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Abstract

Incorporating literacy instruction in science is a beneficial practice that uses interdisciplinary strategies to address connections between language arts and science. Interdisciplinary curricular approaches in education are common expectations for science teachers and there are increasingly more mandates for embedding literacy into science curricula. This interdisciplinary program requires the teachers to apply a common methodology and language to instruction. While ideas for lessons and strategies for incorporation of literacy in science are plentiful, the field falls short in providing guidance on assessment of proficiencies in the literacy embedded science instruction. Therefore, it is critical that teachers receive support in creating common learning goals and assessments to ensure appropriate alignment of interdisciplinary curricula. The purpose of this project is to explore the problem that elementary teachers have with assessment when implementing interdisciplinary science and literacy instruction. The project has practical implications for teachers at the primary and secondary level where many times it is easier to teach only one subject, and sometimes teachers have not had training in teaching both subjects. Additionally, even if teaching interdisciplinary science and literacy is done, it is difficult to assess both subjects in one assessment tool. Therefore it is necessary to determine how teachers can not only design the assessment tools, but use them to identify student learning in both literacy and science instruction. This manuscript will provide our analysis of interdisciplinary teaching and assessment strategies, and a compilation of effective assessment strategies that will be useful for other teachers involved in incorporating literacy curricula into science instruction.

Introduction

A crisis in science education stems from the dearth of robust science programming in elementary classrooms. Science lessons are often neglected in K-5 classrooms (Akerson & Flannigan, 2007) even as elementary teachers desire to provide quality science instruction. Perhaps one of the biggest impediments to elementary teachers providing quality science programming are large blocks of time being mandated to language arts instruction. For example, the Lewistown School District in Texas offers their elementary grade teachers guidelines that allocate 29% of the day to be devoted to language arts while 12% of the day is set aside for science (Lewisville, 2013). There are also language arts mandates in Indiana that require elementary teachers to include ninety-minute blocks of literacy instruction into their daily routine (Indiana Department of Education, n.d.).

Although addressing the problem of insufficient science instruction in the elementary school setting is complex, an exciting solution was explored in the project, *Science the 'Write' Way: Supporting Indiana's Rural Teachers in Addressing the Literacy-Based Science Standards (Science the 'Write' Way).* In this project, interdisciplinary literacy and science curriculum development and instructional practice ideas were promoted for K-8 teachers in a professional development setting. It is important to understand how teachers will effectively assess standards-based learning goals for both subjects of integration when implementing innovative curricula. Such data will be critical in promoting interdisciplinary language arts and science instruction that fulfills educational mandates for multiple subject integration. The goal of the current study was to identify assessment practices of the participants of the *Science the 'Write' Way* project and to understand what kinds of support teachers need in the integration of science and literacy assessment. To do so, we first determined the kinds of teacher designed and tested assessment tools the participants developed in the *Science the 'Write' Way* professional development program. Based on analysis of assessment practices throughout the project, recommendations were then made to support teachers in overcoming obstacles to integrated assessment practices. The questions guiding the study were:

1. How did K-8 teachers in the *Science the 'Write' Way* project assess literacy-based science standards?
2. What kind of assessments provided effective indications of literacy proficiency as well as conceptual understandings in science?

Theoretical Framework

Based on data obtained through the *Science the 'Write' Way* project, this study, was guided by an interpretive framework. Interpretive research assumes that knowledge is gained through social constructions such as shared meanings, language, documents, tools, and other artifacts (Kline & Myers, 1999). The research relied on collaboratively developed lesson plans, focus group interviews, surveys, and teacher reflections to elucidate the ways in which integrated assessments of science and literacy were being designed, implemented, and evaluated. In this way, the interpretive approach allowed us to reveal integrated assessment practices that were socially constructed. Interpretive analysis allows the researchers to explain and create generalizations. In doing so, the researcher can then provide insights that might lead teachers to refine their knowledge and identify problems (Hittleman & Simon, 2006). In the current study, the interpretivist approach guided an examination of common existing integrated assessment practices across the participant's lesson plans and provided the structure necessary for identifying constraints to the development and implementation of such practices.

