Summary Evaluation Report

Inquiring Minds:

Reading to Learn and Innovate in Mathematics and Science

(IQ-MS)

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BSCS Evaluation Report (ER2015-05)

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Executive Summary

This report documents the final year and summarizes three years of the BSCS evaluation of Inquiring Minds: Reading to Learn and Innovate in Mathematics and Science, (IQ-MS), a research study developed by South Carolina's Coalition for Mathematics and Science (SCCMS) at Clemson University in partnership with S^2TEM Centers SC. This research and innovation program aimed to identify and implement reading, writing and communication strategies that make science and mathematics more accessible to middle grade (6th-8th) students. A total of twenty middle schools, ten treatment schools and ten control schools in eighteen school districts of three South Carolina regions were included in the study. Professional development was delivered in two ways. First, a Summer Institute was convened each year through 2014, with all treatment school math and science teachers and administrators expected to attend. Next, S^2TEM Center staff IQ-MS Specialists supported treatment school mathematics and science teachers two days a week as instructional coaches for all three years of the program.

Two main questions drove the research and evaluation of IQ-MS, and a variety of measures were employed to assess the impact of IQ-MS on teacher attitudes, understanding and practice and on student achievement. The general conclusion for the three years of the study was that the program is having a positive impact upon teacher attitudes and practice in middle school mathematics and science.

Question 1. What effect does professional development focused on disciplinary literacy strategies have on the instructional practices of middle grade mathematics and science teachers?

First, the Reformed Teaching Observation Protocol (RTOP) was employed in observations of videotaped lessons of three randomly selected teachers from each of the control and treatment schools. An additional set of five items, specifically created to measure teachers' use of Disciplinary Literacy (DL) strategies, was added to the scoring protocol. Mediation analysis indicates that the use of DL practices in the classroom was a significant mediator, contributing to a difference in teacher practice between treatment and comparison groups. In other words, treatment teachers' RTOP scores were over half a standard deviation higher than control teachers' scores for the third year in a row. This indicates that participation in the IQ-MS program led to teachers using more reform-based practices, i.e., DL strategies, than the control teachers.

Next, analysis of the teacher attitude survey results for treatment school teachers from the Summer Institutes of 2012, 2013 and 2014, concluded with a follow-up in fall 2015, revealed significant positive growth in all areas of attitude and understanding for:

- Disciplinary Literacy and STEM
- Disciplinary Literacy Elements and Strategies
- Purposeful Reading
- Meaningful Writing
- Productive Dialogue

In addition, significant growth was shown in the frequency of implementation of DL strategies and in participating teachers' level of satisfaction in employment of DL strategies between 2012 and 2015.

Finally, on-site interviews of teachers at each of three randomly selected treatment schools identified teachers at various stages of use of the DL innovation through the Levels of Use (LoU) branching interview protocol. Of the ten teachers interviewed, four participated for all three years and six were interviewed for two successive years. Two teachers from School A and two from School B were rated at Level IVB Refinement during the first year of interviews, with two advancing to V Integration and VI Renewal by the third year. Notably, within the course of the first year, all except two interviewees were rated at Level IVB or above, indicating a swift advance past the mechanical usage to routine and above.

In conclusion, triangulation of data from the suite of outcome measures indicates that the IQ-MS program is exerting a strong positive influence on the instructional practices of participating middle school mathematics and science teachers in the study's treatment schools.

Question 2. To what extent does the application of disciplinary literacy strategies in mathematics and science classrooms improve student achievement?

The data files that will inform questions 2a and 2b from the 2014-2015 school year, comparing treatment and comparison schools are currently under review and will be analyzed and reported in an appended document in the coming weeks.

Summary: At the conclusion of the three-year IQ-MS project, evidence from multiple sources indicates that IQ-MS is a highly effective program that is positively impacting teacher practice and student learning in middle school mathematics and science classrooms. Triangulated data from this evaluation study reveal that teachers participating in IQ-MS professional development have become strong advocates and implementers of disciplinary literacy strategies. As a result of the well-designed and executed support of school-based Specialists, teachers have demonstrated commitment to the tenets and instructional strategies of IQ-MS. Under the tutelage of the Specialists, many teachers are demonstrating their growing confidence and leadership skills as they reach beyond school boundaries to share the IQ-MS program with educators in district, state and national venues. Finally, enriched by the comprehensive set of resources offered through the S^2TEM Centers SC Virtual Library (*http://www.s2temsc.org/disciplinary-literacy-virtual-library.html*) IQ-MS is approaching the anticipated final innovation aim of "a functional community of support" for STEM education.

Introduction and Background

South Carolina's Coalition for Mathematics and Science (SCCMS) at Clemson University in partnership with S^{2}TEM Centers SC has completed a three-year research and innovation program to identify reading, writing and communications strategies that make science and mathematics more accessible to middle grade (6th-8th) students. Inquiring Minds: Reading to Learn and Innovate in Mathematics and Science (IQ-MS) focuses on a 'disciplinary literacy' (DL) initiative, in direct response to national and state student achievement data, expert advisement and interest expressed by instructional leaders in South Carolina school districts. Disciplinary literacy is an advanced form of literacy requiring adolescent readers to have specific background knowledge about how to read purposefully, write in meaningful ways and engage in productive dialog in the disciplines - skills not often taught in English/Language Arts classes or the content area classes themselves. Disciplinary Literacy instruction engages learners with content in ways that mirror what scientists and mathematicians do to inquire and gain understanding in their disciplines. These abilities are essential to make sense of the complexities of science and mathematics.

A stratified sample of schools was identified within the five S^{2}TEM Centers SC regions of South Carolina. The final distribution of sites includes three regions with two treatment and two control schools each (Midlands, Lowcountry, and Western regions), one region with three treatment and three control schools (Coastal Pee Dee region), and one region with one treatment and a single control school (Upcountry region). The twenty schools are located in eighteen different school districts in South Carolina.

Professional development for treatment schools was delivered in two ways for the 3-year duration of the study. First, a Summer Institute was convened each year for all treatment school math and science teachers and administrators. Next, IQ-MS Specialists served as on-site instructional coaches in the schools at least 2 days per week. Some of the schools also had instructional coaches hired by the school or district. Each IQMS specialist was assigned to one research site, except for one specialist who was assigned to two research sites (nine specialists total). While on-site, specialists facilitated professional learning community (PLC) meetings around disciplinary literacy, modeled disciplinary literacy strategies in the classroom, co-taught lessons, and provided feedback and additional resources for incorporation of disciplinary literacy strategies into classrooms. Comparison schools were provided with three days of professional development of their choosing on any topic not related to disciplinary literacy. Professional development took the form of on-site coaching or traditional workshop sessions.

An additional support for professional development that enriches the program for educators and ensures sustainability is the IQ-MS Virtual Library accessed at *http://www.s2temsc.org/disciplinary-literacy-virtual-library.html*. Developed over the course of the IQ-MS program through the S^{2}TEM Centers SC, the open access resource library offers "promising practices, effective strategies, classroom lessons, and multimedia tools based on the Inquiring Minds: Reading to Learn and Innovate in Mathematics and Science (IQ-MS) research program." This ambitious and comprehensive resource features 5 sections: Lesson Library, Strategy Warehouse, Resources for Professional Development Leaders, Self-Paced Professional Learning Modules, and State and National Conference Presentations. The Lesson Library and Strategy Warehouse include extensive standards-based science and mathematics lessons highlighted with IQ-MS teachers' classroom videos. In addition, the 3-hour session in Resources for Professional Development and the lessons in the Self-Paced Professional

Learning Modules provide an extensive program for self-paced instruction in the background and implementation of disciplinary literacy strategies.

