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The Effects of an Integrated Curriculum on Student Achievement in Saudi Arabia

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ABSTRACT
This study examined the effects of an integrated mathematics and science curriculum with life-skills applications on academic achievement in a Saudi Arabian elementary school. An integrated unit was developed covering the grade 5 'sound and light' science unit and the 'perimeter, area, and size' mathematics unit, using practical applications activities connected to the students' everyday lives. The study involved treatment (n = 36) and comparison (n = 41) groups of grade 5 students (females) enrolled in a private school in Dhahran City. The comparison group was instructed using a conventional approach involving separate science and mathematics units, while the treatment group was instructed using the integrated unit. Two achievement tests for the target science and mathematics units were developed and used in the pretest-posttest design to verify the equivalence of the treatment and comparison groups before conducting the study, and to compare the achievement results after implementing the conventional and treatment units. The study found statistically significant differences favouring the treatment group on the achievement posttest (effect sizes were 0.44 for science and 0.49 for mathematics). These large effect sizes indicated the positive impact of using the proposed strategy of curriculum integration to evaluate the teaching program to see if the goal of improved achievement was actually realised.

Keywords: elementary, integrated curriculum, personally relevant pedagogy applications, science and mathematics integration, student achievement

INTRODUCTION

Education in the Kingdom of Saudi Arabia (KSA) is receiving an unprecedented level of attention (Alghamdi Hamdan, 2015). This trend is largely driven by the Saudi government's decision to embrace the science, technology, engineering, and mathematics (STEM) movement and to place these disciplines at the centre of educational development, with the ultimate objective of developing an internationally competitive, knowledge-based economy and thus reducing the country's dependence on the petroleum industry. Many initiatives have been undertaken since 2008 to achieve quality in science and mathematics education, including the King Abdullah bin Abdul Aziz Public Education Development Project, executed by the Tatweer Company (Alghamdi Hamdan, 2013). This attention is not exactly novel as for several decades various experts, such as Al-Ghanem (1999), have emphasised the need to reform Saudi science education and to reconsider the ways in which mathematics and science are taught (Jiffry, 2013).

Science and mathematics education provide an academic foundation for a vast number of scientific, technological, and industrial applications. This study focuses on the KSA's recent initiatives and explores a

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State of the literature

- The current literature had scarcely discussed how life skills can be part of science teaching.
- The current literature had not discussed an integration model of science and mathematics curricula
- There is some focus on science and mathematics PISA results in Saudi Arabia
- Adoption and usage of an integration model of multi disciplines has been marked with various barriers in relation to implementation.

Contribution of this paper to the literature

- To provide a recent initiatives and explores a purposefully designed strategy to integrate the science and mathematics curricula based on real-life applications.
- To adopt and use the model to teach mathematics and science at elementary level.
- To focus on the merits of integrating mathematics and science curricula.
- To explain the development and implementation of the grade-five curricula and reporting the results of this study in the KSA context

purposefully designed strategy to integrate the science and mathematics curricula based on real-life applications. It is assumed that grounding science and mathematics in students' daily life activities will improve students' achievement in these courses and will provide relevant connections among their component elements (Drake & Burns, 2004).

International concerns surrounding the advancement of STEM education have escalated in recent years and show no signs of abating; in this regard the case of Saudi Arabia is no exception (English, 2016). Sources (Caprile et al., 2015; Honey, Pearson & Schweingruber, 2014; Marginson et al., 2013; Prinsley & Baranyai, 2015; The Royal Society Science Policy Centre, 2014) have indicated that educators, policy developers, and business organisations are highlighting the urgency of improving STEM skills to meet current and future social, economic, and development challenges.

This article begins with a brief overview of the nature of an integrated curriculum and continues with a literature review focusing on the merits of integrating mathematics and science curricula. After describing the Saudi curriculum context and the recent government initiative to update the country's mathematics and science curricula, the article introduces a new theoretical framework pertaining to the standards and steps for the development of an integrated mathematics and science curriculum based on personally relevant pedagogy. After explaining the development and implementation of the grade-five curricula and reporting the results of this study, the paper concludes with a discussion of the implications of using an integrated curriculum for improving student achievement in the KSA context.

LITERATURE REVIEW

Integrated Curriculum

Conventional curricular arrangements present and teach subjects separately, with few connections with students' other courses. Mathematics students, for example, often ask questions like 'Why are we learning this?' as they struggle with the relevance of the course materials to their daily life and with the lack of connection with their other courses. One response to this legitimate concern is an integrated curriculum, which has been a topic of discussion since the mid-1900s (Drake & Burns, 2004; Sherbini & Tanawi, 2001).

An integrated curriculum augments stand-alone curricula by intermixing elements of subjects that are not normally combined (Loepp, 1999). This approach draws on the root of the word integration, which is 'integrate' (i.e., to make whole), and focuses on the benefits of integrating mathematics and science, a process that involves helping students make links between these disciplines and the students' world. According to Loepp (1999), successful curriculum integration should be 'relevant, standards based, and meaningful for students. At the same time, the curriculum should challenge students to solve real-world problems' (p. 21). When students have an opportunity to focus on problems they feel are worth solving (i.e., that are relevant, authentic, and *real*), they are more motivated to learn (Drake & Burns, 2004). Loepp (1999) continued to state that integration can result in 'greater intellectual curiosity, improved attitude towards schooling, enhanced problem solving, and higher achievement' (p. 21).