Literature Review

A review of the literature comprised the following bases of research to inform our study: assessment practices in science and literacy, interdisciplinary curricula, teachers' use of assessment in integrated planning and implementation, and types of assessment valuable in blended literacy, and science instruction. When integrated, literacy and science disciplines can complement each other by providing avenues for forming new curricula that combine essential skills and understandings in a way that bilaterally supports learning (Cervetti, et al., 2011). Assessment tools that can effectively measure multi-disciplinary skills (such as reading comprehension, writing for communication, and conceptual change). This disciplinary integration has great potential to be useful to

overarching elementary and secondary educational goals (Stoddart, et al., 2002). Research by Romance and Vitale (2011) suggests that there are similar deficiencies found in literacy and science disciplines and speak to low levels of scientific literacy in education. This review highlights important aspects of integrated literacy and science curricular development especially as it relates to combined disciplinary assessment.

Literacy and science subjects often are viewed as separate curricular areas requiring a completely different set of skills, approaches, and lessons. During the burgeoning *hands-on* movement in science, Baker and Saul (1994) described language arts and science being perceived as rivals. However, there are many instances where integrated science and literacy instruction benefit multiple-subject learning objectives through harmonization in curricula. Similarities with science practices and whole language approaches both center on inquiry and learning processes (Akerson & Young, 2007). Inquiry-based science and literacy share skills, strategies, and goals central to integration instruction (Yore & Treagust, 2006). An example of a shared interest among science and literacy is the use of discussion to support comprehension and making meaning of complex ideas (Cervetti, et al., 2012). Also, it makes sense to connect language arts to science because of the similarities of reform goals in each discipline (Akerson, et al., 2010).

Edwards (2013) describes assessment as, "an integral part of learning and is seen as a key component in quality teaching; essential for raising student achievement by supported learning" (p. 213). To understand the intricacies involved in assessing for science and literacy competencies, it is important to define the student skill sets necessary for integrating reading, writing, and science (Romance & Vitale, 2011). The elucidation of these common skills provide support for teachers with diverse assessment practices across content areas (Zang & Burry-Stock, 2003) and elementary teachers who are more comfortable with purposeful assessment design in language arts than science (Gearhart et al., 2011). Britsch and Shepardson (2007) offer the CLASP checklist of observable scientific literacy behaviors. For example, when looking for observable behaviors, a teacher might determine if their students include evidence of prior knowledge in their integrated assessments. Literacy instruction for adolescent learners tends to drop off at the same time that older students are challenged by more and more complex technical writing. Disciplinary literacy can help provide a setting to continue to build language-based skills in secondary science courses (Shanahan & Shanahan, 2008). Although specifically associated with language as it pertains to English language learners, the *science-language integration rubric* developed by would be useful for indicating teacher development in thinking of the practice of science and language integration (Stoddart, et al., 2002).

Challenges for Teachers

Standardized Testing

Teachers face many challenges when developing assessment for integrated literacy and science instruction. High-stakes testing can stifle innovation in curricular integration. In a study exploring nature of science (NOS) assessment, researchers found the teacher participants to be under enormous pressure to improve state test scores (Akerson et al., 2010). In part, this pressure is due to the decontextualizing of the assessment. Kamen (1996) argues that such high stakes testing pressures prohibit teachers from employing [assessment] knowledge *wisely, fluently, flexibly, and in particular contexts* (p. 860). Assessments that fail to detect outcomes of systematic

educational reform because of a lack of alignment of curriculum and instruction and the standardized test (Marx, et al., 2004) . These external pressures for accountability further present challenges for integrated literacy and science programming in the way of time constraints for effective integrated curricular implementation as well as a lack of support from school leaders (Koh, 2011). Morrison (2007) speaks to teachers stressing memorization in a competitive academic atmosphere derived from standardized testing while Kamen (1996) highlights a fundamental problem with published tests that fail to accurately measure levels of understanding, providing little information on student knowledge.