The Theory of Change (Figure 1) below illustrates the hypothesized path of influence for the IQ-MS disciplinary literacy intervention. Through professional development focused on DL strategies, it was expected that the influence on teacher practice and teacher attitudes would affect changes in instructional practice to positively impact student achievement in mathematics and science.

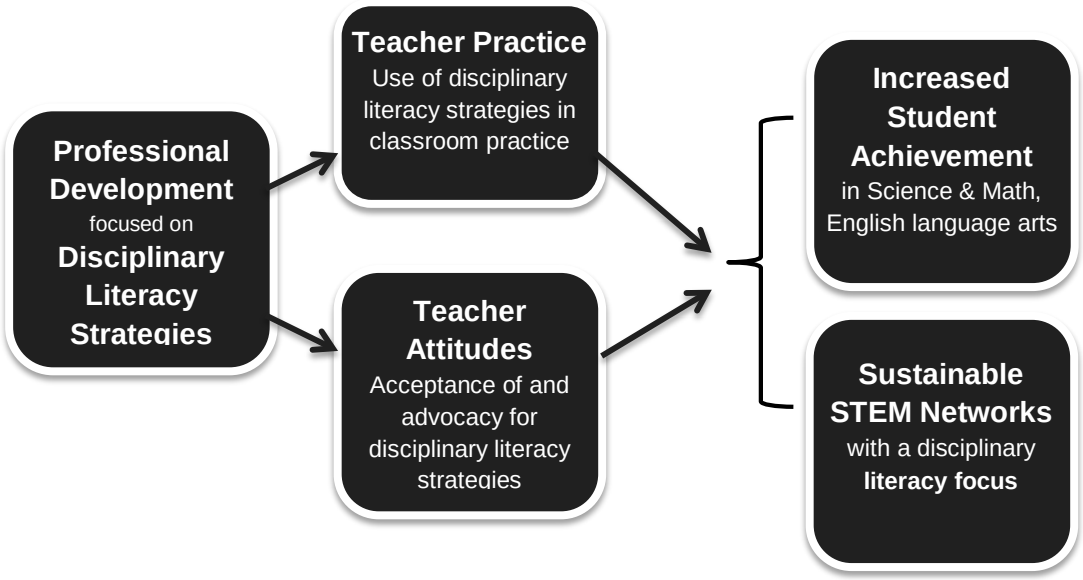

Figure 1. IQ-MS Theory of Change

The research aim of IQ-MS is to answer the following questions based on the Theory of Change:

Question 1. *What effect does professional development focused on disciplinary literacy strategies have on the instructional practices of middle grade mathematics and science teachers?*

Question 2. *To what extent does the application of disciplinary literacy strategies in mathematics and science classrooms improve student achievement?*

Using a mixed-methods approach, the BSCS evaluation plan employed measures of teacher practice, teacher attitudes, and South Carolina Palmetto Assessment of State Standards (PASS) student achievement to address the research questions.

This summary report presents comparative data and analysis focused on the IQ-MS program's original anticipated final stages of the IQ-MS innovation aims:

1. To develop via iterative processes a professional learning storyline for instructional improvement in mathematics and science through the application of disciplinary literacy strategies.

2. To develop a robust virtual library of vetted, disciplinary literacy resource materials for middle grade teachers.
3. To sustain and scale instructional innovation through regional networks of mentors and other champions for STEM education with a disciplinary literacy focus.

Evaluation Data Sources and Methodology

Data from a variety of sources were collected, analyzed and triangulated to address the following research questions:

Question 1*: What effect does professional development focused on disciplinary literacy strategies have on the instructional practices of middle grades mathematics and science teachers?*

> **Measure 1a.** Reformed Teaching Observation Protocol (RTOP) and IQ-MS Supplemental Items.

In spring 2015, Year 3, observation of teacher practice via video-recorded lessons was accomplished by video recording teachers who were randomly selected from the treatment schools and comparison schools. The video recorded lessons from each group were observed and scored on 25 items of the Reformed Teaching Observation Protocol (RTOP) (Pitburn et al., 2000; Sawada et al., 2002) and five additional IQ-MS DL-focused items. Statistical analysis was conducted to compare scores of treatment and comparison groups

As indicators, the IQ-MS leadership's anticipated baseline (Year 1) for this measure was stated as "Minimal evidence of teacher use of disciplinary literacy strategies in classroom practice." The anticipated interim (Year 2) result was: "Evidence of regular teacher use of disciplinary literacy strategies in classroom practice when supported by an instructional coach." The anticipated final outcome was "Evidence of regular, self-directed use of disciplinary literacy strategies in classroom practice."

> **Measure 1b.** Survey of Teacher Attitudes toward Disciplinary Literacy for teachers in treatment schools who attended the annual summer institute.

A survey constructed collaboratively by the IQ-MS leadership and BSCS evaluators was administered as a baseline to teachers prior to attending the first Summer Institute in June 2012 and then again to Institute participants in June 2013 and June 2014. This survey served as a record of teachers' changing attitudes toward DL through the course of the project. The survey was administered as a follow-up measure in 2015 at the conclusion of year 3.

The IQ-MS leadership's anticipated baseline (pre-Year 1) for both this measure and measure 1c is: "Teacher reports of skepticism regarding the use of disciplinary literacy strategies." The Anticipated Interim (pre-Year 2) level was projected as "Teacher reports of acceptance regarding the use of disciplinary literacy strategies." The anticipated final result of the survey was stated as, "Teacher reports of advocacy regarding use of disciplinary literacy strategies."

Measure 1c. The Levels of Use (LoU) branching interview protocol (Hall, Dirksen, George, 2006) to measure the implementation of DL innovations by randomly selected science and mathematics teachers in treatment schools.

Teacher interviews were conducted at three randomly selected treatment schools in March 2013, February 2014, and March 2015. The instrument classifies scores in one of 8 levels of use, from 0 - Nonuse through IVA - Routine to VI – Renewal with each category describing the interviewee's perception of his/her use of the innovation at the time of the interview. It was anticipated that, as with measure 1b, the interviews would reveal teachers' advocacy regarding use of disciplinary literacy strategies demonstrated by increased levels of implementation.

Question 2a: *To what extent does the application of disciplinary literacy strategies in mathematics and science classrooms improve student achievement in literacy?*

Measure 2a. PASS: ELA informational text subsection scores

Question 2b: To what extent does the application of disciplinary literacy strategies in mathematics and science classrooms improve student achievement in these content areas?

Measure 2b. PASS: Mathematics and Science Scores

The anticipated Interim findings for 2012-13 and 2013-14 state that: "Student performance will demonstrate improvement trends over baseline data in decreasing % of students not meeting standards and in increasing students at the exemplary level." The anticipated final effect in year 3 was, "2014-15 student performance will demonstrate statistically significant improvement over baseline data." The data files that will inform questions 2a and 2b from the 2014-2015 school year, comparing treatment and comparison schools are currently under review and will be analyzed and reported in an appended document in the coming weeks.

Findings

Question 1: What effect does professional development focused on disciplinary literacy strategies have on the instructional practices of middle grades mathematics and science teachers?

