WeBWorK in moderate enrollment college algebra classes." *Journal of Computers in Mathematics and Science Teaching* 24.3 (2005): 229-253.

[12] Segalla, Angelo, and Alan Safer. "Web-based Mathematics Homework: A Case Study Using WeBWorK in College Algebra Classes." *Exchanges: The Online Journal of Teaching and Learning in the CSU* (2006).

[13] Weibel, Chuck and Lew Hirsch. Statistical evidence that web-based homework helps. MAA FOCUS, 23(2):14, 2003, http://www.maa.org/pubs/feb03.pdf

[14] Zerr, Ryan. "A quantitative and qualitative analysis of the effectiveness of online homework in first-semester calculus." *Journal of Computers in Mathematics and Science Teaching* 26.1 (2007): 55-73.

[15] Cunningham, Alice W., Olen Dias, and Nieves Angulo. "Math is not a spectator sport: The effect of online homework-completion tutoring on community college remedial mathematics performance." *Journal of Mathematics Education at Teachers College* 2.2 (2011).

[16] Jacobson, Eric. "Computer homework effectiveness in developmental mathematics." *Journal of Developmental Education* 29.3 (2006): 2.

[17] Leong, Kwan Eu, and Nathan Alexander. "Exploring Attitudes and Achievement of Web-Based Homework in Developmental Algebra." *Turkish Online Journal of Educational Technology* 12.4 (2013): 75-79.

[18] Berardi, Victor. "The Impact of Using Randomized Homework Values on Student Learning." *Journal of Effective Teaching* (2011): 4.

[19] Wladis, Claire, Kathleen Offenholley, and Michael George. "Leveraging Technology to Improve Developmental Mathematics Course Completion: Evaluation of a Large-Scale Intervention." *Community College Journal of Research and Practice* 38.12 (2014): 1083-1096.

[20] Wadsworth, J. H., et al. "Online mathematics achievement: Effects of learning strategies and self-efficacy." *Journal of Developmental Education* 30.2 (2007): 6-14.