Algebra Nspired Research Study Phase 2
Final Report

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by
The Center for Technology in Learning
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Executive Summary

The Algebra Nspired Phase 2 research study examined the added value of TI-Nspire Navigator™ classroom network technology as an enhancement to the Algebra Nspired (ALN) instructional materials and TI-Nspire™ handheld devices. Algebra Nspired is a suite of supplemental curricular materials that leverage the affordances of TI-Nspire and TI-Nspire Navigator to enhance instruction and support student learning. In particular, the ALN materials are designed to foster deep student understanding of important mathematics concepts. The TI-Nspire Navigator system has the potential to enhance instruction by wirelessly connecting student devices to a teacher computer to enable teachers and students to jointly construct, observe, and manipulate mathematical representations.

The goal of the Phase 2 research was to address the following research questions:

1. How does the effectiveness of an Algebra curriculum unit taught with TI-Nspire and Algebra Nspired change when it is enhanced by TI-Nspire Navigator, and the unit is implemented as designed?
2. What factors support strong implementation of TI resources (including TI-Nspire, ALN, and TI-Nspire Navigator)?
3. How might the Algebra Nspired learning activities be improved to facilitate greater implementation fidelity and deeper learning for students?

The Phase 2 ALN research yielded the following key findings:

- TI-Nspire Navigator is an important component of the ALN resource suite that complements other TI resources (i.e. ALN and TI-Nspire)
- The research found a marginally significant increase in learning associated with TI-Nspire Navigator, above and beyond TI-Nspire and ALN. (This result may be an underestimate of the full impact, due to implementation variation and other factors inherent to the research.)
- The ALN resource suite influenced teacher pedagogy to emphasize deeper learning for students
- Teachers believe that the ALN resource suite contributed to increased student engagement and supported deeper student learning
- In comparison with their less experienced peers, teachers with *more experience* with TI-Nspire and TI-Nspire Navigator:
    - Were more likely to shift their pedagogy to include more high-level instructional activities
    - Reported that their students were more engaged and learned more
    - Had students who learned more math
- Teachers who *used the technology more frequently* also reported that their students were more engaged and learned more math

These findings have some important implications for practitioners. Most importantly, the research shows that teachers need to have the opportunity to become familiar with the technology in order to accrue maximum benefits for students. In this study, teachers who had been using the technology for a longer

period of time had stronger outcomes. Thus, one strategy is to enable teachers to integrate the technology and stand-alone instructional materials into their regular instruction at their own pace, with the expectation that within just a few years they would develop the familiarity and skills to truly leverage those resources to benefit students. Alternatively, high-quality professional development could theoretically serve as a substitute for time with regard to providing teachers with the experience they need to make the most of the ALN resources.

The Algebra Nspired Phase 2 research suggests that TI-Nspire Navigator is an integral feature of the ALN resource suite. TI-Nspire Navigator appears to support marginal (incremental) student learning gains, especially for higher-achieving students and for students with teachers who have more technology experience. Like ALN and TI-Nspire, TI-Nspire Navigator also supports pedagogical improvements, which could further enhance student learning. It may also be the case that the compilation of the entire ALN resource suite—ALN materials and TI-Nspire and TI-Nspire Navigator—has more powerful benefits for student learning than any of the resources individually. Future research may investigate this hypothesis, examining the value of the ALN resource suite in its entirety as compared with regular instruction without *any* of these resources.

Introduction and Research Goals

The Algebra Nspired (ALN) research study had two distinct phases. The goal of Phase I was to measure the impact of a specified, concentrated intervention using Algebra Nspired materials as an enhancement to TI-Nspire, for student learning in the linear function unit of Algebra I. The study also explored factors related to successful implementation of the Algebra Nspired intervention, and made general recommendations for strengthening the Algebra Nspired resources that TI makes available for teachers. Phase I of this research took place between April 2010 and March 2011. See the detailed Phase I *Research Design* and *Final Report* for more information about Phase I of the ALN research.[1]

The goal of the current study, Algebra Nspired Phase 2, was to measure the impact of TI-Nspire Navigator, as an added enhancement to TI-Nspire and Algebra Nspired, for student learning in the linear function unit of Algebra I. The research also explored supports and barriers to successful implementation of the full suite of ALN resources—i.e. Algebra Nspired, TI-Nspire, and TI-Nspire Navigator. Phase 2 of the research took place between January 2011 and April 2012.

The full suite of resources (ALN materials plus technology) is designed to foster deep student understanding of important mathematics concepts. Algebra Nspired consists of a collection of supplemental curricular materials designed for use with TI-Nspire software and, optionally, TI-Nspire Navigator classroom connectivity technology. The ALN materials are available publicly online, as part of the Math Nspired series of supplemental lessons. Each lesson is designed to be a stand-alone activity, such that teachers can pick and choose individual lessons to use with their students; and teachers have the ability to edit any of the lesson worksheets and activity files. TI-Nspire is an individual mobile device with extended graphing calculator capabilities. TI-Nspire Navigator is a classroom networking system linking all of the student devices to a teacher computer to enable seamless file exchange and data transfer, collaborative construction of mathematical representations, and other interactive features. Taken together, the goal of this suite is to support deep student understanding of important concepts in mathematics.

Background: ALN Research Phase I

Phase I of the Algebra Nspired research study examined the implementation and impact of a specified intervention using ALN resources as an enhancement to TI-Nspire. TI-Nspire Navigator was not part of Phase I.

The research questions for Phase I of the study were as follows:

1. How does the effectiveness of an Algebra curriculum unit taught with TI-Nspire change when it is enhanced by Algebra Nspired learning activities, and the lessons are implemented as designed?

[1] These reports are available at the TI research library, accessible from: http://education.ti.com/research.

2. How might the Algebra Nspired learning activities be improved to facilitate greater implementation fidelity and deeper learning for students?

The Phase I research yielded the following key findings:

- More teacher experience with TI-Nspire and more frequent use of TI-Nspire both contributed to greater student learning outcomes (within the treatment group)
- When teachers used TI-Nspire and ALN, their pedagogy changed to emphasize deeper learning for students
- Teachers reported that TI-Nspire contributed to increased student engagement—and that both TI-Nspire and ALN supported deeper student learning
- However, the research found no statistically significant increase in student learning associated with ALN, above and beyond TI-Nspire (note that sample size was relatively small, so the comparison was not very sensitive).
- ALN appears to help teachers understand and realize the potential of TI-Nspire, more than to directly improve student learning, at least while teachers are using the ALN materials for the first time.

These relationships suggest that ALN has potential to enhance math instruction. Teachers also see benefits for student engagement and student learning, even before those benefits translate into learning gains on tests. But teachers need sufficient familiarity with the technology—and they need to use TI-Nspire and ALN with some minimum frequency and intensity—in order to accrue those benefits for their teaching. The current Algebra Nspired Phase 2 research study examines the teacher-student link in the relationship between ALN resources, teachers, and students by asking: Does enhancing teacher-student interaction via TI-Nspire Navigator *also* enhance student learning?

Research Questions for Phase 2 Study

The focus of this research is the effectiveness of TI-Nspire Navigator, as an enhancement to TI-Nspire and Algebra Nspired, on student learning in the linear function unit of Algebra I. The research also seeks to identify factors that support strong implementation of the full suite of ALN resources, and opportunities to strengthen the ALN resources so as to improve implementation and, in turn, student learning.

The research questions for Phase 2 of the study are as follows:

1. How does the effectiveness of an Algebra curriculum unit taught with TI-Nspire and Algebra Nspired change when it is enhanced by TI-Nspire Navigator, and the lessons are implemented as designed?
2. What factors support strong implementation of TI resources (including TI-Nspire, ALN, and TI-Nspire Navigator)?
3. How might the Algebra Nspired learning activities be improved to facilitate greater implementation fidelity and deeper learning for students?

The following section describes the research methods.

Research Methods

The research used a mixed-methods approach and a pre-post comparison within a delayed treatment design (Table 1). In Phase 1, we randomly assigned schools to either the treatment or control group. Teachers in both groups taught the slope and linear function unit using their regular curriculum and TI-Nspire; teachers in the treatment group also used the eight supplemental ALN lessons on slope and linear function. In Phase 2, all teachers implemented the full suite of resources—namely Algebra Nspired, TI-Nspire, and TI-Nspire Navigator—during the slope and linear function unit of Algebra I.