Measure 1a. Reformed Teaching Observation Protocol (RTOP) and IQ-MS Supplemental Items

In the spring of 2013, 2014 and 2015 three randomly selected teachers from each treatment and comparison school were video recorded during one math or science class period for the teacher practice outcomes study. The IQ-MS staff created codes to replace the teacher names that linked the teacher to their treatment group to facilitate an unbiased viewing of the video recordings. One BSCS evaluator viewed and scored each video using the Reformed Teaching Observational Protocol (RTOP). In addition, five additional items created by the IQ-MS staff to assess teacher use of strategies key to Disciplinary Literacy (DL) were scored. A second evaluator linked the scored data file with treatment group identifiers, matched the files for all three years, and conducted the analysis. Due to teacher-level attrition, the number of schools participating in this portion of the study with sufficient 2013 covariate data and 2015 teacher practice videos was reduced to 17 in the 2015 analyses.

The RTOP, a criterion-referenced instrument, measures the extent to which science and mathematics teaching aligns with the recommendations for instructional reform described in national science and mathematics standards. The instrument is composed of 25 Likert-type items, divided into 5 subscales. Each item is scored on a 0-4 scale, from 0 - never occurred, to 4 – very descriptive. Descriptions of the five subscales below are adapted from the RTOP Reference Manual (Pitburn and Sawada, 2002).

- Lesson Design and Implementation emphasizes instructors' attention to students' prior knowledge, to engaging students as members of a learning community, and promoting exploration before formal presentation. In addition, teachers receive high scores when they encourage students to seek and value alternative modes of investigation or problem solving, and use students' ideas to direct lessons.
- Content is scored in two forms of knowledge - knowledge of what is (Propositional Knowledge), focuses on the level of significance and abstraction of the content, the teacher's understanding of it, and the connections made with other disciplines and with real life.
- Knowledge of how to (Procedural Knowledge) represents the kinds of processes that students are asked to use to manipulate information, arrive at conclusions, and evaluate knowledge claims.
- Classroom culture consists of Communicative Interactions and
- Student/Teacher interactions in which it is considered important that students be heard, and often, and that they communicate with one another, as well as with the teacher. The nature of the communication indicates the ways in which knowledge is constructed in the classroom environment.

Table 1 below shows results for comparison and treatment groups in each of the 5 subscales and the IQ-MS supplemental set at Year 1, 2 and 3 time points. Treatment school teachers attained higher means than comparison teachers in every subscale each year.

Table 1. RTOP+ score comparisons Years 1, 2 and 3.

Subscale	Comparison 2013	Treatment 2013	Comparison 2014	Treatment 2014	Comparison 2015	Treatment 2015
	Mean (n), Std. Dev	Mean (n), Std. Dev	Mean (n), Std. Dev	Mean (n), Std. Dev	Mean (n), Std. Dev	Mean (n), Std. Dev
Lesson Design and Implementation	4.25 (25), 3.85	6.40 (32), 4.05	5.63 (19), 3.40	6.68 (25), 3.42	5.10 (21), 4.37	6.84 (19), 4.19
Content- Propositional Knowledge	7.16 (25), 4.24	10.09 (32), 4.59	9.63 (19), 3.59	10.00 (25), 3.85	9.76 (21), 4.16	11.26 (19), 4.11
Content - Procedural Knowledge	4.12 (25), 3.73	5.41 (32), 4.79	5.63 (19), 3.55	6.84 (25), 3.56	5.62 (21), 4.77	5.79 (19), 3.78
Classroom Culture - Communicative Interactions	5.12 (25), 3.80	7.13 (32), 4.62	6.63 (19), 2.31	7.96 (25), 3.25	6.04 (21), 3.61	7.26 (19), 4.65
Classroom Culture - Student/Teacher Relationships	6.96 (25), 4.53	9.25 (32), 3.78	8.21 (19), 2.62	9.80 (25), 3.38	7.86 (21), 4.49	9.37 (19), 5.46
IQMS - Disciplinary Literacy Strategies	3.52 (25), 3.51	6.00 (32), 6.05	1.58 (19), 1.87	6.56 (25), 6.69	2.57 (21), 2.87	6.21 (19), 6.13

Five IQ-MS-developed items for inclusion in the observation protocol, identified in Table 2 as IQMS 1-5, rated the extent to which the disciplinary literacy strategies of purposeful reading,

meaningful writing and productive dialogue are implemented into instruction. IQ-MS 1 considers selection and use of strategies. IQ-MS 2 describes fidelity and intentionality of implementation. IQ-MS 3, 4 and 5 rate the appropriate use of reading, writing and productive dialogue to support students' content knowledge construction. Table 2 below illustrates the differences in the use of IQ-MS strategies between comparison and treatment teachers. The highest means occur within the productive dialogue category, indicating that of the three types of DL strategies, dialogue is observed most often in mathematics and science lessons. Again, treatment teachers implement all DL strategies more frequently than their comparison school counterparts.

Table 2: Comparison of RTOP+ classroom observation scores on DL strategies Years 1, 2, and 3

	Comparison 2013	Treatment 2013	Comparison 2014	Treatment 2014	Comparison 2015	Treatment 2015
	Mean (n), Std. Dev	Mean (n), Std. Dev	Mean (n), Std. Dev	Mean (n), Std. Dev	Mean (n), Std. Dev	Mean (n), Std. Dev
IQ-MS1 – The lesson included purposeful reading, meaningful writing, and/or productive dialogue strategies.	0.56 (25), .82	1.10 (32), 1.40	.00 (19), .00	1.24 (25), 1.67	.29 (21), .78	1.42 (19), 1.71
IQ-MS2 – Disciplinary literacy strategies are implemented with fidelity and intentionality. Strategies may be adapted to support learning of the content.	0.48 (25), .82	1.09 (32), 1.57	.00 (19), .00	1.44 (25), 1.73	.14 (21), .48	1.32 (19), 1.64
IQ-MS3 – Students are reading with purpose to learn mathematics or science content.	0.72 (25), 1.06	0.91 (32), 1.53	.37 (19), .83	.68 (25), 1.35	.38 (21), .87	.63 (19), 1.26
IQ-MS4 – Students are writing with meaning to learn mathematics or science content.	0.56 (25), .92	0.94 (32), 1.29	.37 (19), .68	1.28 (25), 1.51	.57 (21), .98	1.32 (19), 1.34
IQ-MS5 – Students are engaging in productive dialogue to learn mathematics or science content.	1.20 (25), 1.00	1.87 (32), 1.19	.84 (19), .96	1.92 (25), 1.55	1.19 (21), 1.21	1.53 (19), 1.43

Using the 2015 data set, the first task was to investigate the "intent to treat" model, which tests the direct effect or the IQ-MS treatment on teacher RTOP score. (Figure 2). Because of the nested nature of the data (teachers within schools), a two-level hierarchical linear model (HLM) was used to detect statistical significance between the treatment and comparison groups, seeking a direct effect of school level participation in the IQMS program on teacher practice as defined by the RTOP.

