Co-teaching in the digital information era: Comprehending the role of information and technology literacy in the sciences

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Abstract

This qualitative study investigates two university professors' co-teaching partnership in teaching college students (48 certificate completers) over five semesters (8, 3 credit-hour courses). Data were collected from student records, student and professor course material artifacts, and student surveys to investigate the role of information and technology literacy in the sciences. The courses were a significant part of a three-year research project, *Science*, *Technology, Engineering, and Mathematics: Information, Technology, and Scientific Literacy for ALL Learners (STEM-ALL),* funded by a Laura Bush 21st Century Library Program grant from the Institute of Museums and Library Services. Teacher-effectiveness was viewed through the theoretical lens of intensity of effort by the two co-teaching university professors and their students' achievement by analyzing 22 learning outcomes assessed 187 times in 58 assignments in four, three-credit hours courses (12 credit hours) for Group A (23 students) and Group B (25 students). Because physical sciences expertise was one-half and library and information science was the other half of the co-teaching collaboration in the STEM-ALL project, this study builds interdisciplinary educational theory relevant in both the area of science teacher education and library and information science education. Study findings revealed high levels of student achievement, which support the Dow and Thompson (2017) intensity of effort theory of co-teaching and confirms Dresang's (1999, 2005) and Dresang's and Koh's (2009) theory of Radical Change with evidence of connectivity, interactivity, and access of use of digital information across all aspects of the STEM-ALL program.

Keywords: co-teaching; STEM; teacher effectiveness; teacher collaboration; interdisciplinary education; teacher education; school librarian partnership

Co-teaching in the digital information era: Comprehending the role of information and technology literacy in the sciences

Calls are heard around the Nation for innovative education that prepares today's children and youth to develop interests and find positions in a diversified, robust science, technology, engineering, and mathematics (STEM) workforce. This expectation, one we accept, may be accomplished through change in university education of PreK-12 teachers and school librarians when teacher education is transformed by co-teaching that involves partnerships among two or more professors. There is much to indicate that a transformative shift of this kind is underway and is moving educators away from traditional, solo-teaching in isolated classrooms to being involved in contemporary co-teaching. Co-teaching creates a new image of learning environments, replacing the image of educational isolation in *silos designed for storing grain* with the image of connected, digital information era education in the sweeping, *accelerated cybernetic effervescence of virtual spaces*. With awareness of the need for a robust, highly technical workforce and to reinvent learning environments that involves connectivity, interactivity, and access to digital information, many educators and education stakeholders ask, "Why?" and "How?"

Questions about why and how to move out of educational silos are answered in publications by the National Science Teachers Association. For example, Bybee (2013) asserts that when physical and virtual data are created and disseminated, opportunities exist for new pedagogy and solutions to this century's emergencies through scholarship in STEM disciplines and social sciences. He identifies cross-disciplinary relationships among educators for solving emergencies such as "energy efficiency, environmental quality and evidence-based responses to global climate change; limited natural resources; mitigation of natural hazards; health maintenance and reduction of preventable diseases; public understanding of technological innovations in health and human welfare" (p. 34-35). To address these emergencies, problems must be studied using scientific methods and findings communicated in the form of research-based evidence then used to negotiate scientific claims, engineer solutions and to lead positive change. In addition to authentic experiences, this study points out that substantive reading of authoritative sources is critical to understanding topics and to designing studies that address research problems indicating conflict, confusion, contradictions, vagueness, and gaps in knowledge. Progress demands new studies built on existing, published scientific evidence. Inquiry-based studies require initial and ongoing professional development of teachers and administrative support.

Circumstances are in motion now as information proliferates and new ultra-technologies continue to produce landmark changes in the way humans experience learning and carry out research. Through this wave of change, children and youth will likely see themselves with STEM careers such as water resource specialists, agronomists, wind turbine technicians, and radiation therapists. Industrial era idealism of educators and the education establishment must change, too, to reflect the digital information era and today's culture of learning.

In response to this fast pace of change and to expose the role of information and technology literacy in science education, this research began with two assumptions. The first assumption is that future successful students will come from many backgrounds with various abilities and talents and possess many interests. Future students will be broadly educated, critical thinkers who graduate high school, or college, secure and retain jobs and career opportunities, and continue throughout their lives as life-long learners. Students will be prepared to reliably interact and share responsibilities with others. They will clearly communicate and effectively explain the relevance of their work to the general public and elected officials.

The second assumption is that while co-teaching is still a relatively uncommon pedagogical practice observed in practice or reported in publications, collaborative teacher partnerships have gained momentum as an educational reform strategy. As the literature review in this study reveals, co-teacher effectiveness is indicated where the American Association of School Librarians (2007) standards and/or the Association of College and Research Libraries (2015) framework are used in conjunction with content curriculum standards (Thompson and Dow, 2017; Lewis, 2016; Loertscher, 2014; Todd, 2013; Kuhlthau, C., Maniotes, L., & Caspari, A., 2012). However, little is published about co-teaching involving multiple, university professors engaged in collaborative partnerships. The public, the education establishment, and other private and government sector stakeholders need to know more about co-teaching as a useful strategy for effective teaching. Educators should learn more about what are co-teaching effects on today's college students' academic achievements and on the traditional, educational hierarchical structures, policies, and practices that keep faculty and students segregated.

Purpose and Significance of the Study

The purpose of this study is to examine the intensity of effort by two university professors involved in co-teaching. This study is important because it explains a unique university project, *Science, Technology, Engineering, and Mathematics: Information, Technology, and Scientific Literacy for ALL Learners* (STEM-ALL), a three-year project, funded by a 2015 Laura Bush 21st Century Librarian Program grant from the Institute of Museums and Library Services. It is an example of university professors recognizing an educational need and imagining a creative response to the need (Dow, 2014). This research adds to existing literature about co-teacher effectiveness. It develops the educational concept of collaborative teaching a new, advanced position of working with others in efficient, equitable, and interdisciplinary teaching partnerships.

This study is important because it suggests a new theory, the "*intensity of effort theory of co-teaching*" (Dow & Thompson, 2017, p. 17) that explains "what happens when two or more educators work together to build maximum intellectual strength in themselves that can be measured by their students' achievement of identified learning outcomes" (p. 17). Because physical sciences expertise is one-half and library and information science is the other half of the co-teaching collaboration in the STEM-ALL project, this study builds educational theory relevant in both science teacher education and library and information science education. Further, this study investigates the supposition that if co-teacher effectiveness as measured by student achievement of learning outcomes is related to intensity of effort by co-teaching partners in physical sciences and information science, then greater intensity produces more students achieving more outcomes at higher levels.

Literature Review

A review of literature published in education journals provides an overview of how co-teaching emerged as an alternative to one-teacher, one-classroom forms of instruction. There are indications in publications that co-teaching may have always served as an attempt to improve students' learning rather than as a strategy to lessen the responsibilities of teachers. The infrequency of co-teaching, in contrast to other pedagogical strategies, presented in the literature suggests that co-teaching may have been, and perhaps continues to be, difficult to conceive of and carry out within the confines of existing school structures that isolate teachers. So, where does co-teaching occur and why?