Table 1: Algebra Nspired Research Design

Research Group	Phase 1 Control	Phase 1 Treatment (Phase 2 Comparison)	Phase 2 Treatment
Implementation dates	Oct 2010 – February 2011		Oct 2011 – February 2012
Regular curriculum slope & linear function unit	Yes	Yes	Yes
TI-Nspire	Yes	Yes	Yes
ALN lessons	No	Yes	Yes
TI-Nspire Navigator	No	No	Yes

The Phase 2 research compares the student learning results from Phase 2, with the results from the Phase 1 treatment group, in order to examine the added benefit of TI-Nspire Navigator, on top of TI-Nspire and ALN. In other words, the current research compares results from teachers who used ALN, TI-Nspire, and TI-Nspire Navigator this year, with results from teachers who used just ALN and TI-Nspire last year. The design does not isolate the effect of ALN (last year) or TI-Nspire Navigator (this year) from the rest of the enacted curriculum. The varied business-as-usual curricula that teachers used operated in conjunction with the ALN resources within each individual classroom to produce the observed results. At the same time, the use of ALN (last year) and TI-Nspire Navigator (this year) was the only *systematic* difference between the groups, allowing us to examine the impact of these individual resources.

The ALN Intervention and Data Collection

Teachers who completed Phase 1 received their TI-Nspire Navigator systems in spring 2011. To compensate for attrition, nine additional teachers were recruited for Phase 2 (of whom eight completed the study). These teachers received their TI-Nspire Navigator systems during the summer of 2011. The research guidelines asked teachers to use TI-Nspire and TI-Nspire Navigator technology regularly (about 2x/week) starting as soon as the TI-Nspire Navigator system was set up and

continuing through the fall semester. All participants received the standard TI-Nspire Navigator professional development, including some explicit training about using ALN materials with TI-Nspire Navigator, during the summer.

Teachers used their regular curriculum (which varied across teachers) and integrated the ALN lessons as they fit within the linear function unit. As a result, the timing of the ALN lessons also varied considerably across teachers, from October 2011 through February 2012. Teachers administered the ALN pre-test just before beginning the linear function unit, and the ALN post-test just after finishing the unit. Teachers completed a pre-questionnaire just before the unit; a post-questionnaire just after the unit; and an ALN Lesson Log after teaching each of the eight ALN lessons. In addition, in fall 2011, SRI researchers conducted interviews and classroom observations with a sub-set of participants.

Research Instruments and Measures

The ALN Phase 2 research includes three key data sources: 1) student assessment data from Algebra Nspired pre- and post-tests; 2) teacher-reported data from a Pre-Implementation Questionnaire, Post-Implementation Questionnaire, and an Algebra Nspired Lesson Log completed by all teachers after teaching each of the eight ALN lessons; and 3) qualitative data from teacher interviews and classroom observations with a sub-set of participating teachers.

The ***Algebra Nspired student assessment*** was identical to the ALN assessment that we created and used for the Phase 1 research. The assessment was designed to align with the instructional goals of the intervention, including items that address both basic skills and conceptual understanding. The final assessment had 28 items, the majority of which were multiple-choice items, with a few open-response items. The majority of these items came from existing research-based assessments, including NAEP, TIMSS, PISA, and state standardized tests from California, Ohio, Florida, and Massachusetts. SRI also created a number of items from scratch, in order to align with particular ALN objectives for which we were unable to find acceptable existing items. We did not alter the assessment at all, in order to ensure that assessment results would be comparable across the two phases of research. For more details about the assessment development and characteristics, see the ALN Phase 1 Final Report.

The ***teacher-reported data protocols*** (pre- and post-questionnaire and lesson logs) were also nearly identical to the Phase 1 versions of these same instruments. Again, to enable comparisons of data from Phase 1 to Phase 2, we kept the instruments mostly intact. In order to capture information about the added component of TI-Nspire Navigator, we added some new questions to these instruments about the implementation and impacts of the TI-Nspire Navigator technology. For more details about the contents of the questionnaires and lesson logs, see the ALN Phase 1 Final Report.

For the Phase 2 research, we also created a teacher interview protocol and a classroom observation protocol, to capture information during our telephone interviews and site visits. The ***classroom observation protocol*** enabled researchers to collect information about how teachers use TI resources (specifically, TI-Nspire, ALN, and TI-Nspire Navigator) in the classroom. For example, the protocol included information about: the classroom context (e.g. physical environment); the lesson content (math objectives and goals, etc.); lesson activities (e.g. warm-up, main activity); teacher pedagogy (using pedagogical metrics that align with those in other ALN data collection instruments); classroom interactions (e.g. teacher questions, student discussion); and student engagement.

The ***interview protocol*** enabled researchers to talk with teachers both about the observed lesson and about their overall experiences using the ALN resources in the classroom. For example, the interviews covered: strengths and weaknesses of the ALN resources themselves (e.g. ALN content and language; technology challenges); contextual factors that support or hinder teachers in being able to effectively implement the ALN resources in the classroom (e.g. school- and district-level characteristics that impact implementation); and perceived student outcomes associated with the TI resources (e.g. student engagement and student learning).

Research Validity

The research is predicated on the comparability of the treatment and comparison groups, and the sound performance of the data collection instruments. This section describes the research sample (including a priori characteristics of the participants) and features of the research instruments (including response rates and performance of the assessment) to establish the validity of the research.

Study Sample

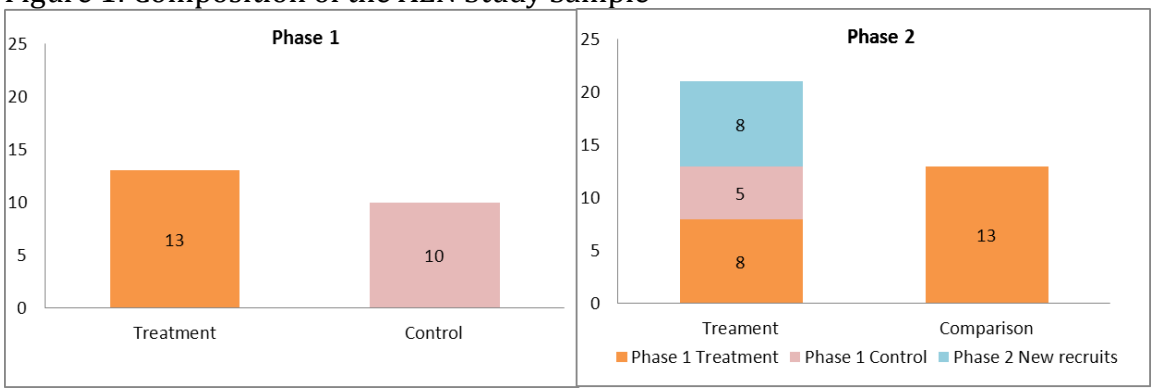
All of the participants in this study are Algebra I mathematics teachers in California who volunteered to take part in this research. Most participants taught in high schools, although a few teachers taught in middle schools (this year, 3/21). The participants have classroom sets of TI-Nspire devices and some familiarity using TI-Nspire in the classroom; they all began using TI-Nspire Navigator prior to the Phase 2 research. Teachers use a variety of different Algebra I textbooks, curricula, and pacing guides.

In the current study, the treatment group includes all of the teachers who participated in Phase 2, implementing the slope and linear function unit using the full suite of ALN resources—Algebra Nspired materials, TI-Nspire, and TI-Nspire Navigator. The comparison group consists of teachers who participated in the treatment group last year, i.e. implementing the unit using TI-Nspire and Algebra Nspired.

The final Phase 2 research sample includes 21 participants: 8 former-treatment, 5 former-control, and 8 new recruits, from 15 different schools overall (Figure 1). At

the outset, the Phase 2 sample consisted of 32 teachers, including all of the teachers who completed Phase 1, plus nine newly recruited teachers, eight of whom came from the same school.[2] As is common, the research experienced some attrition, primarily due to individual circumstances. In one case, we dropped one participant from the analytic sample because that teacher failed to implement the intervention with an acceptable degree of fidelity—specifically, using TI-Nspire Navigator for only two of eight ALN lessons. To note, this breakdown means that eight teachers appear in both the Phase 2 treatment and comparison groups, having participated last year using both ALN and TI-Nspire, and this year using ALN, TI-Nspire, and TI-Nspire Navigator. This year, the average class size was 28 students, with a range from 17 to 37 students (based on submitted assessments).

Figure 1: Composition of the ALN Study Sample



Overall, the treatment and comparison groups were similar, a priori, on a variety of characteristics, suggesting that it is appropriate to compare implementation and outcomes for the two groups. Since there were only two new schools in the sample this year, it is not surprising that the school demographics are similar across groups (Table 2).

Table 2: School-level Demographics

	Treatment *This year's schools*	Comparison *Last year's treatment group*
Number of students (avg)	2177	1949
Student : teacher ratio (avg)	24:1	23:1
White (%)	17.9	15.4
African-American (%)	6.7	13.0
Hispanic (%)	66.7	66.5
Asian/Pacific Islander (%)	5.1	2.7
FRPL (%)	65.8	66.0

The teacher-reported student demographic data revealed that the treatment and comparison groups were roughly similar with regard to percentages of low-,

[2] A total of 23 teachers completed Phase I of the research study, including 13 treatment and 10 control, from 19 different schools.

middle-, and high-achieving students, and percentages of ELL and special education students. Further, in both groups, teachers reported that the vast majority of their students had not used the technology before this school year (73.9% treatment; 75% comparison).