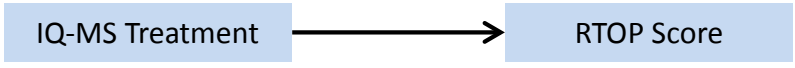

Figure 2. IQ-MS Treatment Model

The equations for this analysis are

Level 1:

$$(RTOP14)_{ij} = \beta_{0j} + \beta_{1j} * (RTOP2013) + e_{ij}$$

Level 2:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(TREATMENT) + u_{0j}$$

The HLM analysis of the 2015 teacher RTOP scores, using RTOP 2013 score as a covariate in the model, revealed that school level participation in IQ-MS while not a significant predictor of teacher practice as measured by the RTOP (γ_{01}(TREATMENT) = 8.59, SE = 5.45, p = 0.136), is approaching significance. The Hedges' g effect size associated with this significant finding is g = .60 (slightly larger than 2013). In other words, treatment teachers' RTOP scores were more than half of a standard deviation higher than control teachers' scores.

Next, the mediation model was tested, adding the practices of DL (as measured by the five-item scale developed by IQ-MS) into the model (see Figure 3 below). Essentially, this is investigating whether the use of DL practices in the classroom mediates the relationship between participation in IQ-MS and RTOP score. This is known as a 2→1→1 mediation design because the treatment is delivered at the second level (school), the mediator (DL practices) is measured at the first level (teacher), and the outcome is also measured at the teacher level (RTOP score). In this approach, separate equations for the mediator and the outcome can be used to estimate the indirect effect and determine if mediation is present.

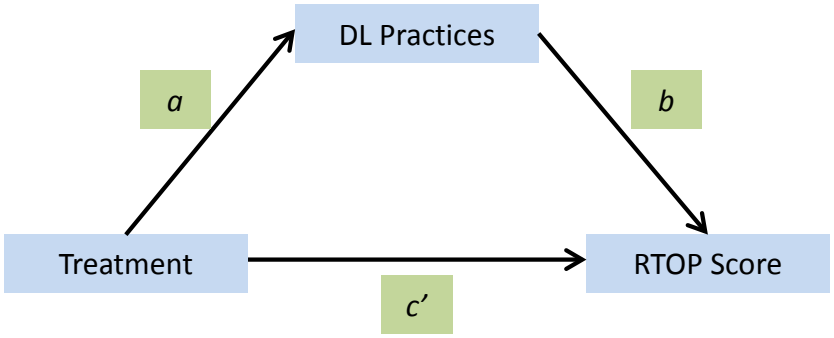

Figure 3. Mediation model

The following Level 1 and 2 equations estimate path a from Treatment to DL Practices

Level 1:

$$(DLPRACTICES)_{ij} = \beta_{0j} + e_{ij}$$

Level 2:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(TREATMENT) + u_{0j}$$

For the path *a* analysis above using the 2015 data set, treatment is a significant predictor of DL Practices(γ_{01} = 3.59, SE = 1.87, p = 0.077).

The following Level 1 and 2 equations estimate paths *b* (DL Practices to RTOP) and *c'* (Treatment to RTOP Score, mediated)

Level 1 (Path *b*):

$$(RTOP)_{ij} = \beta_{0j} + \beta_{1j}(DLPRACTICES) + e_{ij}$$

Level 2 (Path *c'*):

$$\beta_{0j} = \gamma_{00} + \gamma_{01'}(TREATMENT) + u_{j}$$

Where $\gamma_{01'}$ is path *c'* of Figure 2 and β_{1j} is the fixed effect of DL Practices on RTOP score (controlling for treatment), or path b. The fixed effects from this two level model are *c'* ($\gamma_{01'}$) = 3.93, SE =6.11, p =.56 and *b* (β_{1j}) = 1.97, SE = .52, p < .001. The presence of a significant effect on the DL Practices mediator, a significant association between DL Practice and RTOP score and a remaining, non-significant direct treatment effect (*c'*) indicates a partial mediation effect as was observed in the 2013 and 2014 analyses.

The indirect effect of DL practices can be estimated as the product of the *a* and *b* paths or the *ab product.* This product is: $(\gamma_{01})(\beta_{01})$ = (3.59)(1.97) = 7.07. The 95% confidence interval for the indirect effect was computed using the RMediation program (Homer, 2011), yielding

[-0.139↔16.44] [-0.158, 16.958] indicating a nearly significant finding. We expect that the inclusion of a slightly negative lower confidence interval (-0.158) is likely the result of a loss of power to detect an effect in the 2015 data set. In the 2014 data set, 16 schools (level 2) were included in the analysis. In 2015 this number increased to 17. However, many schools lost teachers by year 3, thus the level 1 units were reduced from 67 in 2014 to just 40 in 2015.

Further investigation of the direct effect, the c' prime, and the *ab* product allows estimation of the indirect or mediation effect of teacher practice is (7.07/10.66), or 66% of the total effect of the intervention. The effect size of the direct effect in 2013 was g=.56, in 2014 it was g=.60, and in 2015 it was g=.59. It is somewhat expected that as teachers move away from the intervention, the effect will likely decrease, but we see a steady hold in effect size over the course of the project. However, the nearly significant *ab* product (mediation model) indicates that teachers who are applying DL strategies in the classroom are also scoring higher on the RTOP. Based on the goals of the IQ-MS project, we feel that there is evidence in these data to suggest that IQ-MS is approaching the originally established goals.

Measure 1b. Survey of Teacher Attitudes toward Disciplinary Literacy

BSCS evaluators, in collaboration with the IQ-MS leadership, constructed a teacher attitude survey administered as a pre-test before the 2012 Summer Institute and then again before the Summer Institutes in 2013 and 2014. The survey was administered to participating teachers as a follow-up at the conclusion of Year 3, 2015. Included in the survey as Likert-type items are six sets of statements asking teachers to rate their confidence, understanding, acceptance and implementation of DL strategies. Ratings are based on a scale from 1 = strongly disagree through 3 = uncertain to 5 = strongly agree. Continued use of this instrument provided longitudinal data on teachers' maturing attitudes about DL strategies. To illustrate these changes, annual results for each section of the survey are compared to the 2012 baseline data in Tables 3 through 7 below.

Table 3: Disciplinary Literacy and STEM Attitude Comparisons Years 1, 2 and 3

Set 1	2012 Baseline	2013 Year 1	2012 Baseline	2014 Year 2	2012 Baseline	2015 Year 3
Disciplinary Literacy and STEM	**Mean**	**Mean, t-test(degrees of freedom), p value**	**Mean**	**Mean, t-test(degrees of freedom), p value**	**Mean**	**Mean, t-test(degrees of freedom), p value**
I understand the basics of STEM(Science, Technology, Engineering, Mathematics) instruction.	3.45	4.24, t(41)=4.968, p=.000***	3.42	4.39, t(35)=5.68, p=.000***	3.80	4.81, t(20)=6.481, p=.000***
I believe STEM instruction can be enriched with disciplinary literacy strategies	3.98	4.43, t(41)=3.968, p=.000***	3.97	4.55, t(35)=4.55, p=.000***	4.24	4.81, t(20)=4.382, p=.000***
I feel comfortable enhancing my STEM instruction with disciplinary literacy	3.55	4.20, t(39)=4.005, p=.000***	3.61	4.39, t(35)=5.02, p=.000***	3.95	4.71, t(20)=4.202, p=.000***
I understand the basics of disciplinary literacy	3.64	4.41, t(41)=6.246, p=.000***	3.64	4.47, t(35)=6.17, p=.000***	3.86	4.71, t(20)=6.000, p=.000***
I believe disciplinary literacy can enhance students' learning of science and/or math concepts	4.10	4.41, t(41)=2.473, p=.018*	4.11	4.56, t(35)=3.63, p=.001***	4.14	4.76, t(20)=3.833, p=.001**
I feel confident that I can implement disciplinary literacy strategies in my classroom	4.12	4.41, t(41)=2.077, p=.044*	4.08	4.39, t(35)=1.8, p=.070	4.30	4.75, t(20)=2.932, p=.009*

***significant at p<0.05; **significant at p<0.01, ***significant at p<0.001**

In Table 3 above, comparison of the 2012 baseline results with those in successive years reveals strong positive growth in attitudes toward disciplinary literacy with larger gains in means from 2012 to 2015, even with a smaller 'n' due to fewer matched pairs. In every year after the 2012 baseline survey, a significant change at the p<.001 level in teachers' reactions to STEM instruction with disciplinary literacy strategies is seen in the first four statements that detail understanding of, and confidence with, disciplinary literacy strategies.