Assessment Design

Interpreting student needs is another challenge teachers may face when incorporating literacy skills into science lessons. Knowledge of younger students' conceptual understandings as being constrained by reading and writing abilities that cannot adequality share ideas and reasoning (Akerson, et al., 2010). Designing enriching integrated learning opportunities is not a simple task in that it requires consideration of disciplinary, psychological, and pedagogical perspectives (Yore & Treagust, 2006). Although complex in nature, teachers who design their own classroom-based integrated science and literacy assessment tools will be more responsive to students and therefore, more effective in instruction. Designing science and literacy integrated curricula and assessment requires teachers to be reflective practitioners. A bulk of this reflection should happen in a collaborative setting where teachers can confer on instructional goals and assessment purposes. This collaboration can build ideas in integrating authentic assessment and be beneficial in examining the quality of the assessment and student work to ensure the validity of the assessment (Koh, 2011).

Science and Literary Integrated Assessment Competencies

Another important factor in successful determinations of skill achievement and content literacy is to consider a variety of assessment types that are appropriately aligned with learning objectives and purposeful use of the information obtained from the assessment. As Edwards (2013) points out, teachers should be able to articulate clear learning intentions that are congruent with content and depth of thinking implied by standards and curriculum goals in such a way that is attainable and assessable. Koh (2011) highlights key indicators of assessment literacy: to start with a clear purpose, to understand the importance of assessing interrelated achievement targets, representative performance tasks that allow for sampling of student achievement, and avoidance of bias and distortion of assessment (resulting from technical and/or practical problems). Cervetti, et al., (2012) describes literacy and science assessment as being designed to assess students' mastery of science vocabulary, reading comprehension, science writing, and science understanding. It is also important to look specifically at the capability of formative assessments for creating responsive integrated assessment. Bell and Cowie (2000) remind us that formative assessment should provide information for adjustments made in instructional strategies and also that responsiveness is the essence of formative assessment. Formative assessment can often be tacit in practice but should be made explicit when planning integrated science and literacy curricula (including assessment) as it may not be intuitive for teachers who are incorporating new lessons in their science and language arts programming.

Integrated Assessment

Although there are several instances in the literature where science and literacy curricula are integrated, there is little reference to the use of assessment in measuring cross-curricular skill sets and competencies. A primary function of assessment is to provide evidence of student progress to support learning for the purpose of providing helpful feedback for students and making appropriate adjustments in instruction (Edwards, 2013). Gearhart et al., (2011) states to support student learning, teachers need to gather evidence of student progress and use this to give helpful feedback and make adjustments in instruction. Morrison (2007) agrees that feedback should be descriptive, not evaluative or comparative. It would be appropriate for teachers to set up varied learning situations to provide opportunity for formative assessment information to be gathered (Bell & Cowie, 2000). Yore and Treagust (2007) cite multiple representations in knowledge and science literacy (such as models and analogies) as important in enhancing conceptual knowledge and improving communication skills. Blintz and Moore (2007) describe the literature-based text cluster as being beneficial in that it has unlimited potential to create and communicate meaning from literature and suggests building libraries of high-quality books to match major themes in science. Questioning through discussion can also be an effective formative assessment using language to communicate science ideas. Clough (2006) suggests teachers should ask questions like, "how might you present your data in a way that is easiest for the reader to grasp" helping the student to reflect not only on the science concepts driving the data but also the most effective way to communicate scientific understandings through writing (p.485). Checklists were recommended by Kamen (1996) as an effective tool to assess conceptual understandings in science developed through the literacy skills involved in creative drama in the classroom.

Methods

This study inspected the assessment of literacy-based science educational goals. The interpretive model provided the framework for this analysis across a variety of data sources (Kline & Myers, 1999). Participants created lesson plans, focus group interviews, field notes from classroom observations, and a post-workshop survey comprising the qualitative data collected over the course of the two-and-a-half-year *Science the 'Write' Way* program. Both researchers reviewed the data and compared analyses to ensure valid interpretation of the data. Also, multiple data sources were analyzed to ensure valid interpretation of the data.