With regard to student achievement, pre-test scores revealed that students in both groups had similar prior understanding of slope and linear function (Table 3). The overall average pre-test scores did not show a statistically significant difference between the two groups. As in Phase I, we categorized the items on the assessment in two ways: difficulty level (easy, medium, and hard) and skill-type (procedural, conceptual, or both). The two groups did not differ significantly in their pre-test performance on any of the sub-categories of items either.

Table 3: Comparison of pre-test scores

	Treatment	Comparison	Significance (p-value)
Overall	37.6%	37.6%	.98
Easy	40.7%	38.9%	.59
Medium	36.2%	36.0%	.96
Hard	30.8%	34.5%	.29
Procedural	32.4%	34.9%	.41
Conceptual	41.1%	37.9%	.25
Both	37.3%	38.6%	.73

Not surprisingly, treatment group teachers had slightly more experience than comparison group teachers, both in terms of overall teaching experience and experience with TI-Nspire. This makes sense given that the two groups include eight overlapping teachers, who gained an extra year of experience from last year to this year. Given that the Phase 1 research showed that teachers with more experience with TI-Nspire had students with higher learning gains, this difference in experience is important for interpreting the Phase 2 results[3]. To note, teachers participating in Phase 2 had 1.5 years average experience with TI-Nspire Navigator.

Instrument performance

Most teachers completed all the data collection activities required for participation in the research. All teachers included in the analysis sample administered the pre-test and post-test to their Algebra I students. All of the teachers also completed the Pre-Implementation Questionnaire and the Post-Implementation Questionnaire. The completion rate for the ALN Lesson Logs was as follows: 15 teachers completed all 8 logs; 3 teachers completed 7 logs; 1 teacher completed 6 logs; and 2 teachers completed 4 logs. To analyze the log data, we collapsed the data for each teacher, across all of the logs submitted by that teacher. For teachers who did not complete all eight logs, we simply collapsed the data from the logs that they did submit. We

[3] This finding applied to the treatment group only, and was correlational in nature; the difference was not statistically significant.

then used the collapsed data to create basic descriptive statistics and run additional analyses for the log data.

The ALN student assessment performed well, as it did in Phase I. In both years, the majority of teachers told their students that the Algebra Nspired post-test would count toward their class grade. As such, we would expect that students took the test seriously. Again the average student scores on the items categorized as easy, medium, and difficult, respectively, suggest that these a priori categorizations accurately reflect the difficulty level of the items (Table 4).

Table 4: Average student post-test scores, by item difficulty level

	Treatment *Phase 2 classrooms, using ALN, TI-Nspire, & TI-Nspire Navigator*	Comparison *Phase 1 classrooms, using ALN & TI-Nspire, but NOT TI-Nspire Navigator*
Easy	60.1%	56.1%
Medium	44.7%	43.3%
Hard	37.4%	37.0%

Moreover, the pre-test scores had a very large range: from 0-100% in the comparison and from 0-93% in the treatment. Given this range, and the fact that the mean scores fell somewhere in the middle for both groups, it is unlikely that students encountered either a floor or ceiling effect on the post-test.

Because the Algebra Nspired study was a small-scale pilot study, it was necessarily limited as far as sample size and data collection. Nonetheless, within its scope, the research design was upheld (i.e. the Phase 1 randomization was upheld, and the treatment and comparison groups were comparable on a variety of a priori characteristics), the instruments performed appropriately, and the study did not encounter any overt problems or biases.

Research Findings

This section describes the research findings related to classroom implementation of the ALN resource suite; teacher outcomes with regard to pedagogical change; teachers' perceptions about the impact of the ALN resources for student engagement and student learning; and the impact of TI-Nspire Navigator for student learning outcomes. The results come from all of the multiple data sources for this study, including teacher-reported data on questionnaires and logs; student assessment results; and qualitative findings from interviews and observations.

Implementation Basics

While the treatment and comparison groups were similar on a variety of a priori characteristics, some implementation differences did emerge. These differences relate broadly to the students' opportunity to learn the target math content, and appear to consistently favor the comparison group. Although it is impossible to quantify the impact of this implementation variation, it is important to consider

these differences when interpreting the research results, because they might have led to an underestimate of the effect size of the treatment.

Opportunity to Learn the Target Content

First, the data indicate that the comparison group students had slightly more time in math class than treatment group students—giving the comparison group students more time on task and thus greater opportunity to learn. Within the treatment group, fewer classes met on a daily schedule than was the case for the comparison group (78.3% treatment; 91.7% comparison). At the same time, the treatment group had shorter average class duration (62.0 minutes treatment; 71.7 minutes comparison). Treatment group students also spent slightly less time doing the actual ALN lessons (average of 44.9 minutes treatment; 51.1 minutes comparison), which accumulated to less total time on ALN (average of 330 minutes per class for the treatment, compared with 400 minutes for the comparison).[4] Within both groups, teachers spent a variable amount of time on the slope and linear function unit—ranging from 2-10 weeks for the treatment to 2-8 weeks in the comparison.

Second, treatment and comparison teachers did not uniformly cover the topics on the ALN assessment during the ALN unit. In Phase 1 (last year) most teachers covered all of the topics in the linear function unit *after* the pre-test (83.3%) and *before* the post-test (91.7%). In Phase 2 (this year), most teachers covered some topics *before* the pre-test (66.7%) and some topics *after* the post-test (95.2%), meaning that students did not learn as much of the content in between the two tests. This trend theoretically advantages the comparison group, where students learned everything between the pre- and post-test, enabling them to make the greatest gains from one test to the next.

Classroom practice within our study sample was fairly typical. Observations revealed that students typically sat in rows facing forward; and most classes split their time between individual or pair/group work, and whole-class instruction. In all of the observed classes, the ALN worksheet was the primary guide for the lesson: teachers and students followed the worksheet chronologically, and they did not use any additional textbooks or materials.

Adopting ALN Materials into Instruction

Overall, teachers this year found it easy to integrate the ALN lessons into their scope and sequence (i.e. finding time), and even easier to integrate the ALN content with their regular curriculum (i.e. aligning content). Moreover, teachers had a slightly easier time this year than they did last year—perhaps because many teachers participating this year had already gone through the process once before. The majority of treatment teachers (61.9%) reported that it was either somewhat or very *easy* to fit the ALN lessons into their scope and sequence. In contrast, the majority of comparison teachers (66.7%) reported that it was either somewhat or

[4] The total amount of time spent on ALN ranged from 160 to 505 minutes in the treatment group, and from 167 to 568 minutes in the comparison group.

very *difficult* to fit the ALN lessons into their scope and sequence. In both cases, challenges arose primarily for teachers who were required to follow a strict district or school-based pacing guide, especially when that teacher was the only one in the school implementing ALN. One teacher explained,

> Our pacing guide is very impacted. I had to squeeze in activities and assessments around set dates for tests and lessons. This has put me a week behind my PLC […].

Many of the teachers who reported that finding time for ALN was not a problem also noted that they had freedom and flexibility with regard to pacing schedules, or they had extra time with their class for some reason, allowing them to integrate ALN easily. Some teachers acknowledged the benefits of spending more time with ALN upfront. One of the treatment group teachers reported,

> The linear equation unit is never an easy or short concept to teach. Most of the time is spent re-teaching when students do not understand. This time it was spent more with discovery learning and less re-teaching needed to take place. So even though it seemed longer to teach the topics, it evened out in the end with student learning and understanding.

This year, most teachers found it easy to align ALN content with their curriculum. Specifically, 71.4% of treatment teachers said aligning content was somewhat or very easy (compared with 58.3% of comparison teachers). In interviews and written comments, teachers expressed near unanimity that the ALN content aligned well with their regular curriculum. For example, teachers said,

> The lessons cover the same content, but in a different way. It is easy for a teacher to incorporate the lessons.

> The alignment was very close to our textbook, and if it wasn't the error was more because the textbook did not explain enough of a concept.

As indicated in these comments, teachers also agreed that the ALN content "goes deeper" and focuses more on conceptual understanding than the regular curricula/textbooks, which tend to be more procedural. Teachers also see ALN as more challenging for students than the regular curriculum.