As teachers became more familiar with DL strategies through contact with the IQ-MS Specialists during each year of the program, they reported increased comfort with the concepts of STEM and disciplinary literacy. The final two items on Table 3 examine teachers' beliefs about the efficacy of DL for student learning and teachers' confidence in implementing the strategies in their classrooms. The steady growth of the means and significance of responses to these

statements over the 3-year period is testimony to teachers' response to and acceptance of the IQ-MS program and the educational benefits of disciplinary literacy.

Table 4. Comparison of responses on DL elements and strategies for Years 1, 2 and 3

Set 2	2012 Baseline	2013 Year 1	2012 Baseline	2014 Year 2	2012 Baseline	2015 Year 3
Disciplinary Literacy Elements and Strategies	**Mean**	**Mean, t-test(degrees of freedom), p value**	**Mean**	**Mean, t-test(degrees of freedom), p value**	**Mean**	**Mean, t-test(degrees of freedom), p value**
Disciplinary literacy in science and mathematics includes three components: purposeful reading meaningful writing, and productive dialogue.	4.05	4.73, t(40)=5.335, p=.000***	4.08	4.61, t(35)=4.09, p=.000***	4.095	4.95, t(20)=6.000, p=.000***
I think that instruction in purposeful reading, meaningful writing and productive dialogue facilitates learning of science and/or mathematics.	4.17	4.55, t(41)=3.106, p=.003**	4.17	4.56, t(35)=3.39, p=.002**	4.24	4.86, t(20)=4.240, p=.000***
I feel competent in integrating purposeful reading, meaningful writing and productive dialogue strategies into my science and/or mathematics lessons.	3.88	4.26, t(41)=2.333, p=.025*	3.92	4.50, t(35)=3.86, p=.000***	4.24	4.76, t(20)=2.950, p=.008**
Disciplinary literacy strategies can be tailored to enrich any science and/or mathematics lessons.	3.85	4.24, t(40)=2.804, p=008**	3.85	4.33, t(35)=2.41, p=.021*	3.95	4.57, t(20)=2.914, p=.009**
Many students do not need disciplinary literacy strategies to learn science and/or mathematics. (negative wording)	2.59	2.54, t(40)=.264, p=.793	2.42	2.19, t(35)=1.09, p=.282	2.38	1.86, t(20)=2.750, p=.012*
I feel competent implementing appropriate disciplinary literacy strategies to meet the needs of my students.	3.67	4.24, t(41)=4.309, p=.000***	3.64	4.36, t(35)=5.11, p=.000***	3.95	4.71, t(20)=3927, p=.001**

***significant at p<0.05; **significant at p<0.01, ***p<0.001**

Table 4 above investigates teachers' understanding of and beliefs about DL strategies. The first three statements as well as the last show a general trend toward significant changes from Year 1, 2012, through 2015, reflecting growth of understanding of the methods and utility of DL and confidence in classroom implementation. The fourth statement reveals steady significant growth in teachers' beliefs in the flexibility of DL strategies to meet students' needs. Of note is the response to the statement "Many students do not need disciplinary literacy strategies to learn science and/or mathematics." The declining means and corresponding increase in significance indicate that teachers continue to disagree with the 'reverse' statement, thus attesting to their support of the importance of including strategies for students in mathematics and science classrooms.

Table 5. Comparison of responses to purposeful reading for Years 1, 2 and 3

Set 3	2012 Baseline	2013 Year 1	2012 Baseline	2014 Year 2	2012 Baseline	2015 Year 3
Purposeful Reading	**Mean**	**Mean, t-test(degrees of freedom), p value**	**Mean**	**Mean, t-test(degrees of freedom), p value**	**Mean**	**Mean, t-test(degrees of freedom), p value**
There are many techniques to effectively teach purposeful reading of STEM materials.	3.73	4.29, t(40)=4.141, p=.000***	3.69	4.44, t(35)=6.15, p=.000***	3.86	4.71, t(20)=4.954, p=.000***
There is no difference in strategies for teaching purposeful reading in different subjects. (negative wording)	2.57	2.59, t(41)=.133, p=.895	2.58	2.50, t(35)=.386, p=.702	2.67	3.14, t(20)=1.746, p=.096
I feel I have a command of a variety of instructional strategies for teaching purposeful reading.	3.49	3.98, t(40)=3.592, p=.001***	3.38	4.29, t(33)=7.06, p=.000***	3.65	4.60, t(20)=5.596, p=.000***

***significant at p<0.05; **significant at p<0.01, ***p<0.001**

Table 5 above compares the baseline scores on Purposeful Reading to those after three years of DL implementation. Increasingly significant results are reported for each of the statements. A significant positive change is seen in attitudes about the effectiveness and personal command of purposeful reading techniques. For the second statement, a negatively worded item, the expected response would be an increase in means as teachers tended to disagree with the statement. With fluctuating changes in means and an unexpected change in the p value for Year 3, it is hypothesized that respondents were confused by the negative wording rather than by belief in the item as it is stated.

Table 6. Comparison of responses to meaningful writing for Years 1, 2, and 3

Set 4	2012 Baseline	2013 Year 1	2012 Baseline	2014 Year 2	2012 Baseline	2015 Year 3
Meaningful Writing	**Mean**	**Mean, t-test(degrees of freedom), p value**	**Mean**	**Mean, t-test(degrees of freedom), p value**	**Mean**	**Mean, t-test(degrees of freedom), p value**
I understand the difference between teaching meaningful writing techniques for mathematics and/or science and for other content areas such as history or language arts.	3.21	3.88, t(41)=5.496, p=.000***	3.06	4.06, t(35)=6.71, p=.000***	3.33	4.38, t(20)=5.215, p=.000***
Writing techniques vary with the subject area and topic being expressed.	3.55	3.95, t(39)=3.122, p=.003**	3.37	3.94, t(34)=2.72, P=.010**	3.33	4.00, t(20)=2.467, p=.023*
I am competent in designing and/or teaching lessons that incorporate meaningful writing in STEM topics	3.29	3.90, t(41)=5.047, p=.000***	3.28	4.28, t(35)=6.48, p=.000***	3.71	4.61, t(20)=4.663, p=.000***

***significant at p<0.05; **significant at p<0.01, ***p<0.001**

Responses to the first and last statements on meaningful writing (Table 6) show positive changes in means and significance between 2012 and 2015. Teachers appear to have gained knowledge and competency in the area of meaningful writing over the course of the school year. Responses to the second item show little variation through the IQ-MS project. Although significance appears to decrease slightly over succeeding years, the means are similar. One explanation for the lack of change is that due to schools' previous emphasis on writing, teachers entered the program with an understanding that writing techniques must be differentiated for specific content areas and topics.