Regular and Special Education Co-teaching

Co-teaching models have appeared in education literature since the later years of the 20th century largely in response to challenges of educating children with significant, individual differences and the legal requirements in the Individuals with Disabilities Education Act (IDEA) of 1997, 20 U.S.C. 1412 that provided funds to states for the education of children with disabilities. Regular and special education teachers grappled with strategies for meeting the needs of children and youth with physical and intellectual disabilities in regular education classrooms. An early collaborative teaching model by Cook & Friend (1995) emphasized variations on co-teaching including: one teaching-one assisting; station teaching dividing the class into sections; parallel teaching where each teacher simultaneously teaches half the students; alternating teaching to one small group and one large group; and team teaching wherein the teachers alternate the role of primary instructor within lessons.

Others have weighed-in on how to best have two teachers in one classroom to educate students in regular and special education focused on the issue of who would be the instructional leader for given periods of time (Walter-Thomas et al., 2000; Vaughn, Schumm, & Arguelles, 1997). Regular and special education teachers working together apparently deliberated on guidelines to determine who should do what and when to do it. While research on teacher effectiveness of regular and special education co-teaching has been conducted, according to Kloo and Zigmond (2008), studies failed to present a picture of significant improvement in students' academic learning. They report some "increases in social competence and social acceptance of students with learning disabilities" (p. 14). Recently, according to Conderman and Hedin (2015), co-teaching provides equitable learning opportunities and increases collaboration between instructional leaders in regular and special education.

Co-teaching across Subject Areas

In addition, co-teaching done to bring about educational improvement appears in education literature that describes co-teaching between regular education teachers. For example, Lee (2007) studied co-teaching using integrative curriculum and hands-on lessons in subject areas that include mathematics, science, language arts, religion, art, physical education, music, sociology, and geography. Bacharach, Heck, and Dahlberg (2013) maintain that co-teaching is an effective strategy to enhance student teaching experiences. They suggest co-teaching in teacher education programs wherein veteran teachers allow pre-service teachers to teach with them rather than the typical supervisory-managerial role that veteran teachers assume during student teaching assignments. This description of co-teaching is based on the Academy for Co-Teaching and Collaboration at St. Cloud State University (2012) model that defines co-teaching as "two teachers working together with groups of students – sharing the planning, organization, delivery and assessment of instruction, as well as the physical space. Both teachers are actively and engaged in all aspects of instruction." (p. 43).

The science education community has addressed collaboration as a form of joining science leaders with people from within the same discipline or across disciplines. Although not using the co-teaching term, Spector, Strong, and King (1996), university professors from three different academic areas of expertise, addressed the shift in science education from the dominant reductionist approach to a holistic approach. This shift is based on the ideas (Spector and Spooner, 1993) that "human beings must interact with each other in order to construct social truth" (p. 179), and that "[c]ause and effect relationships involving multiple factors, are complex, and may be difficult to distinguish" (Spector, Strong, & King, 1996, p. 178). Their contributions to defining collaboration likely served to clear up differing expectations for collaboration and laid the groundwork for our reference to intense collaboration efforts by two, or more, educators as co-teaching. To enable and encourage science educators to develop instructional strategies that will be effective in educating future science teachers and leaders to be good collaborators, Rhoton and Bower (1996) identified the following 12 characteristics that "collectively differentiate collaboration from other human cooperative group activities: (1) equal empowerment, (2) a valued knowledge base, (3) trust, (4) commitment, (5) synergism, (6) emotional bookkeeping, (7) hedonic tone (including joy), (8) intrinsic motivation, (9) momentum, (10) time, (11) product, and (12) communication" (p. 180). They point out that during the past decade many educators were "asked to establish collaborations within the hierarchical structures of most current educational organizations, even though collaboration is consistent with the holistic paradigm, not the reductionist paradigm" (p. 182-183.) They further assert that collaboration is multidimensional with "six dimensions that comprise the continuum: (1) size dimension, (2) equal empowerment dimension, (3) time and goal dependency, (4) propinquity, (5) depth of involvement, and (6) culture" (p. 183-184).

Teacher and Librarian Partnerships

The concept of collaboration has gained momentum in literature related to partnerships between teachers and school librarians, but the concept does not yet expand to the level of co-teaching addressed in our study. Publications portray collaboration between teachers and school librarians positively, as "hard work" (Latham & Gross, 2017, p. 64) and "a way to build relationships that can enhance instructional strategies, facilitate learning, and achieve learning outcomes" (p. 66). In addressing STEM courses, collaboration between teachers and school librarians is identified as a way to enhance student learning (Harada, 2001; Mardis & Hoffman, 2007; Montiel-Overall & Grimes, 2013). High school science teachers' perceptions and experiences with inter-personal collaboration, including barriers to collaboration, involving school and public librarians was addressed by Latham, Julian, Gross, and Witte (2016), who point out that there is a need for a new model of collaboration between STEM and librarian experts. While science teachers in the Latham et al. (2016) described their relationships with school librarians as “excellent” (p. 196), they did not report working directly with librarians as an instructional strategy. Science teacher participants in this study mentioned, “librarians could play a key role in fostering collaboration among teachers and between teachers and librarians” (p. 196). Science teachers also mentioned 21^{st} century skills, and “reported that they are providing instruction to their students in certain 21^{st} century skills, particularly those related to using technology” (p. 198).

Montiel-Overall’s (2005) model of four levels for school library (PreK-12) and content area teacher collaboration is used to describe collaboration. In Model A, the lowest level, collaboration involves coordinating events, activities, and resources. In Model B, librarians and teachers consult with each other on topics and resources. In Model C, teachers and libraries together develop and deliver instruction, and evaluate student assignments. In Module D, all the teachers in a school work with the librarian to develop an integrated curriculum that emphasizes instruction across the curriculum. At this level, there is a culture of collaboration in the school and school administrators understand the value of collaboration. While Montiel-Overall’s highest level of collaboration accounts for shared responsibilities and is a variation of co-teaching, it stops short of directly addressing collaboration as co-teaching across disciplinary content areas, and short of addressing collaborative partnerships as “inquiry-based information-literacy instruction” as is indicated in the new *National School Library Standards for Learners, Librarians, and Libraries* (AASL, 2018, p. 84).

Higher Education Co-teaching

Today, teaching partnerships between academic librarians and content-area faculty in institutions of higher education are recommended by the Association of College and Research Libraries (2015). There are many published examples of information literacy instruction by academic librarians that exist along a continuum from basic library instruction to complex research instruction. The continuum is described in the library and information science literature beginning with one-shot demonstrations in sessions held in the library (Luethenhaus, Hvizdak, Johnson, Schiller, 2017); then progressing to library orientation (Boss, Angell, and Tewell, 2015); stand-alone library instruction classes and workshops in the library taught by librarians (Petraits, 2017; Noe, 2015; Mbabu, 2009; Rutherford, Hayden and Pival, 2006); librarians embedded in electronic courses (Schulte, 2012); and finally the continuum progresses to academic librarians providing information literacy skills instruction in the context of college credit-bearing classes (Burke, 2011).

There are very few published reports of librarians and university faculty working together to identify learning goals and course outcomes, implement instruction, and evaluate student learning in the context of content courses. For example, Rose-Wiles and Hofmann (2013) presented experiences from two mid-sized academic libraries where librarians and classroom faculty form partnerships to better engage students in research processes using web-scale discovery services, a centralized index of metadata obtained from many publishers and database vendors and subscribing libraries' Online Public Access Catalogs, institutional repository, and other selected resources. Collaboration included both librarians and university faculty engagement in developing consistent goals for teaching information literacy competencies and daylong sessions, not course-long collaboration for evaluating students' papers to identify problem areas.