For the most part, teachers used the ALN lessons as they came—using the whole worksheet without making many changes. This year, teachers reported that, on average, they asked students to complete most or all of the questions on the student worksheets.[5] At the same time, teachers did not usually make changes to the

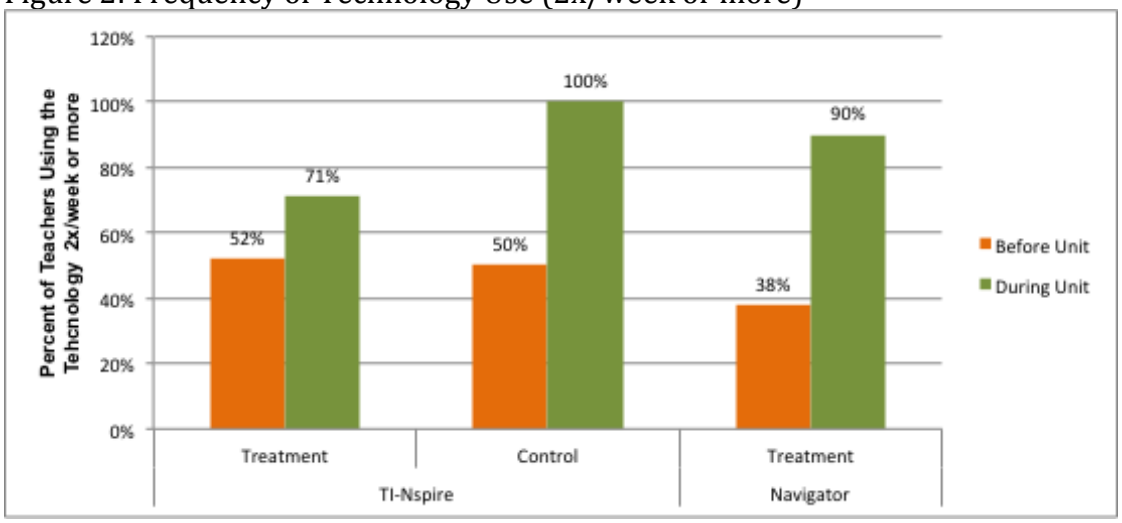
[5] This pattern contrasts with last year, where most teachers asked students to complete none or some of the questions on the worksheet. This difference could theoretically impact differential

lessons: this year, teachers made changes on 36% of lessons on average, compared with 29% of lessons last year.[6] Although teachers made changes on a minority of lessons overall, the fact that treatment group teachers made more changes may stem from the fact that these teachers had already used the ALN worksheet in the past and therefore knew from experience of specific changes they wanted to make.

Technology Access and Usage in ALN classrooms

Technology access and usage was roughly similar across groups and aligned with the research guidelines (Figure 2).[7] In all cases, teachers used the technology more during the ALN unit than before, perhaps simply because the sequence of ALN lessons required for this study provided a set agenda of technology-based activities. Only one teacher reported never having used TI-Nspire Navigator in the current school year prior to starting the slope and linear function unit.

Figure 2: Frequency of Technology Use (2x/week or more)



To note, the majority of classes in both groups had touch-pads on their Nspire devices (82.6% treatment; 75% comparison). And the vast majority of students in both groups were not permitted to take the devices home with them (95.7% treatment; 100% comparison).

On average, treatment group teachers used TI-Nspire Navigator on 96% of the ALN lessons that they taught during the unit. The ALN lesson logs and the classroom observations both confirmed that teachers used Screen Capture and Live Presenter very frequently—much more so than any of the other TI-Nspire Navigator

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learning outcomes between the treatment and the comparison. But we would only be able to assess and interpret that impact with a definitive understanding of how ALN impacts student learning.

[6] As an example, teachers commonly reported (33/60 open-ended responses) that they explained the questions for their students by clarifying the wording and/or changing the vocabulary, so that students would understand what the question was asking.

[7] The exception was the one teacher who reported using TI-Navigator for only two of the eight ALN lessons. This teacher was dropped from the analytic sample, as described above.

applications. On average, teachers used Screen Capture and Live Presenter in 93% of their ALN lessons; teachers used both of these tools in all five of the observed lessons. Of Live Presenter, teachers said, for example:

> I love Live Presenter. That is my favorite feature of TI-Nspire Navigator. All the students want to be live presenters and they want to be picked for doing the live presenter. They walk though the problems and they can see the other person doing the problem and it is a great way to train in solving problems. Live Presenter is the best!
>
> The Live Presenter feature also helps to guide students. Words are not enough when you are studying transformations and slope.

The next most common TI-Nspire Navigator tools were Quick Poll (77% of lessons; 3/5 observed lessons) and Transfer Tools (73%); teachers did not use OS Transfer (22%) or Question App (18%) very commonly. The observations indicated that students used the technology (TI-Nspire and TI-Nspire Navigator) mostly to work on math problems, whether for warm-up or as part of the main class activity. Students also commonly shared their screens—a functionality that teachers and students both appreciated enormously.

Teacher Outcomes: Changes in Teacher Practice

The ALN resource suite has the potential to impact teacher pedagogy: Graphing calculators (i.e. TI-Nspire hand-held devices) and classroom network technology (i.e. TI-Nspire Navigator) have both been found to impact teaching; the ALN Phase 1 research also found that the ALN materials influence pedagogy. The current research has multiple ways of looking at changes in teacher practice. First, the post-implementation questionnaire asked teachers directly whether or not they taught differently when they used TI-Nspire (all teachers) or TI-Nspire Navigator (treatment teachers only). Second, teachers answered two questions about the characteristics of their instructional practice both on the pre-implementation questionnaire and on each of the eight Algebra Nspired lesson logs. By comparing teacher reports of their instructional practices prior to implementing ALN, with those during the ALN unit, we can examine changes empirically.[8] Third, during interviews, researchers asked teachers about how each of the components of the ALN resource suite impacted their teaching.

For teachers, the TI-Nspire and TI-Nspire Navigator technology appear to go hand-in-hand. Although we asked about experiences with these two different technologies separately, teachers often responded interchangeably about either

[8] Self-reports are inherently limited because respondents may be inclined to provide what they presume to be "good" answers. The data from the direct questions about pedagogical changes are certainly subject to this risk. The data from comparing teacher responses about practice over time are less likely to suffer from this bias, because it is unlikely that teachers would remember precisely how they responded to the question on previous questions, and further, to intentionally shift their responses over time.

technology. More to the point, teachers indicated that both technologies have a similar influence on instruction (and similar benefits for student learning). This trend is important because it indicates that teachers see the two technologies as a coherent unit—both in terms of integrating the technologies into classroom practice, and in terms of the style of teaching and learning that they promote.

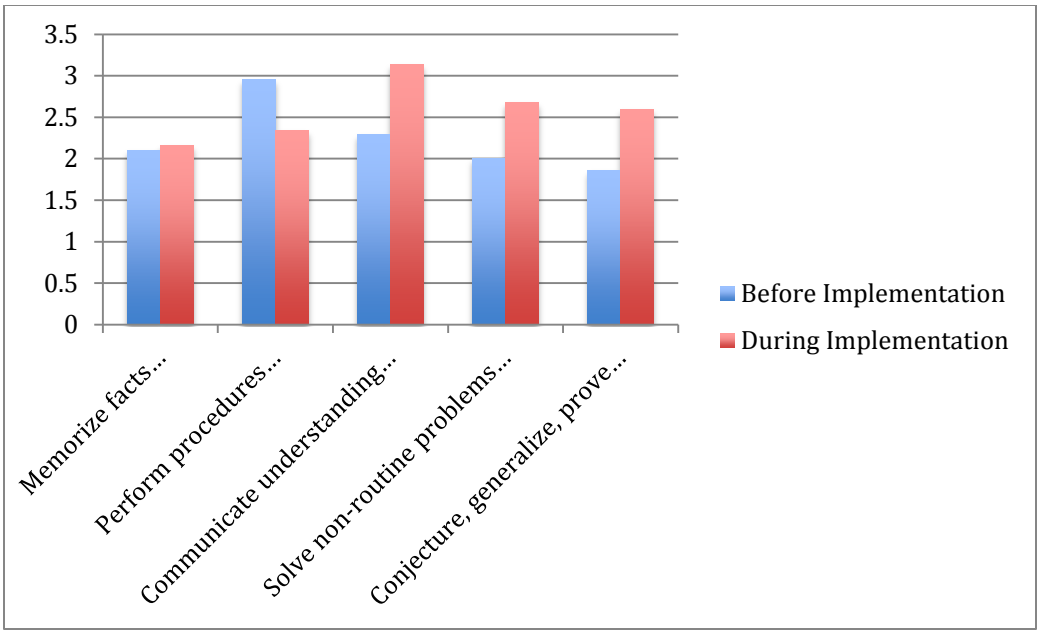
Did the TI technologies influence teacher practice?

The research found that the ALN resource suite did influence teacher practice—and indeed, evidence suggests that each of the three individual resources contributed to these changes. When asked explicitly, most teachers said that the technology impacted their teaching practice. Most teachers reported teaching differently with TI-Nspire than without (85.7% treatment; 66.7% comparison). And within the treatment group, most teachers (76.2%) also said that they taught differently with TI-Nspire Navigator than without. During interviews, most teachers (4/7) reported that the TI technology (TI-Nspire and TI-Nspire Navigator combined) did impact their teaching.

Comparing teacher responses about their own pedagogy before implementation, with responses during the ALN unit, confirms that ***teacher practice did change in some important ways—and moreover, that the ALN resources contributed to these changes***. From the beginning of the school year, teachers were using TI-Nspire and TI-Nspire Navigator technology; when they began the slope unit, they introduced the ALN lesson materials. Thus, changes from before to during implementation of the target unit reflect, at least in part, the influence of the ALN lesson materials.