Table 7. Comparison of responses to productive dialogue for Years 1, 2 and 3.

Set 5	2012 Baseline	2013 Year 1	2012 Baseline	2014 Year 2	2012 Baseline	2015 Year 3
Productive Dialogue	**Mean**	**Mean, t-test(degrees of freedom), p value**	**Mean**	**Mean, t-test(degrees of freedom), p value**	**Mean**	**Mean, t-test(degrees of freedom), p value**
Productive dialogue is an important skill for learning science and/or mathematics	4.10	4.45, t(41)=3.344, p=.003**	4.08	4.50, t(35)=3.25, p=.003**	4.10	4.71, t(20)=4.240, p=.000***
Productive dialogue is not as essential a skill in STEM instruction as it is in language arts. (negative wording)	2.36	1.90, t(41)=2.883, p=.006**	2.31	1.77, t(34)=3.62, p=.001***	2.24	1.76, t(20)=2.351, p=.029*
I feel confident instructing my students with strategies for productive dialogue to enhance learning in science and mathematics.	3.49	4.15, t(41)=5.112, p=.000***	3.33	4.33, t(35)=6.96, p=.000***	3.52	4.62, t(20)=5.319, p=.000***

***significant at p<0.05; **significant at p<0.01, ***p<0.001**

In Table 7, significant changes in responses to the first and third statements illustrate beliefs about the importance of and confidence with productive dialogue in the teaching and learning of science and mathematics. The second statement (negatively worded) with slightly decreasing means again reflects an unexpected result. With very little change in means and a decrease in significance, it is again hypothesized that teachers were confused by the negative wording. It is therefore difficult to assign validity to this item.

Documenting teachers' reported frequency of classroom implementation of DL strategies is more illustrative in the form of Table 8 below. The dramatic increase in daily use is correlated to the absence of teachers who report never employing the strategies in the last two years of the program. In 2015, all surveyed teachers report implementing DL strategies no less than once a week, with 64 percent of respondents using strategies daily.

Table 8. Frequency of DL strategies implementation

Frequency of use %	2012 (n=86)	2013 (n=46)	2014 (n=48)	2015 (n=25)
never	14	2.2	0	0
1/semester	14	2.2	4.2	0
1-2/month	40.7	15.2	10.4	0
1-2/week	23.3	56.5	45.8	36
daily	8.1	23.9	39.6	64

Finally, IQ-MS teachers' increase in level of satisfaction with their current understanding and implementation of STEM lessons and units is reported in Table 9 below. As in previous tables, the increase in satisfaction can be interpreted as testimony to the success of the IQ-MS program.

Table 9. Satisfaction with personal understanding and implementation of STEM lesson/units

Level of Satisfaction % frequency	2012 n=86	2013 n=46	2014 n=48	2015 n=25
Very satisfied	1.2	11	20.8	48
Satisfied	10.5	43.5	22	48
Neutral	52.3	37	10	0
Unsatisfied	22.1	6.5	3	0
Very unsatisfied	14	2.2	3	4

Sustainability. The IQ-MS leadership constructed additional items for the teacher attitude survey to be administered for final two years of the study. Focused on the sustainability of IQ-MS and the continuation of disciplinary literacy in schools through teachers' collaboration and outreach, these items are centered on continued learning, sharing and dissemination of program content and methods. Results for this section of the survey, reported in Tables 10 -12 below, provide evidence for teachers' commitment to continue the program beyond the three years of the Specialists' on-site support. The majority of responses fell in the “strongly agree” and ”agree” categories for every item, with the percentage of those in ”strongly agree” increasing from Year 2 to Year 3. The only exception is for statement 6, "I regularly share my learning with others in the IQ-MS project through collaboration using Edmodo." Teacher interviews revealed that Edmodo was not commonly used for collaboration for a number of reasons including local technology issues, personal time constraints or frustration with the inefficiency of the Edmodo program. In comparison, increases in agreement between years 2 and 3 for items 3 and 7 illustrate the rising popularity of the Virtual Library for learning and sharing, which, according to one interviewee, "exploded" over the past year. Also, responses to items 1 and 2 indicate strong agreement that video recording for collaborative discussions led by Specialists to facilitate implementation of DL strategies, a regular feature of the Specialists' on-site professional development program, is valued by teachers.

Finally, the high ratio of responses in the 'strongly agree' and 'agree' categories attest to teachers' positive feelings about DL and their personal commitment to disseminate the IQ-MS work on disciplinary literacy.

Table 10. Frequency percentages for Sustainability items on Teacher Attitude Survey Years 2 and 3: Learning

Learning		**Strongly agree**	**Agree**	**Uncertain**	**Disagree**	**Strongly disagree**
1. Analyzing video of my own teaching with my IQ-MS Specialist helps me implement Disciplinary Literacy strategies.	Year 3(n=26)	35.6	38.5	3.9	11.5	11.5
	Year 2(n=48)	16.3	40.8	22.5	20.4	0
2. Analyzing video of others' teaching with my colleagues and IQ-MS Specialist helps me implement Disciplinary Literacy strategies.	Year 3	30.8	38.5	15.4	7.7	7.7
	Year 2	16.3	49.0	22.5	12.2	0
3. I learn about successful practice with Disciplinary Literacy from others by viewing lessons in the IQ-MS Virtual Library.	Year 3	30.8	26.9	19.2	23.1	0
	Year 2	6.1	46.9	20.4	24.5	2.0
4. I regularly learn from others in the IQ-MS project through collaboration using Edmodo.	Year 3	11.5	26.9	19.2	34.6	7.7
	Year 2	10.4	35.4	10.4	37.5	6.3

Table 11. Frequency percentages for Sustainability items on Teacher Attitude Survey Years 2 and 3: Sharing

Sharing		**Strongly agree**	**Agree**	**Uncertain**	**Disagree**	**Strongly disagree**
5. I share my learning about Disciplinary Literacy with others through Edmodo.	Year 3(n=26)	15.4	26.9	11.5	38.5	7.7
	Year 2(n=48)	8.3	33.3	18.8	33.3	6.3
6. I regularly share my learning with others in the IQ-MS project through collaboration using Edmodo.	Year 3	7.7	26.9	15.4	42.3	7.7
	Year 2	10.4	41.7	12.5	35.4	0
7. I share my successful practice with Disciplinary Literacy in my classroom by submitting video lessons for the IQ-MS Virtual Library.	Year 3	42.3	42.3	3.9	3.9	7.7
	Year 2	10.2	55.1	10.2	20.4	4.1
8. I share my learning about Disciplinary Literacy with others through school PLTs.	Year 3	38.5	46.2	3.9	11.5	0
	Year 2	2.1	8.3	12.5	58.3	18.8
9. I share my learning about Disciplinary Literacy with others in my district and region.	Year 3	34.6	50.0	0	15.4	0
	Year 2	4.3	17.0	4.3	57.4	17.0
10. I share my learning about Disciplinary Literacy with others at state and national conferences.	Year 3	26.9	30.8	7.7	30.8	3.9
	Year 2	10.6	44.7	14.9	21.3	8.5

Table 12. Frequency percentages for Sustainability items on Teacher Attitude Survey Years 2 and 3: Disseminating

Disseminating		**Strongly agree**	**Agree**	**Uncertain**	**Disagree**	**Strongly disagree**
11. Disseminating the IQ-MS work on Disciplinary Literacy is important.	Year 3(n=26)	46.2	42.3	11.5	0	0
	Year 2(n=48)	24.5	53.1	22.4	0	0
12. My role in disseminating the IQ-MS work on Disciplinary Literacy is important.	Year 3	38.5	46.2	15.4	0	0
	Year 2	25.5	53.2	21.3	0	0

Measure1c. Levels of Use Teacher Interviews

In another measure of the effect of disciplinary literacy strategies on instructional practice, three research site schools were randomly selected from the five participating regions for the initial set of on-site interviews conducted by a BSCS evaluator in March 2013. After one school withdrew from the project, another was selected for participation in the interviews conducted in February 2014 (year 2) and March 2015 (year 3). The Levels of Use (LoU) Branching Interview protocol (Loucks, Newlove & Hall, 1975; Hall, Dirksen & George, 2006) was selected for the interviews. As a scripted, focused interview protocol, this instrument provides consistency in data collection and helps determine teachers' level of use of DL strategies through eight stages from nonuse to renewal. In addition, the interview protocol provides valuable data to triangulate with the observational and survey data addressing the research questions. Table 12 below describes the 8 Levels of Use.