Another report of librarians and university faculty working together is by Loesch (2010) who describes librarians as professors in new roles including participating in university core curriculum development addressing information literacy as a required proficiency and teaching new core courses. Loesch points out the example of librarians teaching information literacy credit bearing courses at Seton Hall University based on librarians' second master's degrees or work experience in programs such as Gender Studies, Women's Studies, School of Business, and Anthropology.

This literature review supports our view that co-teaching is known to educators and librarians but only used in limited ways as an instructional strategy to enhance learning at universities. Based on the expectation articulated in this study that educators and librarians must move outside existing silos and into the digital information age, emerging from this review of literature are indications that co-teaching may be a useful mechanism to facilitate this shift. If so, there is need to answer research questions about what is involved when two professors work together to co-teach information, media, visual, and technical knowledge and skills in content area courses. In addition, there is need to know the effects two different content area professors working as co-teachers have on student learning compared to the current dominant one-classroom, one-teacher style education that results in segregation of students and faculty.

Research Questions

This research examines co-teacher engagement and intensity of effort of the two content area professors who created and taught the STEM-ALL courses. "As co-teachers, one a professor of library and information science and one a professor of physical sciences, we set out to make co-teaching and cross-disciplinary learning a new reality for educators enrolled in the STEM-ALL project" (Dow & Thompson, 2017, p. 17). The study builds on exiting research about co-teaching effectiveness and answers this central question: How does intensity of effort of two different content area professors affect instruction in university courses? The sub-questions are:

1. What was the intensity of effort required by both professors when co-teaching?
2. What impact did co-teaching by two university professors, one in physical sciences and one in library and information science, have on student practices?
3. What impact did co-teaching by two university professors have on students' achievement of identified competencies based on course learning outcomes?

Definitions

Co-teaching. Co-teaching as collaborative partnerships in this study was defined as two or more teacher experts representing multiple content areas facilitating all aspects of learning in classrooms and libraries and in a variety of shared physical and/or virtual learning environments. All teachers utilize their expertise in the teaching and learning process. Co-teachers rely on each other for expertise, accuracy, and quality. Together, co-teachers "1) lift and support substantive aspects of the weight of the curriculum and instruction; 2) contribute multiple repetitions explaining what students should know, do, and learn; and, 3) exert significant efforts during the planning, implementation, and evaluation of ongoing instruction" (Dow & Thompson, 2017, p. 17). With more than one teacher for the same audience of students, the number of possible instructional repetitions increases. Co-teaching transforms the industrial era one-teacher, one-classroom, one textbook learning approach to an information era learning experience that allows a focused audience of students to study topics and problems through an inquiry process that includes multiple teachers, multiple formats and multiple sources of authority.

***STEM education*.** STEM education, as a set of education programs and practices, produces STEM literate individuals who have knowledge, attitudes, and skills for inquiry-based learning across multiple disciplines. Using scientific methods, they are able to integrate substantive knowledge to engage in solving global problems such as work force development, energy efficiency, environmental quality, use of natural resources, natural hazards and health and human welfare. STEM literate individuals are able to ask questions and define problems; conduct investigations, analyze and interpret data; engage in argument from evidence; and obtain evaluate and communicate information. STEM literate individuals are able to anticipate and plan for college, jobs and careers in a deep technical workforce. STEM literate individuals are prepared to influence present and future STEM policies.

Method

Research Design

As researchers, we share the transformative worldview that constructivist assumptions about education have not always gone far enough to address critical problems or to advocate for an action agenda for change. As Mertens (2010) asserts, we hold that inquiry needs to be intertwined with politics and political change agendas such as are described in this study's introduction. A qualitative case study (Stake, 1995; Yin, 2009, 2012) design was selected for this inquiry to address educational changes, in particular the change from solo teaching to co-teaching to enhance students' learning across university-based academic programs. This case study is an exploration that produces descriptive data used to support our intensity of effort theory that greater intensity produces more students achieving more outcomes at higher levels.

Participants

The population in this study was a "purposefully selected" (Creswell, 2014, p. 189) sample. Study participants are initially 51 elementary through high school classroom teachers and school librarians enrolled in the STEM-ALL program and their two professors, the researchers in this study, at a mid-western United States university. Table 1 shows course numbers, course titles, term of offering, number of enrolled students by certificate program (physical sciences; library and information science). Enrolled students received scholarships that paid tuition, books, and travel expenses to the University's main campus to attend two all-day, Saturday sessions for each three-credit hour online hybrid course. Students were eligible to earn the University's *information, technology, and scientific literacy certificate* that required successful completion of four required, three-credit hour courses. The enrolled students, PreK-12 teachers and school librarians, participated together in the same higher education courses, some earning undergraduate or graduate physical sciences credit and some earning master of library science credit. During course-work, enrolled students studied and practiced together as co-teachers learning to ask questions and define problems; conduct investigations, analyze, and interpret data; engage in argument from evidence; and obtain, evaluate, and communicate information. The ideal was that when co-teachers mastered these skills that were embedded in STEM topics (Bybee, 2013), they will then be prepared to function as co-teachers working together to teach scientific process skills to students in today's elementary, middle, and high schools. The curriculum and learning outcomes in the STEM-ALL program can serve as an instructional model to be adapted across grades and ability levels.

Research Instruments and Procedures

Data for the study were collected in three forms: student records; student and professor course material artifacts; and surveys.

Student records. When applying for this certificate program, students gave consent for their participation to be part of a funded research study. We collected, organized, and examined enrollment records and assignment and evaluation documents to quantify and qualify student participation and achievement based on assignment and course scores.

Course materials artifacts. Course syllabi and assignment documents were collected, organized, and examined for intensity of effort by quantifying time spent in planning, creation, and organizing electronic and face-to-face instruction; delivering instruction; guiding and teaching students; and evaluating student assignments and giving feedback to students about their achievement of course learning outcomes including: five course learning outcomes in course one (791); five course learning outcomes in course two (792); six learning outcomes in course three (793); and six learning outcomes in course four (794).

Surveys. We administered surveys using SurveyMonkey®. We designed an initial survey completed by new STEM-ALL students to gather their perceptions of PreK-12 students' perceptions of information and technology literacy. We also administered an end-of-program self-assessment survey to learn how the STEM-ALL program affected teaching practices, and student perceptions on the level of achievement of co-teaching competencies.

Data Analysis

Miles and Huberman (1994, as cited in Merriam, 2009) described the data analysis period of a study in three phases: data reduction, data display, and drawing conclusions and verification. Following this three-part framework, all STEM-All project data were read and reduced to relevant reports; reports of data were displayed in tables and figures, and all the evidence was reviewed and verified. The triangulation (Denzin and Lincoln, 2011; Merriam, 2009) method was used to check and establish validity by analyzing research questions from multiple perspectives across student records, instructional material artifacts, and survey data to arrive at consistency across data sources. To achieve validity and reliability, both researchers and the STEM-ALL project graduate student independently read and analyzed the data making modifications as necessary.

Results

As shown in Table 1, data from five semesters included two groups (Group A, Group B) of students enrolled in four different STEM-ALL courses (8). The four courses in the program included 22 course learning outcomes. Course learning outcomes were taught in 27 assignments in Group A, and 31 assignments in Group B (Table 2). Over five semesters, STEM-ALL course learning outcomes were assessed in assignments a total of 187 times (Table 3). In addition, students completed two surveys. Appendix 1 shows 12 questions included in the initial survey. Table 4 shows Likert questions and responses in the end-of-program survey about impact of co-teaching. Table 5 shows end-of-program survey open-ended question responses. Specific findings from these data sources were organized in three categories: student records; course material artifacts; and surveys.