Context and Participants

The context in which data was derived for our study was a professional development program for teachers K-12. Seventeen teachers from rural schools in the areas surrounding the university participated in the program, with nearly 100% attendance and little attrition. There were fourteen elementary teachers and three high school teachers who participated. This program was conducted by science education faculty members in conjunction with science education doctoral students, a literacy faculty member, and two doctoral students with a literacy research focus. The two-year program began with an intensive one week summer session (forty hours) followed by four sessions in the academic year (two each semester). Additionally, teachers were provided with materials they could use to incorporate science and literacy instruction. Summer sessions were divided into morning and afternoon activities,

with activities in the first summer comprising sample lessons of activities incorporating science and literacy (including assessment strategies), along with various literacy activities such as scientific writing, story spines, and narrative writing helping teachers who lacked literacy backgrounds conceptualize various strategies they could use within their science lessons. Workshops provided during the academic year enabled teachers to share what they were doing with science and literacy in their classrooms and was an opportunity to receive additional training in integrated literacy and science strategies. Classroom observations took place by project staff to provide feedback to teachers in promotion of alignment of integrated learning goals and instruction. The second summer incorporated additional science and literacy instruction, contextualized within a *Chopped* (from the TV show) framework, where teachers were given materials and asked to design a science and literacy activity from the framework of either literacy or science on their chef hats. In addition to the literacy activities, there were sessions on assessment of science and literacy, instruction about rubrics, why assessment is critical, and how to assess literacy and science objectives. Further classroom observations and workshops took place in the second year of the program.

Data Collection

The surveys and interviews of the teachers collected throughout the program were reviewed to determine participant understandings and agency in development and facilitation of assessment of the interdisciplinary instruction. Both researchers independently reviewed the surveys and interviews for understanding of interdisciplinary instruction and assessment of such instruction. Classroom observations were reviewed alongside participant designed formative and summative assessments to identify outcomes from the combined literacy and science instruction. Patterns became evident in terms of types of assessment strategies used to help students attain objectives in literacy and science and the challenges teachers face in doing so.

Data Analysis

Researchers used an open coding method to identify patterns in assessment practices discussed in the focus group interviews and survey. Patterns based on the codes emerged and were categorized and counted for frequency. Assessment strategies targeting integrated literacy and science goals were compiled from lesson plans and researcher classroom observations. Commonalities in assessment practices were identified and subsequently categorized as being science, literacy, or interdisciplinary specific. Individual researcher analyses were compared, and discrepancies found were further discussed through consultation of data before final determinations were made.

Results

Our analysis suggests that although teachers are eager to provide integrated literacy and science curricula, they often do not consider assessment in lesson design. Lack of time, resources, and knowledge of integrated instructional techniques and assessment design for integrated literacy and science programming was found to be a hindrance for combined science and literacy planning and instruction. Assessment practices that targeted

sciences and literacy together were often not in place or explicitly mentioned. Because of assessment's critical role in planning, implementation, and reflection of integrated curricular instruction we acknowledge that these assessment challenges are important to address (Table 1).

Table 1. Focus Group and Survey Responses Frequency of Mentions of Interests, Constraints, Lack of Resources, and Assessment Practices for Integrated Science and Literacy Planning in the K-12 Classroom

Participant	Interests	Time constraints	Lack of resources	Assessment
Focus Group 2017 (n= 13)	10	4	6	5
Focus Groups 2018 (n=8)	5	3	3	2
Survey Respondents (n= 14)	4	2	2	1

Time Constraints

Five of the teacher participants reported having more time would help them achieve intended outcomes. Two specifically mentioned that more planning time would be necessary to meet subject integration goals. Eight of the respondents had professional development needs for science and literacy lesson planning support. Time was mentioned as a constraint to integrated curricular planning and execution in all but one of the seven focus group interviews. Indication of both an interest in incorporating literacy into science programs and a lack of time to appropriately do so was expressed in this teacher comment, "…all the great ideas fall by the wayside because who's got time?" Another participant highlighted the need for more time for reflection when she stated, "…I think it's more about planning time…and time to reflect on implementation, and you know, being a teacher, there's never enough time." One focus group participant admitted to "sneaking" science instruction in because, "time's always an issue." Standardized testing was the cause of a third-grade teacher's ability to incorporate integrated science and literacy lessons because "I've got I-Read and I-STEP." According to one teacher, new ideas [integrated literacy and science instruction] are difficult to execute because "once your day starts or the year starts, there is never enough time to go back and look at it again."