This year, we found that teachers did not change how they structured their classes: both before and during the unit, teachers used whole class activities most commonly, followed by pair/group work and individual work. Teachers did, however, alter the tasks they most commonly asked students to complete. Notably, the relative frequency with which teachers asked students to perform "higher-order activities"—such as communicating concepts, solving non-routine problems, and making conjectures—increased during the ALN unit (Figure 3).

Figure 3: Frequency of math activities, prior-to and during Phase 2 Algebra Nspired implementation (i.e. treatment group)



Comparing practices from last year to this year also shows that, in both years, teacher practice was similar before the unit—and using ALN catalyzed similar changes during the unit. This pattern indicates that teachers have similar practices whether they are using just TI-Nspire or the combination of TI-Nspire and TI-Nspire Navigator. Further, the findings suggest that ALN has a similar *impact on pedagogy*, regardless of whether teachers are using just TI-Nspire or both TI-Nspire and TI-Nspire Navigator. In both cases, the ALN resource suite (and specifically the ALN lessons themselves) appeared to promote instructional practices that offer opportunities for deeper student learning.

Evidence from the classroom observations tempers the teacher-reported findings about pedagogy. In the observed classes, the "middle-band" of instructional activities was the most common: teachers frequently conducted more routine practices, like asking students to perform procedures or solve routine problems (5/5 observations). They also commonly asked students to communicate their understanding of concepts (5/5 observations) and provide depth or clarity for their answers (4/5 observations). Activities at the ends of the spectrum, including memorizing facts at one end, and solving non-routine problems or making conjectures at the other, were much less common (observed in only one or two lessons each).

Taken together, these findings about teacher practice are important for understanding how teachers use the ALN resource suite, and how the resources influence instruction. Teachers clearly believe that the technology influences their practice. And indeed, the data indicate that teachers did shift their practice to include more high-level instructional activities, when using the ALN materials in conjunction with the technology. Nonetheless, observations indicated the *most common* instructional practices with the ALN resources were still mid-level

activities, such as teachers explaining concepts and procedures, and students solving routine problems and explaining their answers. Our admittedly small observation sample suggests that the highest-level instructional activities are still the bailiwick of the most advanced teachers, and do not represent common, widespread usage for the ALN resource suite.

How did the technology influence teacher practice?

Teachers were consistent in their reviews about precisely how the technology influenced their instruction. For the most part, teachers spoke interchangeably about TI-Nspire and TI-Nspire Navigator. However, teachers did specify that TI-Nspire Navigator—above and beyond TI-Nspire—made their instruction (and the ALN lessons) more powerful. One teacher reported being glad that he was in the control group last year, since he would not have wanted to implement Algebra Nspired without TI-Nspire Navigator. He said,

> I would never use the Nspire calculators separately. It is extremely helpful to have the Navigator system with the calculators.

With regard to the whole ensemble, teachers reliably reported that when using the ALN suite of resources, their ***instruction became more "student-centered"*** and less teacher-led. In interviews, for example, two teachers who said they were typically very lecture-based reported that the ALN suite changed their pedagogy and got students doing more thinking for themselves. Teachers found that the technology enabled and encouraged students to manipulate and explore the mathematics for themselves, creating a more student-centered environment. On the questionnaires, teachers cited this change when thinking about both TI-Nspire and TI-Nspire Navigator, suggesting that the two technologies complement each other in supporting this type of pedagogy. For example, teachers reported:

> I relied more heavily on the Nspire handhelds for student discovery as opposed to lecture and textbook examples. Also, I used more discussion based on the Navigator responses.

> My "normal" teaching consists greatly of lectures and note taking as opposed to discovery based learning like the TI-Nspire lessons.

Often in the same breath that they mentioned student-centered instruction, teachers would also talk about the fact that when using the ALN resources, they ***focused more on conceptual understanding than procedural skills***, as compared with their typical instruction. Not surprisingly, one teacher whose normal instruction focused heavily on conceptual understanding reported that her instruction did not change when she used the ALN resources. Other teachers described the conceptual depth fostered by the ALN resources. For example, one teacher reported: "ALN focused on conceptual development, not teaching rules or step-wise learning."

Teachers also commonly cited one of the intended benefits of the technology—namely that it can provide ***immediate feedback to teachers*** about student

understanding. Teachers can then use that information to adjust their instruction accordingly—whether to change gears for the whole class, or address particular topics with specific individuals. In their logs, teachers reported that, on average, they used feedback from TI-Nspire Navigator to inform instruction during 73% of lessons. It is likely that teachers also used TI-Nspire Navigator to inform future lesson plans, making this capability one of the most used features of TI-Nspire Navigator. During interviews and in their written responses, many teachers highlighted this feature as one of the most valuable aspects of the technology. One teacher spoke for many when he said:

> With Navigator we are able to take the pulse of the class, see where exactly everyone is, see warm-up, see it on the bar group, who needs extra help, guides to the lesson, who didn't get it right, who did. That is powerful!

This immediate feedback provided by the technology further enabled teachers to ***adjust instruction and address misconceptions***. Some teachers also mentioned that the feedback enabled them to "monitor students" to ensure that they remained "on task". Teachers also mentioned the flip side of this same coin—namely that TI-Nspire Navigator increases student accountability because students know that the teacher can see what they are doing. One teacher summed it up, explaining:

> With Nspire this year, I was able to hold all students accountable for their own understanding and bring individual misunderstandings to light. This allowed for great teachable moments, and less students left behind.

Finally, teachers reported that the technology enabled them to provide more ***individualized and differentiated instruction*** for students. Using the TI-Nspire devices, students are able to work independently while teachers monitor their progress. Based on the feedback from the technology, teachers can provide differentiated assistance to individuals or small groups of students who need help with particular topics or skills. One teacher described this benefit as follows:

> Teaching with Navigator allows me to quickly check for understanding and deal with issues of understanding on an individual basis rather than wasting many students' time by having a whole group discussion on concepts that most already understand. This also means that I have to plan accordingly to differentiate instruction when students show understanding.

Taken together, the evidence clearly suggests that the ALN resources influence instruction in the classroom and promote more high-level pedagogy to some degree.

Student Outcomes: Teacher-Reported Engagement and Learning

This research found that teachers were enthusiastic about the value of all the ALN resources for both student engagement and student learning. In a pattern that

parallels the findings from last year, the research found that teachers were more enthusiastic about the value of these resources for learning than for engagement. Further, teachers were most positive about the benefits of TI-Nspire Navigator, followed by TI-Nspire, and then by ALN. These findings are important because they indicate the relative value that teachers attribute to each of the three components of the resource suite.

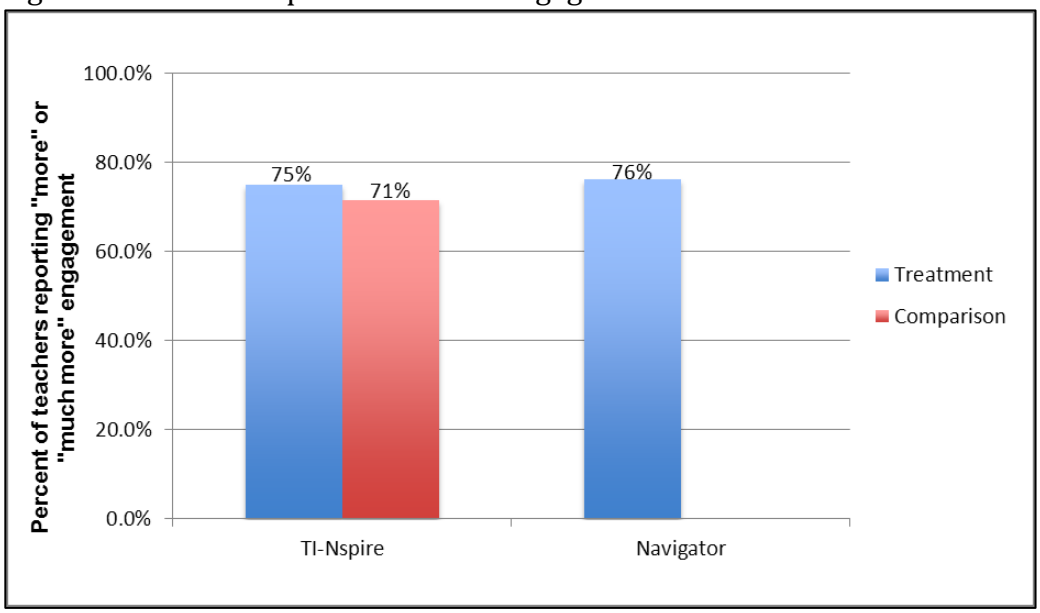
Teacher-Reported Student Engagement

Overall, most teachers reported that ***the ALN resource suite overall improved engagement for some or all of their students***. One teacher spoke enthusiastically about ALN, writing:

> As a result of the Algebra Nspired technology and activities, I observed more student engagement. [...] The students loved open response questions from the quick polls. They would always want me to ask them a question and to reveal their responses to the whole class.