Student Records

Student records data present a picture of the distinctive composition of pre- and in-service educators by type who were enrolled in the STEM-ALL courses. Table 1 shows the enrollment distribution by academic programs of 51 individuals who initially enrolled in each of the four consecutive courses with 50 individuals successfully completing the *information, technology, and scientific literacy* certificate program: undergraduate physical sciences student (1); graduate physical sciences students (26); and graduate students in library and information science (23). Except the undergraduate student and three graduate students, 46 enrolled graduate students already held professional education degrees including: elementary education classroom teachers; high school science teachers; mathematics teachers; high school physics and engineering teacher; technology coordinators; and elementary and high school librarians. Four students applied the STEM-ALL courses to teaching degrees in: elementary science teaching (1), the master of library science (2) and the master of education in teaching (1).

Student records data were used to identify working partners from among school districts willing to learn together and to participate in a research project focused on promoting co-teaching as a strategy for enhancing student learning. Co-teaching teams were formed based on pairing classroom teachers with school librarians. Based on our observations, these students demonstrated that it is possible to have meaningful, cross-disciplinary learning experiences. Connectivity and interactivity were achieved through a combination of face-to-face and technology assisted instruction using the Canvas Learning Management System. Students discovered the power of deliberate reliance on each other's areas of expertise when using scientific methods to address STEM topics relevant to their lives, to the lives of students in PreK-12 classrooms, and relevant to many others around the world. They improved their knowledge and skill levels to become exact and precise when teaching in PreK-12 classrooms. These students through their educational and professional backgrounds and efforts raised the quality of teaching and learning in the STEM-ALL courses, in their teaching, and challenged each other to optimize teaching and learning opportunities.

Course Material Artifacts

Course materials required enrolled students to read and use peer-reviewed journal articles available in digital library collections and 17 required textbooks (student book stipend provided) that addressed multiple aspects relevant to examining topics and problems in STEM areas outlined by Bybee (2013) such as energy efficiency, clean water, nutritious food, health and healthcare, and environmental quality. Learning outcomes were selected from across six national standards documents (Figure 1) including learning principles from the sciences; technology; engineering; mathematics; English language arts; and library and library and information science. All learning outcomes are concepts and principles derived from a comprehensive search and systematic review of standards documents undertaken by the two professors working together during their new-program preparation and the University's new-course approval phase of the STEM-ALL grant from June to December, 2015. These learning outcomes capture information and technology literacy expectations running through all six national content area standards and the library and information science standards documents in four broad areas: (1) asking questions and defining problems; (2) conducting investigations, analyzing and interpreting data; (3) engaging an argument from evidence; and (4) obtaining, evaluating and communicating information. Learning outcomes guided our joint development of curricula including instructional modules and lessons, assignment instructions, and criteria for evaluation of assessed competencies.

All four courses where taught by both professors in a hybrid course delivery model that included a combination of technology-assisted instruction using Canvas and two face-to-face class sessions for each course that were held all-day Saturdays on the University's main campus. The Saturday classes for each 3 credit hour course were strategically scheduled each semester to benefit students' learning processes. Both professors together delivered lectures, engaged in online and face-to-face discussion with students, and evaluated all assignments and provided feedback to the student. In this way, and based on our observations, students benefited from the expertise and presence in the same spaces of both professors rather than the traditional solo, one-at-a-time approach to teaching and learning. Professors benefited from each other's experience and expertise during each and every part of course development and delivery.

In addition to the expertise of course professors, two guest speakers were jointly identified by the course professors and invited to teach (approximately 2 hour sessions) during each of the four courses. Guest speakers received a $300 stipend provided by the STEM-ALL grant. The co-teachers selected guest speakers with specific areas of STEM expertise and guided them to address explicit aspects of a course. Over the four courses, 16 guest speakers addressed different topical areas including: library and information science; chemistry; earth science, climatology, and soil science; hydrogeology; biological sciences; nutrients for life; educational technology; mathematics and economics; radiation therapy; forensic science, STEM education (government); and chemical engineer (private sector). This multifaceted approach to delivery of content enabled students to experience rigorous content and to observe how more than one content area teacher can contribute to building substantive, current research-based understandings of meaningful and important topics and problems.

Surveys

Initial survey. New STEM-ALL students (51/51) completed an initial survey (Table 4) comprised of 12 questions designed to indicate their perceptions of PreK-12 students on information and technology related issues. Survey respondents indicated that most PreK-12 students appear to be satisfied with simple searching (40/51, 78%). More than half of the survey respondents (27/51, 53%) agree that PreK-12 students experience uncertainty, anxiety, and/or frustration when locating information beyond what is available in the class textbook. When survey respondents were asked whether PreK-12 students understand that co-teaching by classroom teachers and school librarians is necessary for learning information skills only 13/51

(25%) of the respondents agreed with the statement. Further, 37/51 (72%) survey respondents disagreed with the statement that students use the phrase *information literacy skills* when discussing what they learn at school. More than half the respondents (28/51, 55%) indicated that the lack of computers, Internet availability, and/or assistance at home does not result in unenthusiastic learners at school. In addition, survey responses (34/51, 67%) indicated that respondents perceive that students who participate in science projects and competitions are motivated by communicating their findings. These initial survey findings point to the need for preparing educators to accept the challenges and opportunities articulated by Bybee (2013) in STEM education goals.

End-of program survey. STEM-ALL students (48/50) completed an end-of-program survey that asked respondents to self-assess the impact of the STEM-ALL program on their teaching practices. Table 5 displays respondents' self-assessment of competencies for co-teaching between content teachers and school librarians using information and technology across STEM content areas. Data indicate that the majority (72% as a low and 91% as a high) of respondents in both groups reported definite achievement of the listed co-teaching knowledge and skills competencies in the STEM-ALL program. When asked about knowledge and skills to deliver STEM instruction in the same classroom, most indicated that they definitely (38/48, 79%) developed competencies to co-teach, and no one indicated no-progress in development of competencies to co-teach. Most respondents indicate definite development of skills in these areas: jointly planning and conducting investigations and instructing students in analyzing and interpreting data (37/48, 77%); jointly advancing and defending new ideas through engaging scientific argumentation from evidence (36/48, 75%); abilities to co-teach the nature of work in a variety of STEM fields (39/48, 81%); and jointly create assignments and assignment evaluations that integrate information and technology skills with more than one STEM content area (39/48, 81%).

Also in the end-of-program survey, STEM-ALL students answered open-ended questions addressing program impact on their teaching practices including the following categories: (1) what to teach; (2) how to teach; (3) when to teach certain topics and skills; (4) materials or resources used in instruction; and (5) STEM activities or events at their schools. An analytic-inductive procedure adapted from the work of Krathwohl (1998) was used to read, review, and interpret 13 pages of narrative response data with 239 response items (Table 6). Our focus was not a priori codes but the initial research questions, which according to White and Marsh (2006) should be used in qualitative content analysis. For both student groups, the program's greatest impact on what to teach was in the area of integrated/connected STEM content or STEM Careers (21/43, 49%). Greatest impact on how to teach was in the area of focused planning for guided inquiry and STEM integrated content (25/51, 49%). Greatest impact on when to teach certain topics or skills pointed to respondents perceived flexibility to exercise professional judgement when to teach certain topics or skills (32/47, 68%). Greatest impact on decisions about what materials or resources to include in instruction was in the area of use of databases and other electronic resources (21/49, 43%). When asked about impact on activities and events at schools, the greatest impact was on curricular activities during the school schedule (38/49, 78%). Not reported in the table, but when asked about how to teach or plans to teach topics like evidence, bias, or alternative facts, most respondents reported their related intent to teach use of proper citations and importance of intellectual freedom (30/40, 75%).