Resources

Responses to the survey question, "What challenges or opportunities have there been with integrating literacy into your science lessons?" highlight a need for curricular guidance. For example, one elementary teacher's survey response admitted, "I feel like I'm making it up as I go, it would be nice to have a guide to follow!" A secondary

science teacher called for resources that could efficiently help infuse literacy into a complex stoichiometry unit when she stated, "My students' math abilities aren't up to par and it takes months to teach this dimensional-analysis based unit." However, among the major themes identified, lack of resources was mentioned in only three of the seven focus group interviews. Responses to the interview question, "What forms of literacy enhanced science instruction have you learned about during the workshop this week?" indicate an appreciation of being given resources including science lesson plans that incorporate trade books. A typical response was articulated by a teacher who said, "…getting these books and materials helps me to be able to integrate into my writing lessons easily and a big variety of ways to present." She goes on to mention completing a brochure as the point of intersection between science and literacy was an idea obtained through the *Science the 'Write Way'* workshop. Resource suggestions are welcome according to one response while another mentioned the high cost of quality integrated science and literacy curricula and a need to be able to obtain such materials without purchasing them with her own paycheck.

Instructional Strategies

Teachers who participated in the *Science the 'Write' Way* project cited learning new instructional strategies as being very important to integrated science and literacy implementation. Instructional strategies were addressed in all but one focus group interview and were mentioned multiple times in five out of the seven focus groups. Throughout the project, teachers appreciated new ideas for using questioning as an instructional strategy as indicated by one participant who described being more comfortable in using questioning to increase explanation and argumentation in the classroom after a year of being involved with the project. Another teacher loved the idea of using alternate forms of instructional programming, such as student news cast productions, as a way of combining literacy and science instruction. When one participant stated, "the whole claim, evidence, reason…that was a new form I learned," she was demonstrating a lack of knowledge of basic science instructional strategies that employ literacy skills. For another, "this whole idea of claims, and evidence and reasoning" was helpful in exploring the cyclic nature of science practices and reflected real science methods. Many participants appreciated learning a technique called *Story Spine* in the workshops. This literacy based instructional strategy uses common story characteristics to build science knowledge and one participant was excited about the use of this instructional strategy to encourage her students to "add more detail and information into their science writing" while another envisioned this strategy as useful in science vocabulary acquisition.

Integrated Assessment

No survey response question mentioned specific assessment measures to provide evidence of students' learning. Thus, it is not determined if project participant responses indicated a use of valid assessments for integrated science and literacy learning goals. Five survey responses indicated confidence that their students made achievement gains in their science and literacy lessons. No teacher who reported being confident detailed why they were assured that students were gaining knowledge (such as meeting learning objectives). Eight of the fourteen participants reported being somewhat confident in their students' growth while two reported not being at all confident that their students were reaching learning goals through literacy-based science lessons. Without

explicitly addressing integrated science and literacy assessment, the following focus group interviewee seemed to be considering the assessment possibilities in using the *Story Spine* instructional strategy when she stated, "it would be helpful in coaxing them to put more information into their answers." One teacher reported using journaling to enhance scientific instruction while another appreciated learning forms formative assessments such as role-playing and brochures as opposed to paper tests. Another participant successfully reported using exit tickets to understand how students are reasoning about science concepts. About standardized tests, one participant notices, "…even though they [her students] understand it [science concepts] but to explain, that is where a lot of them struggle."

Assessment Strategies

Teacher created lesson plans and researcher observations were analyzed for evidence of assessment for blended literacy and science activities (see Figure 1). Thirteen teachers were involved in the *Science the 'Write' Way* project in year one while four dropped out of the study in the second year. Four of the twelve planning forms collected were incomplete. The form petitioned the following information: relationship to combined subject instruction workshop goals, science topic, short abstract as well as a detailed description of the combined unit plans, and teacher and student products. All but one response used this section to provide the Indiana Science and Processing Standards, Indiana Science Disciplinary Core Standards, and Indiana Literacy- Enhanced Instruction Standards associated with the integrated unit." There was indication of science assessment strategies being implemented in lessons in seven out of the twelve responses. These strategies included: charades, questioning, sorting circles, illustration, data sheets, card matches, and sequencing strips. Literacy assessment strategies were noted in one of the twelve planning forms where predictions, comparisons, and comprehension questions associated with a trade book about robots were incorporated.