Table 13. Levels of Use of the Innovation

Users	VI	**Renewal:** State in which the user re-evaluates the quality of use of the innovation, seeks major modifications of or alternatives to present innovation to achieve increased impact on clients, examines new developments in the field, and explores new goals for self and the system.
	V	**Integration:** State in which the user is combining own efforts to use the innovation with related activities of colleagues to achieve a collective impact on clients within their common sphere of influence.
	IVB	**Refinement:** State in which the user varies the use of the innovation to increase the impact on clients within immediate sphere of influence. Variations are based on knowledge of both short- and long-term consequences for clients.
	IVA	**Routine:** Use of the innovation is stabilized. Few if any changes are being made in ongoing use. Little preparation or thought is being given to improving innovation use or its consequences.
	III	**Mechanical Use:** State in which the user focuses most effort on the short-term, day-to-day use of the innovation with little time for reflection. Changes in use are made more to meet user needs than client needs. The user is primarily engaged in a stepwise attempt to master the tasks required to use the innovation, often resulting in disjointed and superficial use.
Nonusers	II	**Preparation:** State in which the user is preparing for first use of the innovation.
	I	**Orientation:** State in which the user has recently acquired or is acquiring information about the innovation and/or has recently explored or is exploring its value orientation and its demands upon user and user system.
	0	Nonuse: State in which the user has little or no knowledge of the innovation, no involvement with the innovation, and is doing nothing toward becoming involved.

Source: From *Measuring Levels of Use of the Innovation: A Manual for Trainers, Interviewers, and Raters* (pp. 171-195) by S. F. Loucks, B.W. Newlove and G.E. Hall, 1975: Austin: the University of Texas at Austin, Research and Development Center for Teacher Education.

Levels of Use are first distinguished between non- users (0-II) and users (III-VI). Users are then categorized in five stages progressing from mechanical use (III) to routine through refinement of the innovation to integration and finally to renewal, in which users go beyond the innovation to evaluate and explore new goals. Each level represents the teachers' increasing comfort and confidence with an innovation. Of course, this is not always a definite progression, and ratings may vary with the teacher's position with the innovation at the time of the interview.

In 2013, four teachers at each of the selected schools were randomly identified for the LoU interviews. In addition, an administrator and the IQ-MS specialist from each school were informally interviewed, classroom observations were conducted when time allowed, and photos were taken to document the visits. Following the 2012-2013 academic year, School C withdrew from the study and another treatment school, D, was randomly selected as a replacement. After educator retirements and transfers, 4 of the original 12 teachers interviewed in 2013 participated in interviews 2014 and 2015. Two replacement teachers from School B and 4 from School D were interviewed in the subsequent years. Table 13 below lists the LoU ratings for all three years of the study.

Table 14. Cumulative LoU ratings for IQ-MS teachers Years 1-3

IQ-MS LoU Ratings				
Interviewee	*Course*	*2013*	*2014*	*2015*
A1	6M/S	IVB	IVB	V
A3	M	IVB	V	VI
B3	7M	IVB	IVB	IVB
B4	7S	IVB+	VI	IVB
B5	M	x	III*	IVB
B6	6S	x	IVB+	IVB
D1 new 2014	7M	x	III-	III
D2	7S	x	V	V+
D3	8M	x	V	IVB
D4	6S	x	V+	V

Associating the theory and practice of Disciplinary Literacy as the 'innovation' to be measured, teachers' responses to the LoU interview questions were matched to behaviors associated with criteria for the Levels of Use on Table 14 above. Descriptions of the participants' Levels of Use for implementation of Disciplinary Literacy follow.

Interestingly, all four teachers interviewed in Year 1 were initially rated at Level IVB Refinement. Through the duration of the project, they remained at this level or moved to Level V and/or VI. It is notable that they had progressed through Level III, Mechanical Use and Level IVA Routine to IVB Refinement within the course of a single school year. This rapid development can be attributed to the on-site presence of Specialists and the positive relationships they built with the IQ-MS teachers. By the conclusion of the 3-year IQ-MS program, one teacher in this group

exhibited behaviors consistent with Level V Integration and another reached Level VI Renewal, the highest level of implementation.

Two teachers interviewed for the first time in Year 2 attained a rating of III, Mechanical Use, and reported implementation of DL strategies supported by the local IQ-MS specialist. Level III teachers revealed their emphasis on personal learning and mechanical attempts at implementation that did not necessarily extend to attention to their students' learning. In terms of DL, these teachers exhibited little knowledge or understanding of the strategies, used them infrequently, and felt that incorporating strategies into instruction was, at this point, "not seamless." They tended to rely on "the ones that worked" in their classrooms and were reluctant to try additional strategies. Some interviewees blamed their students for hesitancy in developing skills in implementing DL. Students were deemed "not ready," "unable to follow directions" or conduct themselves appropriately. Thus the Level III teachers appeared to lack desire and/or confidence in their ability to implement the strategies in the classroom, and some admitted that they "needed guidance" from the Specialist. However, by the final year, only one teacher remained on Level III, stating that the 'clientele' in this 'underachieving school' did not understand basic math concepts and could not read well. Thus it was considered difficult to, "walk the fine line to implement 'higher level' strategies when trying to teach basic facts." The teacher did admit, however, that participation in DL strategies was more helpful for students' learning than memorization of facts.

In Year 3, two previously rated IVB teachers remained at that level, and two exhibited characteristics of Levels V or VI. The teachers rated at IVB, the stage at which one has progressed from mechanical and routine use to refinement, described varying the use of DL strategies to adjust their impact based on knowledge of their students and efficacy of the strategies. A replacement teacher from School B was rated at IVB+. This IVB+ score indicates that the teacher exhibited a high degree of the characteristics of IVB and was beginning to discuss DL with their colleagues, the distinctive element of the next level V.

Level IVB teachers articulated their refinement of DL implementation by revealing an understanding of a wider range of strategies. They were also seeking additional information about DL from the Specialist and perusing additional resources. They recognized the need to adapt strategies to meet the needs of students and classroom situations. "I am driven by what my kids need." They make templates, explain examples of how strategies are adapted, and describe their plans for changes and adjustments. One teacher noted that her goal is to have students master "explanation rather than memorization" through participation in DL strategies. Of note here is the change from emphasis on one's personal learning and control to student-centered learning.