Discussion

Research questions answered below were concerned in several different ways with co-teacher engagement and digital information age changes realized through connectivity, interactivity, and access and use of information and intensity of effort by a professor of physical sciences and a professor of library and information science who together created and taught the STEM-ALL courses.

Question One: Effort Required for Professors When Co-teaching

As data sources reveal, intensity of effort required by professors in this study lead to new ways of thinking and acting while building intellectual strength in themselves with consideration of time, participants, location, problems, products, agreement among participants, and budget for the process of improving STEM education. Their intellectual strength was measured by assessments of competencies resulting in student achievement of learning outcomes from across multiple academic areas. Each professor participated at a high level similar to what is required in solo teaching when one works alone. However, each professor's level of participation was intensified by the amount and kinds of preparation required to develop and implement new integrated curriculum, new courses addressing learning outcomes from multiple standard publications, and new assignments incorporating multi-content area instructional materials. Two professors doubled the time spent in course development, teaching preparation, and delivery of instruction, and they increased recurrences of demonstrating, explaining, and responding to students' questions. The initial work to review and determine commonalities across multiple sets of standards can be described as amassing major relationships and convergences in 21st century learning expectations. This work to create a dense and rich curriculum went beyond the typical usage of standards to design assignments, instruction, and evaluation of student learning in the form of a single subject lesson plan. It advanced lesson planning through combining of standards to construct new instructional experiences.

Question Two: Impact of STEM-ALL Co-teaching on Student Practices

The intensity of effort of two professions resulted in demanding educational exercises practiced by STEM-ALL students. Combining content areas and information and technology literacy, students observed in their professors and practiced through assignments preferred conventions for writing topic-problem scenarios, making claims supported by research-based evidence, and stating research questions that advance and extend current research findings. Learning content in STEM-ALL courses provided greater opportunities to understand fully the importance of one academic discipline to other disciplines. Through the intensity of co-teaching, students pursued learning to understand the conceptual and methodological basis for science, technology, engineering, and mathematics disciplines. Students practiced listening and relying on each other for expertise to complete complex tasks and assignments. They were required to go beyond the bounds of traditional forms of education to a digital environment for learning that was perhaps less certain, and with more shared responsibilities and risks in being innovative as they addressed authentic problems rather than to recycle, or repeat, outdated, past issues. Students were encouraged to stop thinking about barriers such as scheduling, or traditional classroom parameters that prevent imaginative action within their schools. For this reason, assignment completion, and related instruction, increased in length from what could have typically been done by students in a few days to completion times of two or three weeks.

Question Three: Impact of STEM-ALL Co-teaching on Student Achievement of Course Learning Outcomes and Assignment Competencies

The impact of STEM-ALL co-teaching resulted in high student achievement. Students were rated on achievement of competencies as excellent (90 -100%), satisfactory (80 - 89%), and unsatisfactory (< 80%). All program completers achieved ratings of excellent or satisfactory. One student withdrew due to limited capacities that resulted in failure to complete assignments. Another student withdrew due to lack of time. This student was immediately replaced by another student on the waiting list and is counted among the program completers. The number of assignments in course 791 Group A (10) and Group B (6) reflect revision in the distribution, not reduction of, content across courses.

STEM-ALL student learning and achievement was the responsibility of both professors functioning as co-teachers. Determining accuracy, effective, and efficient use of subject area concepts and information skills was achieved through shared responsibilities by both professors. Identified weaknesses in student work were treated as opportunities for co-teachers to do more instruction and for students to do more learning. This procedure is explained as

> Educators together (1) lift and support substantive aspects of the weight of the curriculum and instruction; (2) contribute multiple repetitions explaining what students should know, do, and learn; and (3) exert significant efforts during the planning, implementation, and evaluation of ongoing instruction. Because there are two professors involved, the number of possible instructional repetitions increases. (Dow and Thompson, 2017, p. 17).

To realize high student achievement, it was necessary for some students to engage in additional repetitions to improve assignment products and to achieve course competencies. In other words, every effort was made by both professors to see that students learned at a high level to master significant, accurate concepts.

Limitations of the Study

The design of this study does not result in data that determine the effect of co-teaching on students receiving co-teaching and other students who do not receive the co-teaching treatment. It was not possible to design a study with two groups in side-by-side comparisons for the reason that the curriculum used was distinctively created to include multiple content areas as applicable to topics/problems that emerged from assignments. The small size did not enable us through data collection procedures to achieve saturation (Creswell, 2014, p. 189). Since this is an exploratory case study, data saturation was not our expectation. Surveys were not administered to present pre- and post- impact on student learning. Our survey items could have been written with slightly different wording that would have elicited more direct responses from STEM-ALL participants. In addition, it is important to take into consideration that despite much acknowledgement of high levels of expertise and experience, the enrolled educators in this study may have in the end-of-program survey self-assessed their new information, technology, and scientific literacy skills higher than they might have actually been. Also, in the end-of-program survey responses to open-ended questions, when responses indicated little or no impact, it is possible that respondents already knew what was taught in a particular area of the curriculum.

Future Research

Again, the purpose of the study was to identify descriptors of intensity of effort of co-teaching that could contribute to theory building about co-teaching and inform future studies. Future research should investigate intensity of effort by two or more educators in terms of time, participants, location, problems, products, agreement among participants, and budget for the process of improving STEM education. On the dimension of time, it would be worthwhile to investigate aspects of time that go beyond that required for solo teaching. Future research should also investigate co-teaching between university librarians and professors in academic areas in addition to sciences such as sociology, history, English, art, music, etc. We would recommend follow-up surveys to learn how program completers implement co-teaching practices.

Conclusions

STEM-ALL students taught by college co-teachers achieved all *information, technology, and scientific literacy certificate* course learning outcomes at a high level (satisfactory and excellent ratings). Sorting out the intensity of effort by co-teachers leading to students' deliberate practice and high achievement exposed new, concentrated ways of thinking and acting pertaining to co-teaching time, participants, location, complexities in instruction, final assignment products, agreement between co-teachers, and budget for the process of improving STEM education. Both co-teaching college professors acknowledged their own intellectual and professional growth. In addition, this close exploration of intensity of effort by co-teachers uncovered characteristics of teaching effectiveness that can be used to extend earlier collaborative teaching models by Cook and Friend (1995); Spector, Strong, and King (1996) model including 12 characteristics and six dimensions of collaboration in science education; and Montiel-Overall's (2005) four level model of school librarian and teacher collaborative teaching.

The intensity of effort model of co-teaching that emerges from the STEM-ALL project includes mutual intellectual and technological strengths to 1) amass a dense and rich cross-disciplinary curriculum; 2) identify and engage willing participants who are ready to innovate; 3) lift and delivery instruction throughout complete courses; 3) engage learners at high levels focused on authentic problem-solving; and 4) explain and clarify information and technology literacy knowledge and skills in multiple subject area contexts.