The interdisciplinary assessment strategies were noted as: scientific journals, CERs (claim, evidence, reasoning), story spines, ethograms of animal behavior, power points, movement (to represent learned animal behaviors), comprehension questions about science books, graphing, word trees, student created poetic statements, drawing, and internet-based products. One example of science journals exemplified science concepts illuminated through writing and then critically applied was evident in one students' understandings of sea turtles. In the first comments, the student was able to explain sea turtle's structural and functional relationships and then apply these concepts to critical thinking involving ideas for habitat protection. Important to note is only one rubric was provided by participants so researchers were not able to make an accurate judgement on assessment validity.

Classroom observations were the final data point that was analyzed for integrated assessment. Out of six observations, only two indicated evidence of assessment matching lesson purposes and intended outcomes. Owls were the subject of a literacy-based lesson in which students had to provide evidence for claims about the birds' diet. In another lesson, discussion and written conclusions were used to provide evidence of students' knowledge acquisition of biological relations. In half of the observations, it was noted that teachers were acting as facilitators with questioning strategies that prompted understandings of student comprehension and opinions. In the other half of the observations, researchers witnessed teachers' whose role seemed to vacillate between being a source of

knowledge and a facilitator. In one observation, science journals were being used and could have been a possible implicit source for assessment.

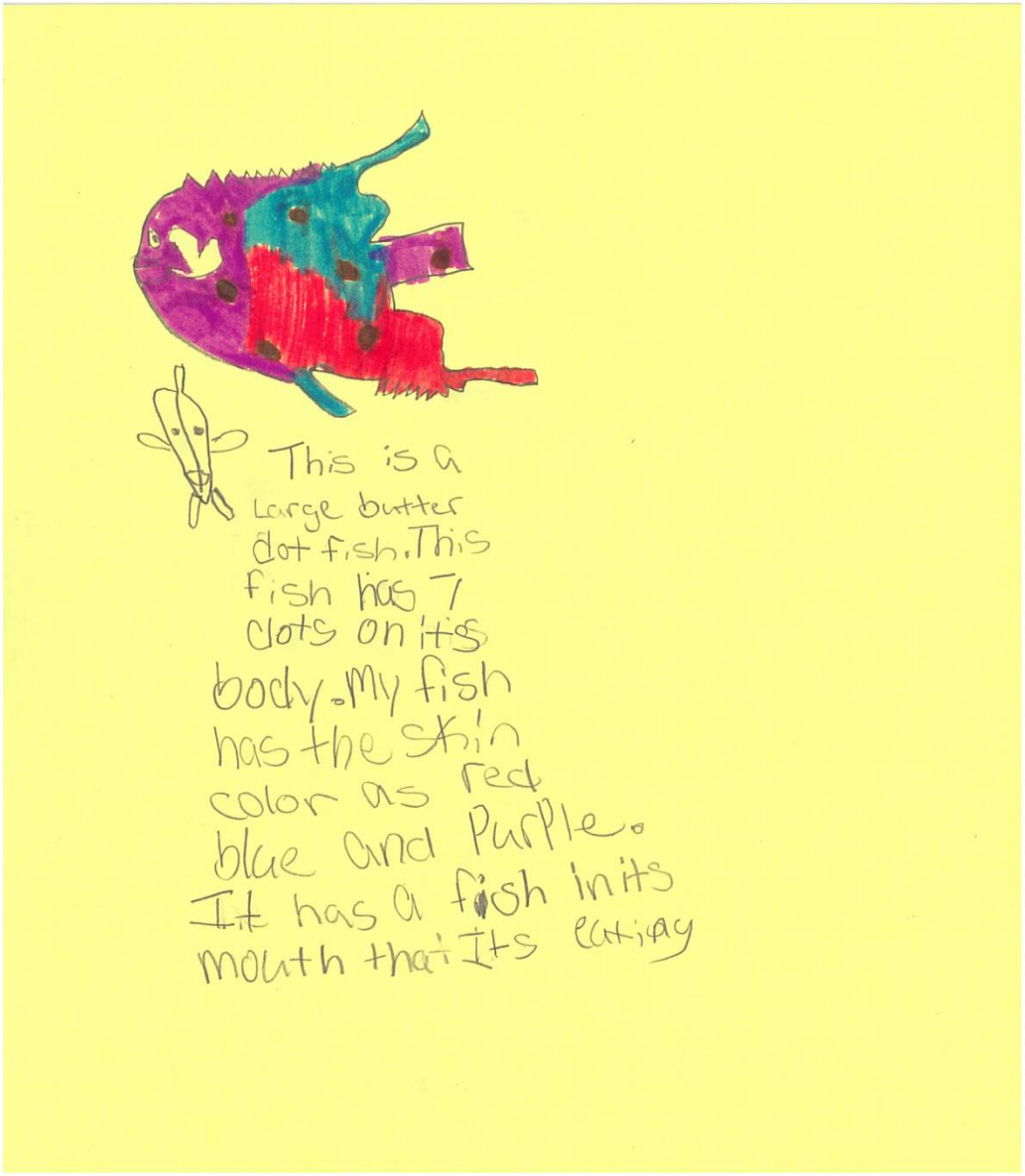

Figure 1. Assessment Sample from a Science Journal

Discussion

In this study, the lack of evidence of appropriate integrated assessment measures provides us with insights necessary to help teachers develop and implement future successful combined subject assessments of literacy-based science instruction. To answer our research questions, we found challenges for teachers in design and implementation of integrated science and language arts lessons which we presume to also hinder development of the necessary assessment practices. It is also interesting to note that although the teachers rarely mention assessment practices in the focus group interviews and survey responses, the lesson plans and teacher observations indicate that there are assessment measures in place. These findings suggest that there is a disconnect with lesson

delivery and assessment development. By identifying barriers in integrated science and literacy planning and implementation and also exploring examples of appropriate use of integrated assessment, this study allows us to make recommendations to help educators incorporate literacy into science.