In particular, teachers reported that ***students liked the TI technology,*** including both TI-Nspire and TI-Nspire Navigator. On the post-questionnaire, a majority of treatment teachers reported that TI-Nspire and TI-Nspire Navigator both increased student engagement (75.0% and 76.2% respectively; Figure 4).

Figure 4: Teacher-Reported Student Engagement



In interviews, teachers made more of a distinction between student responses to the different technologies. While most teachers said that students liked TI-Nspire, teachers unanimously reported that students loved TI-Nspire Navigator.

> Navigator is very fun for the students. They enjoy using technology and love seeing their answer pop up on the LCD projector. It gives every student a voice, but in a safe format because it's anonymous to everyone but me.

Students especially loved using Live Presenter—one teacher even said their students would "beg" to be the Live Presenter. Students also enjoyed the freedom to work at their own pace and the anonymity provided by the calculators. Of course, technical glitches with the TI-Nspire devices sometimes frustrated students, who are accustomed to the very user-friendly, smoothly operating, touch-screen technology of modern smart phones.

In contrast to the technology, teachers reported that many ***students found the ALN worksheets frustrating***, mostly because the language was confusing. This language problem was true for all students, but particularly for ELL students and students who struggle with reading. According to teachers, students also responded negatively to the worksheets simply because they were more challenging than the assignments they usually face and they would rather not tax themselves.

Notably, many teachers described a ***common trajectory of student responses*** to the resources. When teachers first introduced the technology, students were excited and engaged because the whole Algebra Nspired suite was new and intriguing. Eventually, however, the novelty wore off and some of that initial engagement dissipated. One teacher described this scenario:

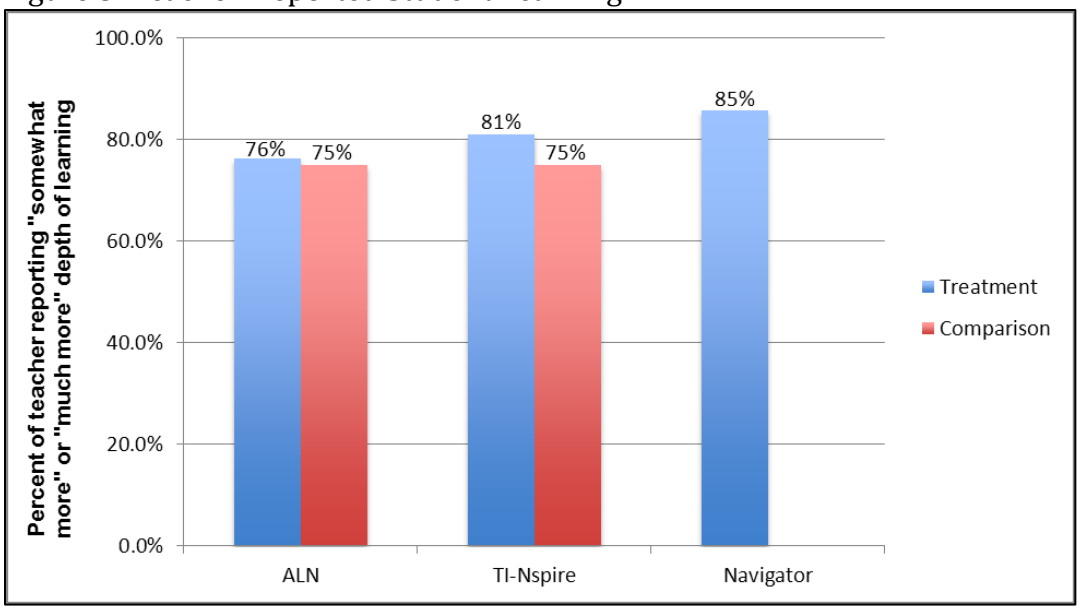
> Students like variety. They like novelty. When I introduced the Nspires and the Navigator system, my students were amazed. They couldn't wait to get started. As they learned how to use the system, it became routine. Now they view it as another tool.

While the observations could not tell us whether the observed students were more or less engaged while using the ALN resources than they would have been otherwise, they did provide insight into student engagement in the moment. Of course it is no surprise that technology is not a panacea for student engagement. As is typical, in some observed classes, students were paying attention and staying on-task, while other classes had more behavior problems. Indeed, of the teachers who mentioned behavior in their open-ended responses, two said student behavior improved with the ALN resources, but one said behavior declined.

Teacher-Reported Student Learning

Teachers were overwhelmingly positive about the value of the Algebra Nspired resources for student learning. The majority of teachers, in both the treatment and comparison groups, reported that each of the individual resources supported student learning (Figure 5). This year, teachers were most enthusiastic about the value of TI-Nspire Navigator, followed by TI-Nspire, and then the Algebra Nspired materials.

Figure 5: Teacher-Reported Student Learning



On their lesson logs, teachers reported that TI-Nspire Navigator enhanced instruction and student learning on 92% of the ALN lessons, on average. In interviews, however, teachers expressed a more nuanced perspective about the influence of ALN resources on student learning: four of seven interviewed teachers reported that student learning improved, thanks at least in part to some components of the ALN resource suite. Two of these teachers identified TI-Nspire Navigator in particular as the essential tool that supported student learning. One teacher explained:

> [I noticed] anxiety going down, [students] feel they are playing, learning, and being recognized. Learning goes up with the tools, [but] not because of the lessons…Navigator definitely supports the goal of deeper student understanding. A few arguments broke out and I loved it because it was all centered around math.

Teachers also qualified their statements about student learning, ***saying that the ALN suite is more beneficial for higher-achieving students than lower-achieving students***. Teachers reported this same trend last year, before the introduction of TI-Nspire Navigator. The fact that teachers still believed this to be the case suggests that TI-Nspire Navigator did not substantially expand the reach of these resources to make them equally valuable for lower- and higher-achieving students.

As was the case for engagement, teachers were consistent with their reports about precisely how the ALN resources support student learning. One of the ways that the resources boost learning is that they ***support greater content depth*** than regular instruction. In general, teachers found that the ability of TI-Nspire and TI-Nspire Navigator to ***provide dynamic visualizations*** of the content and to enable students

to contribute responses (sometimes anonymously) contributed to their ability to engage students with a deeper level of mathematical content than they would otherwise. For example, one teacher reported:

> The ability to move the lines on the graphs allowed me to show students the different components of the slope-intercept form in greater depth, especially since many of my students will not graph anything on paper.

The observations provided evidence that, indeed, one of the biggest immediately observable benefits of the technology is its ability to enable students to see—and therefore understand—important mathematical concepts. For example, during one lesson on slope, the teacher was displaying a student calculator screen for the class to see. The student was changing the y-coordinates of a point on a line, and watching the line change slope accordingly. With each change, the class could see whether the line was rising or falling, and whether the line had a positive or negative slope. The student answered the teacher's question and then exclaimed in disbelief, "I got it? I got it right!" Without even waiting for the teacher's confirmation, the student could see that they had understood the concept and that they were getting the answers right.

A minority of teachers (2/7 interviewed teachers) expressed the opposite belief, reporting that the tools help students get the basic concepts well, but that they do not support deeper conceptual understanding. One teacher explained:

> They are getting an understanding, but [it's] not deep. It's still surface level. I am not sure these lessons are bringing out the more complex issues for them.

Teachers also reported that the resources enable ***students to engage in more active learning***. Teachers used a variety of terms to describe the similar phenomenon that occurs when students are able to get their hands on the technology—and thus on the math itself—in order to manipulate the mathematics for themselves. Teachers report that the technology caused students to be more active in their learning and thus allows for more student discovery. For example, teachers said:

> Using TI-Nspire allowed the students to approach linear functions from a visual and hands-on approach. I believe it added more meaning to what they were learning.

> I think that letting students "play" and explore on the TI-Nspire handhelds is much more powerful and memorable than having them create graphs using paper and pencil.

Many teachers reported that they would use Live Presenter to have students who understood the material explain it to their peers. Teachers explained that this

strategy helped teach students how to solve problems. Moreover, students enjoyed being the "live presenter".

> Allowing students to be presenters, as opposed to me verbally giving instructions was incredibly helpful. After a few uses of student presenters, they were fighting about who could get to be the presenter. It's always nice to have students to compete for participation in the class. [PostQ]

Teachers generally perceived TI-Nspire and TI-Nspire Navigator to contribute equally to each of these benefits for student learning—but in one case teachers highlighted the value of TI-Nspire Navigator alone: Teachers consistently reported that TI-Nspire Navigator in particular supported ***greater student discussions around mathematics***, including ***students asking deeper, more investigative questions***. Because the teacher and students all see and manipulate the same mathematical representations, they can engage in meaningful conversations about what is happening on the screen. Teachers reported that students wanted to know why their peers' answers looked different from theirs and how they arrived at those answers, leading them into substantive mathematical debates. One teacher explained:

> In particular [...] student-led Live Presenter fosters more rich classroom discussions than when I control a TI-Nspire emulator from a Smart Board, and [other applications] spark great class conversations about why certain responses are correct/incorrect.