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Table 1

Course Number, Course Title, Term, Number Enrolled Students by Department

Course Number	Course Title	Term	Enrolled Students UGPS	GPS	LI	Total
791	STEM Classrooms and Competitions:	SP 2016		13	12	25
	Asking Questions and Defining Problems	SM 2016	1	13	12	26
792	Key Literacy Connections in STEM	SM 2016		13	11	24
	Subjects: Conducting Investigations, Analyzing and Interpreting Data	FL 2016	1	13	12	26
793	Advancing and Defending New Ideas:	FL 2016		13	11	24
	Engaging an Argument from Evidence	SP 2017	1	13	12	26
794	Skills for a Deep, Technical Workforce:	SP 2017		13	11	24
	Obtaining, Evaluating and Communicating Information	SM 2017	1	13	12	26
	Total Enrollment		1	26	23	50

Note: UGPS: Physical Sciences Students (undergraduates); GPS: Physical Sciences Students (graduates); LI: Library and Information Science Students (graduate students only). Term abbreviations are: spring (SP); summer (SM); and fall (FL). PS 500 level courses are undergraduate courses; PS 700 and LI 700 level courses are graduate courses.

Table 2

Course Number, Course Title, Term, Number of Assignment by Course Number

Course Number	Course Title	Group	Term	Assignments	Total
791	STEM Classrooms and Competitions:	A	SP 2016	10	16
	Asking Questions and Defining Problems	B	SM 2016	6	
792	Key Literacy Connections in STEM	A	SM 2016	8	16
	Subjects: Conducting Investigations,	B	FL 2016	8	
	Analyzing and Interpreting Data				
793	Advancing and Defending New Ideas:	A	FL 2016	7	14
	Engaging an Argument from Evidence	B	SP 2017	7	
794	Skills for a Deep, Technical Workforce:	A	SP 2017	6	12
	Obtaining, Evaluating and Communicating	B	SM 2017	6	
	Information				
	Total Assignments				58

Table 3

Course Number, Course Learning Outcome by Number, Number of Assessments by Outcome Learning Outcomes

	Number of Assessments of Outcome		
Course Learning Outcome (22)	Group A	Group B	Total
791.1 Generate STEM research ideas from primary and secondary source publications and/or observed experiences; focus on preliminary research topics	5	5	10
791.2 Develop and refine a range of questions to frame the search for new understandings	5	7	12
791.3 Locate and retrieve sources; do close reading to evaluate information; determine what a complex text states explicitly; and make logical inferences from text based on relevance and sufficiency	5	8	13
791.4 Appropriately cite/reference specific textual evidence from multiple print and digital sources when writing, or speaking, to support conclusions drawn from the text	3	4	7
791.5 Write a review of literature avoiding plagiarism that delineates and evaluates specific claims from a selected and organized collection of publications that can be used to state a hypothesis.	2	3	5
792.1 Plan an investigation, or test a design, to produce data to serve as the basis for evidence.	2	2	4
792.2 Select appropriate tools to collect, organize, record, analyze, and evaluate data.	6	6	12
792.3 Analyze data using tools, technologies, and/or models to make valid and reliable scientific claims or determine an optimal design solution.	6	6	12
792.4 Apply concepts of statistics and probability to scientific and engineering questions and problems using digital tools when feasible.	6	6	12
792.5 Collaborate with others to exchange ideas, develop new understandings, make decisions, and solve problems.	7	7	14

793.1 Determine whether a research design is quantitative, qualitative, or a mixed methods investigation.	4	4	8
793.2 Identify and use data and/or findings to develop a model for presenting evidence.	5	5	10
793.3 Compare, evaluate, construct, use, and/or present an oral and written argument, or counter arguments, based on data and evidence.	4	4	8
793.4 Make and defend a conclusion based on evidence about the natural world or engineered world.	4	4	8
793.5 Use information and technology ethically and responsibly.	4	4	8
793.6 Propose action steps for advancing and defending new ideas.	3	3	6
794.1 Be a critical consumer of STEM-related information by reading, analyzing, and identifying topics, subtopics, and topical relationships.	3	3	6
794.2 Communicate information, evidence, and ideas in appropriate forms and in multiple formats in writing and through extended oral discussions.	4	4	8
794.3 Using appropriate resources and technology, develop a formal outline or story board.	3	3	6
794.4 Present, perform, and share information and ideas successfully; evaluate product and/or presentation.	2	2	4
794.5 Observe copyright guidelines; cite following teacher identified rules print and digital sources; and recognize and respect intellectual freedom.	4	4	8
794.6 Identify interests and skills necessary in a technical workforce; connect workforce skills and pathways to STEM career opportunities.	3	3	6
Total Number of Outcome Assessments in Group A & B	90	97	187

Note: *PS: Physical Sciences Students (undergraduates and graduates); **LI: Library and Information Science Students (graduate students only). Term abbreviations are: spring (SP); summer (SM); and fall (FL). PS 500 courses are undergraduate courses; PS 700 and LI 700 courses are graduate courses.

Table 4

New STEM-ALL Participants' Initial Perceptions of Information and Technology Literacy in PreK-12 Students

Statement (N=51)	**Strongly Agree**	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
1. Students can do a simple search for information but appear to be satisfied with what they find.	15 (29%)	25 (49%)	7 (14%)	3 (6%)	1 (2%)
2. Students can do a simple search for information but appear to be frustrated with what they find.	1 (2%)	21 (41%)	8 (16%)	20 (39%)	1 (2%)
3. When students do a classroom project that involves locating information beyond what is available in the class textbook, they appear to experience emotions of uncertainty, anxiety, and/or frustration with learning.	8 (16%)	19 (37%)	11 (22%)	9 (17%)	4 (8%)
4. Students use the phrase "information literacy skills" when discussing what they learn in school.	0	0	3 (6%)	11 (22%)	37 (72%)
5. Students express interest in solving problems in their world such as problems related to sufficient energy; prevention and treatment of illness and disease; maintaining clean food and water; and global environmental change.	5 (10%)	19 (37%)	12 (23%)	10 (20%)	5 (10%)
6. Students understand that the school librarian is also a teacher who specializes in teaching information literacy skills.	7 (14%)	20 (39%)	8 (16%)	12 (23%)	4 (8%)
7. Students understand that co-teaching by classroom teachers and school librarians is necessary for learning information literacy skills.	2 (4%)	11 (22%)	15 (29%)	15 (29%)	8 (16%)
8. Students understand that to advance in science and engineering competitions, they must first have	5 (10%)	14 (27%)	11 (22%)	15 (29%)	6 (12%)

knowledge of a topic and its problems; know how to conduct valid scientific research; and know how to communicate their findings both orally and in writing.					
9. Students who have computers, Internet, and assistance at home are enthusiastic learners.	2 (4%)	11 (21%)	21 (42%)	15 (29%)	2 (4%)
10. Students who do not have computers, Internet, and assistance at home are not enthusiastic learners.	2 (4%)	9 (18%)	12 (23%)	21 (41%)	7 (14%)
11. Students who participate in science projects and competitions are motivated by communicating their findings.	8 (16%)	26 (51%)	12 (23%)	4 (8%)	1 (2%)
12. Students who participate in science projects and competitions tend to express optimism about the future.	7 (14%)	27 (53%)	16 (31%)	1 (2%)	0