Lack of time was often reported as being a barrier to integrated science and literacy development. Teachers reported needing more time for planning, collaboration, and reflection as well as (in the case of elementary teachers) more classroom time for science programing. One teacher even felt as if she was sneaking science into her daily lessons. Although a common problem, there are simple solutions to provide more time for teachers. Building leaders can promote collaborative integrated science and literacy planning. As with all educational innovation, there is a necessity for large swaths of dedicated planning time up front, in order to save time in the school day. Proper time to plan will greatly reduce the amount of time a teacher daily needs to be designing integrated literacy and science lessons. Consistent incorporation of science into dedicated language arts time will allow for teachers to expand explorations rather than compartmentalizing science into small chunks of time (or not at all).

Lack of knowledge of or access to resources is another hindrance for teachers who are developing integrated programming. School leaders who see the value of literacy-based science programming could be instrumental in helping teachers access the materials they need. Educational materials and texts could be chosen based on their incorporation of literacy skills. School librarians could provide trade books to teachers that can easily be incorporated into science lessons. Professional development opportunities that provide ideas of high-quality literacy and science resources could be offered to teachers interested in literacy-based science programming. Teacher participants were enthusiastic about the new instructional strategies they learned in the *Science the* '*Write' Way* workshops. This eagerness to learn and try new ideas in instructions indicates that teachers would also be open to learning how to incorporate formative assessments directly into instructional strategies to inform them of lesson effectiveness in growing understandings in literacy skills and science concepts. This study found plenty of examples of assessments in lesson planning forms and classroom observations. What was not clear was how the assessments were measuring for specific literacy and science learning objectives. This insight provides us with a good place to start in making recommendations for integrated assessment instrumental in planning, implementing, and measuring student achievement.

Recommendations for Integrated Assessment

Although we present our recommendations for integrated science and language arts assessments in a linear way below, it is critical to think of integrated literacy-based science assessment as a continuing cycle that does not end with a lesson, unit, or even school year. Bell and Cowie (2000) cite professional knowledge and experiences as being a fourth characteristic of formative assessment. Consistency and frequency of integrated literacy and science lessons will help teachers to develop and revise integrated assessments that appropriately measure learning goals. The following will describe recommendations for assessment that include developed learning goals, use of multiple representations in assessment products, using sciences notebooks as a *catchall* for integrated science and literacy understandings and skill development and the use of checklists as formative assessment tools (Table 2).

Table 2. Science, literacy, integrated assessment strategies identified from the 'Write' Way Project.

Academic Subjects	Assessment Strategies
Science	sorting circles, illustrations, data sheets, card matching, sequencing strips
Literacy	making comparisons of trade books, making predictions of trade books
Integrated	Science notebooks, CERs, story spines, ethograms, slideshows, movement, comprehension questions, graphing, word trees, poetry, drawings, computer designed projects.