> Typically, I would display student responses to questions and we would critique the responses as a class. We would not simply look for correct or incorrect, but also if answers were complete as worded or if they required elaboration. Perhaps some responses illuminated an aspect of the problem that had not been mentioned as well.

Taken together, these findings are promising because they show that teachers see value in the ALN resources for both student engagement and student learning. Teachers are an important resource for understanding the true impact of any instructional resource in the classroom because they are often able to identify changes in student outcomes before those changes would appear on any standardized measure.

Student Outcomes: Mathematics Achievement

The primary outcome for this research was student learning, as measured by the Algebra Nspired pre- and post-test. In line with teacher perceptions, ***students who used TI-Nspire Navigator did learn more, on average, than students who did not use TI-Nspire Navigator***. However, this difference was only *marginally significant* for gain scores, and was *not significant* for post-test scores controlling for pre-test (Table 5). In other words, it is reasonably likely that the difference in gain scores was not due to chance alone, but was at least partly attributable to the impact of

Navigator. For the analysis of post-test scores, the evidence does not rule out the possibility that any observed differences were due to chance (or other unmeasured factors).[9] An examination of outcomes on each of the sub-groups of items revealed no significant differences between the two groups of students.[10]

Table 5: Student learning on the ALN Assessment of Slope and Linear Function

	Treatment	Comparison	P-value
Pre-test average	37.6%	37.6%	0.98
Post-test average	50.5%	48.1%	0.63
Average gain	12.9 percentage points	10.4 percentage points	0.09
Regression of post-test score, controlling for pre-test			0.25

These findings are encouraging and indicate the potential of TI-Nspire Navigator alone to enhance student learning. Moreover, the actual value of TI-Nspire Navigator may be even greater than observed. Factors that may have led to an underestimate of the impact findings include: the study was underpowered because of a small sample size; implementation variation appeared to benefit the comparison group; demonstrating changes in student learning on assessments is difficult; and the assessment itself may not have been sufficiently sensitive to the type of student learning taking place.

Regarding this last point, assessments used to measure student achievement may or may not be accurate measures of student learning—or more specifically, of the type of student learning supported by a particular intervention. In the case of Algebra Nspired, the content of the assessment was very closely aligned with the content of the instruction. The format of the test, however, differed substantially from how students engage with the material when they are using TI-Nspire and TI-Nspire Navigator. The ALN suite aims to improve student understanding of complex mathematical concepts by allowing students to manipulate different mathematical representations. The ALN assessment, in contrast, was a predominantly multiple-choice, which could arguably be more suited to traditional teaching and learning.

Relationships: Factors that Support Student Learning

In addition to the trends illustrating the value of TI-Nspire Navigator the research also uncovered some important factors that support student learning. As was the case last year, ***more teacher experience with the technology was associated with greater learning for students***. Specifically, teachers with more experience with TI-

[9] Note that the two analyses have slightly different meanings. The gain scores tell us how much students learn regardless of their starting point, while the analysis of post-test scores controlling for pre-test (ANCOVA) tells us how much students would be expected to learn if they all started at the same initial achievement level.

[10] As described above, the items on the ALN assessment were grouped both by difficulty level (easy, medium, hard); and by task-type (conceptual, procedural, both).

Nspire had students who learned more than students of teachers with less experience ($p<0.05$ gain scores and controlled post-test). Further, teachers with more experience with TI-Nspire Navigator had students who learned more than students of teachers with less experience ($p<0.05$ gain scores and controlled post-test). While these findings are instructive, it is important to note that the majority of the teachers in the sample had between zero and two years of experience with TI-Nspire (61.9%) and TI-Nspire Navigator (85.7%). Thus it was a small number of teachers who had more experience with the technology, especially for TI-Nspire Navigator.

These results confirm the findings from last year suggesting that teachers need to become familiar with the technology in order for students to maximally benefit from the enhanced learning opportunities that the technology affords. At the same time, none of the teachers in our sample had enormous amounts of experience with either technology. As noted above, most teachers had 0-2 years of experience with the technology; and only three teachers had more than three years experience with either technology. Thus, it is not the case that teachers need to practice for years on end before they are able to accrue benefits for their students. Instead, teachers simply need some minimal opportunity to get comfortable with the technology, in order to be able to use it most effectively.

Unlike last year, however, this year ***we did not see a relationship between how frequently teachers used the technology and student learning***. One possible explanation is that all participating teachers were using the technology quite frequently this year, such that there was not a sufficient range of practice to enable us to discern impacts for student learning.

Teacher experience with the technology and frequency of technology use were also related, in various constellations, to pedagogical change and to teacher reports about student engagement and student learning. Specifically, ***teachers with more experience teaching Algebra and more experience using TI-Nspire Navigator were more likely to shift their pedagogy during the ALN unit to include more high-level instructional activities*** ($p=<.1$ for both). Not every relationship was statistically significant, but the trend still strongly suggests that teachers who have more time to become familiar with the technology, and teachers who use the technology more frequently in the classroom, are those that reap benefits for teaching and learning.

Teachers' technology experience and frequency of use was also related to teacher reports about student engagement and learning. Teachers with more experience with TI-Nspire and TI-Nspire Navigator were more likely to report that these technologies, respectively, increased student engagement ($p=<.05$ for both). Similarly, teachers who used TI-Nspire Navigator more frequently were more likely to report that TI-Nspire Navigator increased student engagement ($p=<.05$); although this relationship did not hold true for TI-Nspire. At the same time, teachers with more experience with the technology, and who used the technology

more frequently, were also more likely to report that some or all components of the ALN resource suite supported greater student understanding (p=<.05 and p=<.1, for different relationships).

The research also found that the ***use of TI-Nspire Navigator did not appear to equalize or democratize learning for students***. As was the case last year, student ability levels were associated with student learning: In classes with higher percentages of high-achieving students, students learned more ($p<0.1$ for gain scores; $p<0.05$ for controlled post-test scores). Similarly, in classes with higher percentages of low-achieving students, students learned less ($p<0.1$ for post-test scores controlling for pre-test scores). Last year, this relationship held true in all participating classrooms (including those with and without ALN) suggesting that ALN was not better (or worse) for students at any particular achievement level than the regular curriculum. The fact that the relationship between student ability levels and student learning persisted this year indicates that TI-Nspire Navigator did not counteract the status quo. At the same time, there is no evidence to suggest that TI-Nspire Navigator exacerbated the trend or enlarged the learning gap. In sum, the evidence suggest that both ALN and TI-Nspire Navigator are neither better nor worse for students at different ability levels than the regular curriculum alone; these resources neither decrease nor enlarge the existing learning gap.

Challenges with Implementing the ALN Resource Suite

The challenges that teachers reported fell into three main categories: a) the language on the ALN worksheets; b) miscellaneous technology glitches; and c) helping students adjust to new tools and a new style of learning. As was the case last year, some teachers reported that ***students struggled with the language on the ALN worksheets*** (3/13 teachers mentioned this challenge in open-ended responses at the end of the unit; others also mentioned language problems with individual lessons on their lesson logs). The language presented difficulties for all students, but especially for those who struggled with reading and for ELL students. One teacher said:

> Students had problems with the language used in the questions and instructions. I had to rephrase many of the instructions and questions, especially for my English Language Learners.

In addition to challenges with the ALN worksheets, ***some teachers also experienced miscellaneous problems with the technology*** (4/13). For example, two teachers had trouble getting TI-Nspire Navigator to connect to the devices; in another instance some keys on one of the TI-Nspire devices weren't functioning. Some teachers (4/13) also reported that students found the technology cumbersome and became frustrated when it didn't function as smoothly as they expected. However, by and large, teachers were able to resolve whatever

technological challenges they (or their students) encountered and move forward with instruction. [11]

Finally, some teachers (4/13) mentioned that ***adjusting to new tools and a new pedagogical style was a challenge*** for their classes. For example, some teachers explained:

> Some students see [the ALN resources] as a stumbling block. I heard comments like, "The calculator stuff is more confusing than our other work." It might be because the Nspire activities focus on concepts instead of procedures. Students want a formula and steps.
>
> The students' adaptation to student-centered learning from teacher-centered [was a challenge].
>
> It was a real challenge to keep the students engaged in inquiry activities when they are accustomed to being told exactly what to write and think at all times.

None of these challenges were insurmountable. In each case, teachers were resourceful and persistent, and were able to resolve or work around the problems they encountered.

Recommendations for Practice

The findings from this research suggest multiple recommendations for practice. This section describes strategies for when and how to implement the ALN resource suite in order to obtain the optimal benefits for students, based on the research findings.