Table 5

STEM-ALL Participants' End-of-Program Self-Assessment of Competencies for Co-teaching between Content Teachers and Teacher Librarians Using Information and Technology across STEM Content Areas

	Cohort A (n=23)			Cohort B (n=25)		
Competency	**Yes, Definitely**	**Yes Somewhat**	**No, In-Progress**	**Yes, Definitely**	**Yes Somewhat**	**No, In-Progress**
1. I have knowledge and skills to work together with content teachers and teacher librarians to instruct student to ask questions and describe problems that can be solved using scientific principles and methods	21 (91%)	2 (9%)		19 (76%)	6 (24%)	
2. I have knowledge and skills to work together with content teachers and teacher librarians to instruct students to select appropriate databases and to access, retrieve, evaluate, and use publications available through the licensed-web.	21 (91%)	2 (9%)		22 (88%)	2 (8%)	1 (4%)
3. I have knowledge and skills to work together with content teachers and teacher librarians to plan and conduct student investigations and instruct students in analyzing and interpretation of data.	19 (83%)	4 (17%)		18 (72%)	7 (28%)	
4. I have abilities to work together with content teachers and teacher librarians to create and use instructional materials that integrate information and technology skills with more than one STEM content area.	19 (83%)	4 (17%)		20 (80%)	5 (20%)	
5. I have knowledge and skills to work together with content teachers and teacher librarians to instruct students in advancing and defending new ideas through engaging scientific argumentation from evidence.	17 (74%)	6 (26%)		19 (76%)	5 (20%)	1 (4%)
6. I have knowledge and skills to work together with content teachers and teacher librarians to teach students about the nature of work in a variety of STEM fields.	21 (91%)	2 (9%)		18 (72%)	7 (28%)	
7. I have knowledge and skills to work together with content teachers and teacher librarians to instruct students to obtain, evaluate, and communicate information using information and technology skills necessary for a skilled technical workforce.	19 (83%)	4 (17%)		18 (72%)	6 (24%)	1 (4%)

8. I have knowledge and skills to work together with content teachers and teacher librarians to create assignments and assignment evaluations that integrate information and technology skills with more than one STEM content area.	19 (83%)	4 (17%)		18 (72%)	6 (24%)	1 (4%)
9. I have knowledge and skills to work with content teachers and teacher librarians to deliver STEM instruction in the same classroom.	19 (83%)	4 (17%)		19 (76%)	6 (24%)	

Table 6

STEM-ALL Participants' Self-Assessment of Program Impact in the Teaching Categories of What, How, When, Materials, and Events/Activities
Total Pages 13
Total Number Respondents = 48   Total Number Response Items = 239

Category (What, How, When, Materials, Events/Activities)	**Number Group A n=23**	**Number Group B n=25**	**Illustrative Quotes**
What: Integrated/connected STEM Content or STEM Careers	8	13	". . . more scientific inquiry-based projects are implemented in guided-studies courses." ". . . . connect the content the State and district dictates . . . to STEM careers."
What: Research and Writing	2	6	"It has empowered me to go back to my grade-level team and incorporate more research design in our science and literacy instruction."
What: Inquiry-based Projects	3	1	"I approach more things from guided-inquiry model now than I have before."
What: Information Literacy	1	1	"I have made the effort to include more data literacy in my unit lessons . . . ."
What: Other	1	0	"It has also empowered me to join my district's leadership committee."
What: Little or No Change	4	3	"It hasn't." "I'm a STEM teacher but this course did not help change the way I would teach." "Hasn't really changed what I will teach, but more how I will do so."
How: Focused Planning for Guided Inquiry, STEM Integrated Content	15	10	"I now look at my lessons as an opportunity for students to find most of the answers instead of me giving it to them." "I try to encourage more questions and avenues for further research and focus less on providing all the answers." "I will try to incorporate more opportunities for students to take on STEM challenges."

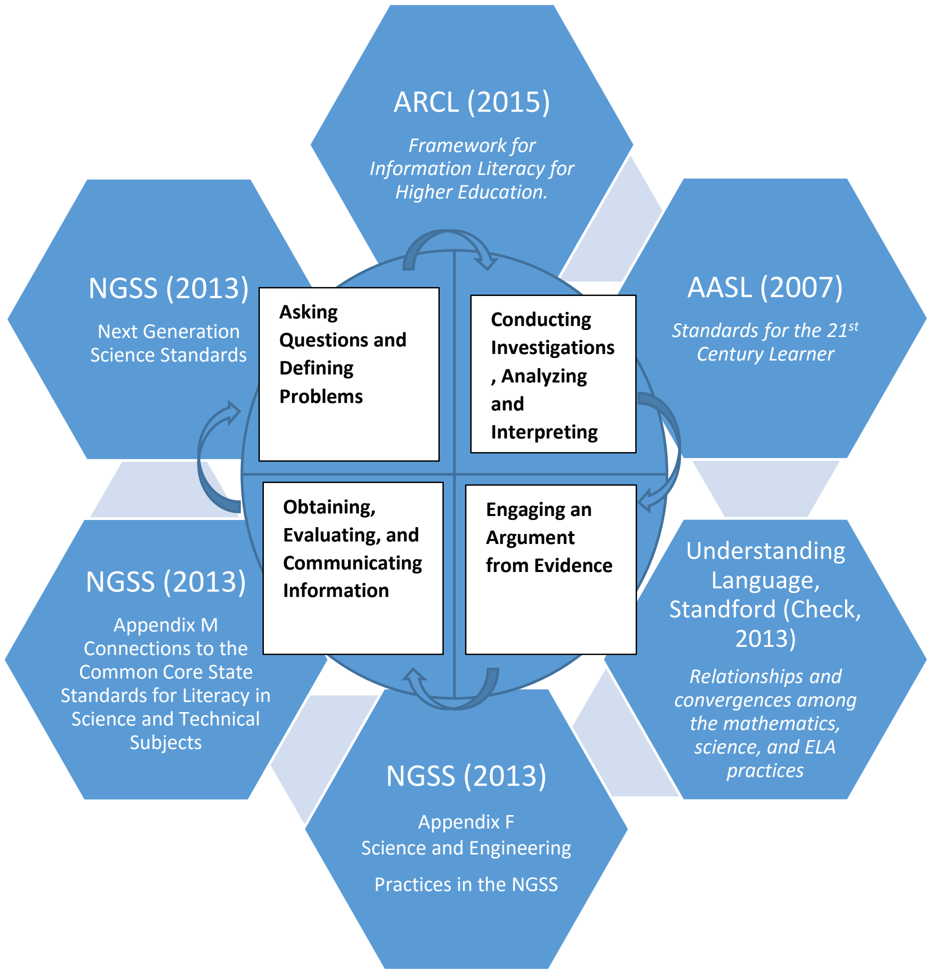
How: Encouraging Students' Interests and Research Questions	4	8	"I am going to try to encourage students more to pursue research in their own scientific interest so that projects we do carry more meaning." " . . . to apply research concepts to real life scenario." " . . . more time for students to share their findings and defend conclusions, which is something that I now know my units have lacked."
How: Collaboration/Co-Teaching	6	5	"It has changed how I work with the science teachers in my building." ". . . work with the librarian to find ways to make math relatable . . . through projects and onsite discussion with professionals from the real world."
How: Little or No Change	1	2	"We are a school that does use the librarians when collaborating on a project."
When: School Determines	2	2	". . . . time lines are driven by curriculum guides." "Districts control my schedule and instructional unit guide."
When: Exercises Professional Judgment	14	18	". . . classes have helped me to prioritize what to teach when students come in. . . have better conversations with teacher regarding what their students need to learn and when." "Integration of certain skills within content may become more cohesive with my new knowledge."
When: Little or No Change	5	2	"It has no affect." "I can't say this category will change much."
When: Other	1	3	"It has given me a good idea of how to approach presenting at conferences and when is best to plan certain programs."