According to the Levels of Use protocol, Level V, Integration, is represented by users' development of more *structured collaboration with colleagues* "to achieve a collective impact on clients." One teacher from School A moved from Level IVB to V and then to VI, and, notably, three of the four interviewees from replacement School D were rated at level V or V+ for both years. Considering educators' relative isolation in classrooms, reaching Level V represents extra effort. A high level of continued refinement of DL implementation is seen in teachers' critical assessment of each strategy's effectiveness, linking student learning to test scores, and enhancing as many lessons as possible with DL strategies. "The more I use them, the more I tweak them." The strategies "help students as tools to understanding." The emphasis on "intentional planning" is clear.

Most important, combining efforts with colleagues takes Level V teachers out of their classrooms into wider venues to share their knowledge and understanding with other educators.

Credit is given to the Specialists who presented opportunities for teachers to present DL strategies in school, district and state venues. Those educators who participated in out-of-school meetings and conferences expressed the importance of Specialists' influence in encouraging them to design and deliver professional presentations which normally would have been outside their comfort zones. As a result the teachers felt empowered and gained confidence in their ability to lead others in adoption of DL strategies.

One teacher moved from Level IB+ to VI renewal due to her strong commitment to DL in her classroom and beyond. Anxious for students to "do more reading and writing" in her class, she "went beyond the binder" to seek additional information and guidance from the Specialist. She also reported that she modified strategies to "bring in deeper questions." For example, she modifies graphic organizers to develop exploration of ideas, not just memorization of definitions, based on her belief that "more student interactions lead to deeper learning." Extending beyond the classroom, this teacher meets weekly with the Specialist, shares DL information with the grade level team in faculty meetings, and creates video recordings for the IQ-MS virtual library. Her goals include using new or modified strategies daily, sharing DL information with teachers not involved in IQ-MS, extending the strategies from math and science to all content areas and disseminating them throughout the entire school. Of interest, the Specialist at this school reported that this teacher's students achieved higher than average test scores on the PASS tests.

It should be noted that in the current study, these LoU ratings have not necessarily indicated the breadth of DL implementation. For Year 1, Specialists focused on a few strategies selected from an extensive group of 37 in order to assist teachers to understand, field test, and then incorporate into instruction. The majority of the strategies practiced in Year 1 were focused on developing students' dialogue skills, a frequently under-utilized, yet essential skill for learning mathematics and science. Year 2 exhibited emphasis on strategies to expand reading and writing skills and deepen critical thinking. It should be understood, however, that 8 of 10 teachers interviewed represented Levels IVB and V and are, by the nature of their rating, refining, innovating, deepening and widening their use of most of the 37 recommended DL strategies for dialogue, reading and writing skills. In Year 3, in an effort to encourage independence, Specialists presented educators with resources and professional development experiences to expand their repertoires of strategies. In addition, a few teachers are independently seeking references on additional DL strategies to meet classroom needs. As educators' proficiency and confidence continue to increase, inclusion and mastery of additional strategies bring deeper dimensions to classroom teaching and learning of science and mathematics as well as foster collaboration with a wider arena of peers.

Discussion of Results

Specialists' Roles: As in 2013 and 2014, positive relationships between and among teachers, administrators, and Specialists were evident at the schools that we visited. These strong interactions have contributed to general local acceptance of the IQ-MS instructional techniques by stakeholders. Specialists serve as mentors to motivated teachers seeking to expand their skills in implementing disciplinary literacy strategies. In addition, their goal is to encourage and support teachers who are hesitant or reluctant to incorporate DL into their classrooms. As voiced by one Specialist, their basic responsibilities include planning, observing, coaching, coordinating, mentoring, and training. Through the course of the IQ-MS program, Specialists intentionally developed teachers' independence by steadily removing supports while

encouraging their differentiated implementation of strategies, planning and development of lessons for the Virtual Library, and designing and conducting professional development sessions at local, district, state and national conferences. Teachers expressed gratitude for the continuing support of the school-based Specialists and freely consulted with them in efforts to improve their competence in DL strategy implementation related to their students' mathematics and science achievement.

Administrators' Roles: Interviews with administrators at treatment schools highlight the importance of administrative support in the integration of DL strategies within classrooms. All administrators who were interviewed expressed both deep understanding and strong advocacy of disciplinary literacy and the impact of the IQ-MS program on their educators and students. With such school-wide advocacy of DL, the potential for successful implementation is strengthened.

School contexts: Local school contexts exert an influence on the success level of IQ-MS efforts in treatment schools. It was frequently noted by teachers, Specialists, and administrators that new curricula such as the Digits math program, changing state standards, the presence of the TAP program, and introduction of new standardized testing have affected teachers' work by adding new requirements for performance. Thus time is an issue for those who desire to seek, learn, and perfect the use of DL strategies in the classroom. Thoughtful teachers see congruencies between and among the 3 entities, but often DL strategies, Common Core standards, and the Digits curriculum are regarded as separate requirements that increase instructional burden on teachers. Additionally, depending on local context, the TAP/DL interface can either be an instructional impediment or an advantage for science and math educators. In some cases the stringent demands of TAP place additional demands on teachers' time and may negatively impact opportunities for planning and implementing DL strategies. In one school, however, the TAP Lead Teacher and IQ-MS Specialist collaborated to combine DL and TAP strategies so both teachers and students interact with strategies across grade levels and content areas.

Finally, schools' organizational structure can affect teachers' ability to meet and collaborate on extending their mastery of DL strategies. As an example, the Levels of Use interview ratings for some teachers were affected by opportunities for sharing that are presented within the school. The difference between Level IVB Refinement and Level V Integration is based partially on "using the innovation with related activities of colleagues." If the school does not provide meeting times such as grade level meetings for teacher collaboration, opportunities to share are restricted to hallway or after school conversations. Specialists thus offer an essential service in their one-on-one sessions with IQ-MS teachers. Where local and district and state meetings are organized, opportunities for IQ-MS teachers to disseminate information about the program are rich. Conferences such as the district Instructional Fair inspired Specialists to be instrumental in developing teachers' confidence and facility in designing and conducting IQ-MS sessions that empowered them to 'spread the word' about the effectiveness of DL and ensure its sustainability beyond the years of IQ-MS funding.

Conclusions

In the big picture, data from the three years of RTOP observations, teacher surveys and LoU interviews indicate that implementation of disciplinary literacy strategies is exerting a positive impact upon mathematics and science instruction in the IQ-MS treatment schools. Continued

strong administrator/Specialist/teacher associations observed in the schools serve to strengthen the potential for improved students' math and science achievement in treatment populations.

Despite challenges, collaboration between and among IQ-MS and non-IQ-MS teachers has increased at treatment schools so that the strategies are extending beyond math and science content areas and classrooms to other content areas, as well as from IQ-MS science and math teachers to those not receiving support.

IQ-MS teachers are also extending their influence by disseminating their knowledge of strategies to school faculty meetings, to presentations at events such as the district, state and national conferences, as well as contributing exemplary videos for the Virtual Library. The steady, concerted efforts of the IQ-MS leadership have guided Specialists to enact program guidelines and to reach their anticipated research aims of:

- Evidence of regular, self-directed teacher use of disciplinary literacy strategies in classroom practice
- Teacher reports of advocacy regarding the use of disciplinary literacy strategies

Thus, strong evidence from multiple sources supports the program's accomplishment of the anticipated final innovation aim of "A functional community of support in each S^2TEM Center's region able to sustain STEM education efforts including IQ-MS."