1. Don't overburden first-year Algebra teachers with new technology (unless of course they are already familiar with the technology!)

The research found that teachers with more experience teaching Algebra I are more likely to shift their pedagogy to include more high-level instructional activities. This finding indicates that there might be a "sweet spot" for introducing technology into a teacher's repertoire. If teachers are not already accustomed to the technology, then adding this tool to the plethora of new practices and resources teachers are trying to master during their first year or two of teaching may be too much. After adjusting to teaching Algebra I in the first place, teachers may be better able to incorporate new technologies into their instruction.

2. Give teachers time to become familiar with the technology.

[11] Note that this study was conducted with a version of the TI-Nspire Navigator software which has since been upgraded.

Teachers with more technology experience had better outcomes than teachers with less technology experience. Specifically, teachers with more experience were more likely to report that the ALN resources improved student engagement and student understanding; they were more likely to shift their pedagogy to include more high-level activities; and their students learned more than that students of teachers with less technology experience. Fortunately, just a few years of experience appears to be sufficient to obtain these benefits. Hence, administrators should give teachers time—and teachers should persist with the technology—long enough to become adept with using the technology for instruction.

3. **Whenever possible, use TI-Nspire Navigator in conjunction with TI-Nspire rather than using TI-Nspire alone**

The TI-Nspire and TI-Nspire Navigator technologies go together intimately. Teachers see the two technologies as a coherent unit, both in terms of integrating into classroom practice and in terms of the style of teaching and learning that they promote. Indeed, evidence suggests that the two technologies influence instruction in similar ways. At the same time, teachers believe that TI-Nspire Navigator made their instruction more powerful, above and beyond TI-Nspire. Thus, TI-Nspire Navigator should be seen as an integral component of the ALN resource suite, not a superfluous embellishment.

4. **Seek ways to leverage the potential of the technology to enhance teaching and learning**

In many cases, teachers could make slight pedagogical adjustments that would provide substantial benefits for learning. For example, many teachers used quick poll regularly, but missed opportunities to optimize its value. Teachers typically went through the answers to the quick poll questions quickly, identifying answers as right or wrong and moving on to the next question. In one observed lesson, however, the teacher took the opportunity to look at the range of student answers to each question and to discuss not only the correct response, but also the incorrect ones. The teacher drew from the incorrect responses explain and dispel common student misconceptions. Expanding teacher practice in this way would be an ideal enhancement to standard teacher practice. Because teachers are already using the quick poll functionality, they would not need to adopt new technology applications or drastically change their instructional style. Instead, teachers could easily build this activity into their existing practice—and potentially garner valuable benefits for students.

5. **Allow for extra time up front to delve into conceptual understanding, with the expectation that this approach will save time generally required for re-teaching content at the other end.**

This year, most teachers reported that it was easy to fit the ALN lessons into their scope and sequence and they did not struggle with not having enough time to cover their core curriculum. One teacher explicitly noted that teaching conceptual understanding takes some more time initially—but that developing greater conceptual understanding obviates the need to re-teach concepts at the end of the unit or semester.

6. **Be open to pedagogical shifts enabled and supported by the technology**.

Teachers consistently report that when they used the ALN resource suite, their instruction: a) became more student-centered and less teacher-led; b) focused more on conceptual understanding than procedural skills; and c) attended more directly to student needs. Specifically, teachers were able to use immediate feedback provided by the technology to adjust instruction and address misconceptions. Teachers with a wide variety of pedagogical styles can use the ALN resources. But they often find that using these resources influences pedagogy in ways that can benefit student learning.

7. **Customize the ALN lessons for specific classes of students, for example, by editing the reading level and vocabulary on the worksheets**

Many teachers noted that their students struggled with the language and wording on the ALN worksheets. To support learning for students at all levels of ability, including both ELL and special education students, teachers should customize the worksheets to be appropriate for their own students. Teachers can edit the language to make it more accessible for struggling readers, or change the vocabulary to match with previously introduced terminology.

Discussion and Conclusions

The Phase 2 Algebra Nspired research examined the value of TI-Nspire Navigator, as an enhancement to TI-Nspire and ALN materials, for student mathematics learning. The research also investigated the implementation of the ALN resource suite (i.e., the ALN materials, TI-Nspire, and TI-Nspire Navigator) in order to understand how teachers and students use these resources, what they value about the resources, and what challenges they encountered.

The Phase 2 ALN research yielded the following key findings:

- TI-Nspire Navigator is an important component of the ALN resource suite that complements other TI resources (i.e. ALN and TI-Nspire)
- The research found a marginally significant increase in learning associated with TI-Nspire Navigator, above and beyond TI-Nspire and ALN. (This result may be an underestimate of the full impact, due to implementation variation and other factors inherent to the research.)

- The ALN resource suite influenced teacher pedagogy to emphasize deeper learning for students
- Teachers believe that the ALN resource suite contributed to increased student engagement and supported deeper student learning
- In comparison with their less experienced peers, teachers with *more experience* with TI-Nspire and TI-Nspire Navigator
    - Were more likely to shift their pedagogy to include more high-level instructional activities
    - Reported that their students were more engaged and learned more
    - Had students who learned more math
- Teachers who *used the technology more frequently* also reported that their students were more engaged and learned more math

The findings from the current research closely parallel the findings from the Phase 1 research—a fact that corroborates teachers' perceptions of TI-Nspire Navigator as an integral component of the ALN resource suite. This close coupling between the various resources—ALN materials, TI-Nspire, and TI-Nspire Navigator—can help explain the lack of strongly significant student learning outcomes observed in these studies. The Algebra Nspired studies examined individual pieces of a larger system—namely, the ALN materials in Phase 1 and TI-Nspire Navigator in Phase 2. But the research shows that teachers see the Algebra Nspired suite of resources as a coherent set of materials and technology that form an integrated system for teaching and learning. Teachers could not envision using the ALN materials without TI-Nspire (indeed, they are designed explicitly for use with the handheld devices). Similarly, after experiencing TI-Nspire Navigator, teachers would be loath to remove it from their arsenal. It is likely that the true value of the Algebra Nspired suite lies in its complete form: Algebra Nspired instructional materials combined with TI-Nspire and TI-Nspire Navigator technology. This research examined incremental components of a coherent system; subsequent research might find stronger results by examining the system in its entirety.

Beyond explaining the outcomes, the interconnectedness of the TI resources also suggests how teachers might optimally adopt these resources: specifically, teachers should use all of the resources jointly from the start. Teachers said that TI-Nspire Navigator made their instruction more powerful. At the same time, teachers did not report that it was easier to start using TI technology with just TI-Nspire. The implication, therefore, is that TI-Nspire Navigator is an important core piece of the technology package from the time teachers first begin working with these resources. The finding that teacher technology experience is important for using the technology effectively to improve teaching and learning further supports an all-at-once approach to adoption, since it would be the most efficient way to build teacher experience with all of the different tools.

The importance of technology experience and, to some extent, frequency of technology use can also help to explain the lack of significant findings about the impact of TI-Nspire Navigator for student learning. Given that the majority of

teachers in our sample were relatively new users of these technologies, their capacity to use them to their maximum potential was undoubtedly limited. Teachers did receive a relatively light-touch professional development at the beginning of the year to get them acquainted with TI-Nspire Navigator, but this training was no substitute for years of experience in the classroom. The evidence from both phases of ALN research suggests that as these teachers continue using the ALN resource suite in the classroom, they will become increasingly more effective at leveraging the affordances of the resources to improve pedagogy and support deeper student learning.

The findings about technology experience also have important implications for practitioners. Most importantly, the research shows that teachers need to have the opportunity to become familiar with the technology in order to accrue maximum benefits for students. In this study, teachers who had been using the technology for a longer period of time had stronger outcomes. Thus, one strategy is to enable teachers to integrate the technology and stand-alone instructional materials into their regular instruction at their own pace, with the expectation that within just a few years they would develop the familiarity and skills to truly leverage those resources to benefit students. Alternatively, high-quality professional development could theoretically serve as a substitute for time with regard to providing teachers with the experience they need to make the most of the ALN resources.

In sum, the ALN research shows that TI-Nspire Navigator can support teaching and learning in math—both on its own and as a component of the coherent ALN resource suite. Across all teachers, the ALN resources (and ALN instructional materials in particular) appear to support a shift to more high-level instructional activities, such as having students solve non-routine problems. The majority of teachers across the board also believed that the ALN resources support increased student engagement and deeper learning. These teacher perceptions corroborate the subdued student learning results observed in this research and provide further evidence that the resources are pushing in the right direction. Importantly, each of these relationships is even stronger for teachers with more technology experience and, to some degree, for those who use the technology more frequently in the classroom. Indeed, teachers with more technology experience had students who learned more mathematics, as measured by the ALN assessment. These findings support ongoing efforts to strengthen teacher use and implementation of TI resources, in order to eventually support deeper conceptual learning for students.