Materials: Use of Databases and Other Electronic Resources	6	15	"I recently used a database with my students that I used in my STEM college class." "I know many more quality search engines and databases." "It exposed me to several new websites and the State of Kansas library system and database searching."
Materials: Use of Books (Print)	3	2	"I placed orders for STEM-related books in our library collection."
Materials: People Resources	3	4	"Yes, I am planning activities with more community resources, including community representation from professionals in STEM fields." "Community resources need to be utilized including corporations, business leaders, as well as academia . . ."
Materials: Other	2	6	"I am always on the lookout to build my resources both intellectually and physically. Curiosity, wonder, and grants makes this more possible." "Since we have a new textbook this year, I will have become more familiar with it before I can use other materials/resources." "This class has pushed me to use resources that I don't usually think of and introduced me to new avenues to conduct research."
Materials: Little or No Change	8	0	"I have always heavily utilized databases for research with students." "No really, I have always used databases in my teaching."
Events/Activities: Curricular	19	19	"It has greatly affected by STEM activities and events. It has helped me develop and give the students a more engaged learning session." "I will be introducing our new makerspace that will involve

			extracurricular opportunities in the mornings before school." "Our school is moving to a more problem-based learning environment and STEM activities will fold nicely into that teaching shift."
Events/Activities: Community	1	0	"One collaborative project where I embedded inquiry was so inspiring to our math teacher that she created a community sharing event where the students shared their findings with parents, community members, and board members."
Events/Activities: Little or No Change	8	2	"My school will not incorporate STEM." "I am disheartened that I would encounter a struggle [given] all that we have learned . . ."
Total Response Items (239)	118	121	

Figure 1

Content Standards Overlapping Series of Information and Technology Learning Outcomes



Note: Six (6) national standards documents, see reference list for complete citations

Appendix 1

Enrolled for College Credit Student Survey Questions Administered at the Beginning of STEM-ALL Program

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Based on your observation of students in grades 4 – 12, please select one response to each question.

1. Students can do a simple search for information but appear to be satisfied with what they find.
2. Students can do a simple search for information but appear to be frustrated with what they find.
3. When students do a classroom project that involves locating information beyond what is available in the class textbook, they appear to experience emotions of uncertainty, anxiety, and/or frustration with learning.
4. Students use the phrase “information literacy skills” when discussing what they learn in school.
5. Students express interest in solving problems in their world such as problems related to sufficient energy; prevention and treatment of illness and disease; maintaining clean food and water; and global environmental change.
6. Students understand that the school librarian is also a teacher who specializes in teaching information literacy skills.
7. Students understand that co-teaching by classroom teachers and school librarians is necessary for learning information literacy skills.
8. Students understand that to advance in science and engineering competitions, they must first have knowledge of a topic and its problems; k now how to conduct valid scientific research; and know how to communicate their findings both orally and in writing.
9. Students who have computers, Internet, and assistance at home are enthusiastic learners.
10. Students who participate in science projects and competitions are motivated by communicating their findings.
11. Students who participate in science projects and competitions are motivated by communicating their findings.
12. Students who participate in science projects and competitions tend to express optimist about the future.

Appendix 2

Enrolled for College Credit Student Survey Likert Questions Administered at the End of STEM-ALL Program

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1. I can generate STEM research ideas using primary and secondary source publications.
2. I can develop and refine a range of questions to frame the search for new understandings.
3. I can identify and use appropriate databases to access and retrieve sources.
4. I can make logical inferences on the basis of relevance and sufficient evidence reported in published text.
5. I can appropriately cite and reference specific textual evidence to support conclusions drawn from the text.
6. Using various publications, I can delineate and evaluate specific claims useful in writing a literature review.
7. I can plan an investigation or test a design to produce data to serve as the basis for evidence.
8. I can select appropriate tolls to collect, organization, record, analyze, and evaluate data.
9. I can analysis data using tools, technologies, and models to design solutions.
10. Using the Harland, STEM Student Research Handbook, I can apply concepts of statistics and probability to scientific and engineering questions and problems using digital tools when feasible.
11. I can collaborate with others to exchange ideas, develop new understandings, make decisions, and solve problems.
12. I can determine whether a research design is a quantitative, qualitative, or mixed methods investigation.
13. I can identify and use data and/or findings to develop a model.
14. I can compare, evaluate, construct, use, and present an oral and written argument and counter argument based on data and evidence.
15. I can make and defend a conclusion about the natural world or engineered world based on evidence.
16. I responsibly and ethically use information and technology.
17. I can propose action steps for advancing and defending new ideas.
18. I can critically use STEM-related information by reading, analyzing, and identifying topics, subtopics, and topical relationships.
19. I can communicate information, evidence, and ideas in appropriate forms and in multiple formats in writing and through extended oral discussions.
20. I can use appropriate resources and technology to develop a formal outline or storyboard.
21. I can effectively present, perform, and share information and ideas.
22. I observe copyright guidelines, properly cite print and digital sources, and respect intellectual freedom.
23. I can identify necessary interests and skills for a technical workforce and connect them to STEM career opportunities.

24. I have knowledge and skills to work together with content teachers and teacher librarians to instruct students to ask questions and describe problems that can be solved using scientific principles and methods.
25. I have knowledge and skills to work together with content teachers and teacher librarians to instruct students to select appropriate databases and to access, retrieve, evaluate and use publication available through the licensed-web.
26. I have knowledge and skills to work together with content teachers and teacher librarians to plan and conduct student investigations and instruct students in analysis and interpretation of data.
27. I have abilities to work together with content teachers and teacher librarians to create and use instructional materials that integrate information and technology skills with more than one STEM content area.
28. I have knowledge and skills to work together with content teachers and teacher librarians to instruct students in advancing and defending new ideas through engaging in scientific argumentation from evidence.
29. I have knowledge and skills to work together with content teachers and teacher librarians to teach students about the nature of work in a variety of STEM fields.
30. I have knowledge and skills to work together with content teachers and teacher librarians to instruction students to obtain, educate, and communicate information using information and technology skills necessary for a skilled technical workforce.
31. I have knowledge and skills to work together with content teachers and teacher librarians to create assignments and assignment evaluations that integrate information and technology area.
32. I have knowledge and skills to work together with content teachers and teacher librarians to deliver STEM instruction in the same classroom.

Appendix 3

Enrolled for College Credit Student Survey Open-ended Questions Administered at the End of STEM-ALL Program

How did the STEM-ALL program, courses, activities, and assignments

affect what you teach or what you plan to teach?

affect how you teach or what you plan to teach?

affect what materials/resources you use or plan to use?

affect when you teach or plan to teach certain topics or skills?

affect STEM activities/events at your school or future planned STEM activates at your school?

affect whether or how you teach or plan to teach topics like evidence, bias, or alternative facts?