Learning Goals

Creating science and literacy objectives is paramount to developing assessments that appropriately align with learning goals. Marx et al. (2004) described standardized tests as being invalid when they failed to align with curricular goals. This skewed alignment of curricular goals and assessment can also happen to teachers who are planning literacy-based science experiences where clear learning objectives of skills and understandings of both disciplines are not recognized. Edwards (2013) stresses the importance of clear learning intentions with accessible and obtainable measures for evaluating student understandings and achievements. Once learning goals are established in science and literacy, curricula development can happen around the specific targets. Formative assessments can then be built into curricular activities to provide a guide for how the lesson unfolds in the classroom. Summative assessments also should be created around learning objectives, allowing the planning of the integrated literacy and science lessons to be backwards in design.

Multiple Representations

The use of multiple representations such as models, analogies, equations, graphs, diagrams, pictures, and simulations is recommended in integrated science and literacy assessment. According to Yore and Treagust (2006), these types of representations are effective in communicating science conceptual understandings. Employing many types of representations in an integrated science and literacy unit can provide a variety of evidence of literacy skills being used to promote communication of new understandings. It is crucial that these multiple representations are intentionally used to measure specific learning targets. Therefore, measurement tools should be in place on the outset of any type of product that will be assessed for sciences and literacy goals. Our study results indicate a lack of preconceived measurement tools implemented into assessment practices. We recommend using rubrics that include integrated science and language arts learning goals as appropriate integrated assessment measures.

Science Notebooks

We recommend that teachers who integrate literacy into science lessons use science notebooks. These notebooks provide a space to capture conceptual understanding developments and also monitor literacy skill progressions.

In science notebooks, students can display the construction of learning while teachers can analyze conceptual understandings in sciences and writing and reading comprehension skills in language arts. Crowther and Cannon (2017) explain that when students experience science note booking it helps students with thought clarification, idea sorting, and provides an illustrated understanding of science subjects. The authors agree with Morrison (2007) who points out that scientific notebooks should be used for formative assessments. He states these notebooks can determine ideas about prior knowledge, building of understandings, mastery of curricular goals, and the ability to apply knowledge. Although he is describing science goals, there is a natural fit for notebooks to be used as formative assessment in literacy goals as well. Consistently using science notebooks in an integrated literacy and science curricula would be very useful in providing assessment information of both disciplines. They also offer structure to the integrated science and literacy lessons. Used consistently for integrated literacy-based sciences lessons, science notebooks can provide accessible information for teachers to evaluate student achievement.

Checklists

We cannot underestimate the usefulness of checklists in providing a swift and comprehensive picture of student understandings and academic gains. Bell and Cowie (2000) contend that using checklists for formative assessment is an efficient and powerful indication of learning. Teachers can create comprehensive lists of learning goals in literacy and science for a particular lesson or unit. This list can then easily be used for the teacher who is monitoring progress through notebooks in the classroom or literacy-based skills in science activities. The use of checklists then, can accommodate for assessment for integrated learning objectives in active, hands-on science lessons in a non-invasive way.

Conclusion

This study identified constraints to adequate literacy infused science instruction in elementary classrooms. We consider a backwards design approach as a solution for helping teachers include all standards-based subject areas in daily lessons. This entails proper alignment of learning goals for both literacy and science instruction followed by the development of integrated assessments before lesson planning begins. Analysis of data gathered in the *Science the 'Write' Way* project supports practical implementations of effective interdisciplinary teaching and assessment strategies across grade levels, and a compilation of effective assessment strategies that will be useful for other teachers. Future research that will inform planning and implementation of a fully integrated literacy and science program should look at providing support for elementary teachers in planning time, resources, implementation strategies based on properly aligned integrated learning objectives and assessments. This support will encourage teachers to provide adequate, if not exemplary, science curricula concurrently compiling important assessment information that will inform them of their student's academic progress in both literacy and science objectives but also to provide evidence of their ability to meet language arts instructional mandates through integration of standards-based science content. With proper integrated assessment in place, elementary teachers will be closer to fulfilling their earnest intentions to provide robust elementary academic experiences for their students.

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