Curriculum integration can vary in terms of degree and method. Drake and Burns (2004) identified the following degrees of integration: (a) through correlation teachers give casual attention to related materials in other subject areas; (b) the curriculum integrates sub-disciplines of a discipline, an example being science (biology, chemistry, and physics); (c) some teachers combine two subjects, called fusion (e.g., mathematics and science); (d) other teachers draw together a collection of skills, knowledge, and attitudes and infuse them into all subjects; and (e) full integration involves unifying the subject matter with students' life experiences. Curriculum designers can use thematic units (via learning centres), issues-based learning, inquiry-based learning, and problem-based learning as their underlying method of integration. Other examples include service learning (which connects students with their community via citizenship ethics) and the interdisciplinary approach. The latter organizes the curriculum around concepts and skills that are common to several disciplines, with the focus being on integration (and on associated overlaps) rather than on individual disciplines. Though challenging to coordinate, some schools try to sequence their course offerings so that the students study the same topic or issue concurrently in multiple subjects, an approach that is called parallel integration (e.g., the students learn about England in history, social studies, literature, and economics) (Allagani, 2003; Drake & Burns, 2004; Kurt & Pehlivan, 2013; Loepp, 1999). Another strategy is to organize the integration around approved learning outcomes for various subject areas (e.g., mathematics and science standards). In an era of accountability and outcomes-based learning, this approach to integration has to be balanced with the need to cover the standards and outcomes that are specific to each subject area. Finally, the trans-disciplinary approach depends on problems and concerns identified by the students. They develop personally relevant pedagogy as they apply what they have learned in real life, especially through project-based and inquiry-based learning (Allagani, 2003; Drake & Burns, 2004; Kurt & Pehlivan, 2013; Loepp, 1999).

A number of recent studies in science education and some monographs provide some recent and critical reviews of the literature on curriculum integration. Studies such as Rennie, Venville and Wallace (2012a) and Rennie, Venville and Wallace, (2012b) explore the value of STEM integration, especially in light of the trend for policy makers to follow the international trend towards greater emphasis on the STEM disciplines.

All of hese efforts are oriented, in varying degrees of scope and intensity and in varying time frames, towards helping students *make connections* between what they are learning in school and in their daily life. The role of the teacher tends to be one of facilitator, co-planner, and co-learner, along with some combination of being a specialist and a generalist. The intensity of integration can range from a moderate level all the way up to a comprehensive paradigm shift. Even assessment strategies can change, evolving into a combination of traditional and authentic assessments, with activities striving in varying degrees for the integration of various disciplines' thinking, which can then be applied in real-world contexts (Drake & Burns, 2004).

Integrated Science and Mathematics Curricula

Loepp (1999) predicted 'the topic of integrated curriculum is destined to receive a lot of attention soon' (p. 25). In the era of curriculum reconstruction, considerable attention is being focused on curriculum integration (Davison, Miller & Metheny, 1995), especially in the mathematics, science, and technology education communities that are undertaking major reform initiatives in curriculum design, instructional approaches, and assessment practices. The adoption of an integrative approach to science and mathematics curricula is a natural response to the call for interdisciplinary approaches, including the removal of the disciplinary 'silos' in school curricula (Drake & Burns, 2004).

National standards. National standards for content, professional development, and assessment have been developed for mathematics, science, and technology education, especially in the US (International Technology Education Association, 2000; National Council of Teachers of Mathematics, 1989, 2000; National Research Council, 1996). The International Association of Science Teachers has proposed integration among the humanities (sociology, geography, history, philosophy, and law) and integration between the academic scientific subjects (science and mathematics). Such integration should be based on broad concepts/themes, which leads to more meaningful learning (National Science Teachers Association, 2004). The National Council of Teachers of Mathematics (2000) standards emphasise the importance of providing applications that are outside the traditional limits of mathematics. The National Science Education Standards (NSES) also emphasise the importance of providing learners with life applications based on the synergy of science with many other knowledge disciplines (Hatch & Smith, 2004).

Bosse et al.'s (2010) review of the international standards of science and mathematics education reveals that there is a broad similarity between both disciplines that requires concordance in their teaching. Both subjects seem to be equivalent in terms of their content and learning objectives, and this can be used as a basis for finding themes to bring about a more holistic integration of these disciplines. Davison, Miller and Metheny (1995) stated that 'The "doing" of mathematics and the "doing" of science create a new way for students to look at the world that develops depth rather than breadth in mathematics' and science curricula' (p. 227).

Rationale for integration. The connections between science and mathematics were made more apparent by scientific developments that took into account the orientations of value and the digitisation theories of mathematics. Mathematics and science integration is justified for several reasons (Ibrahim, 2002; Lee et al., 2011; Merrill & Comerford, 2004; Obaid, 2004). First, mathematics can be characterised by a high degree of abstraction; thus, the integration of science with mathematics represents an opportunity to provide real-life examples of mathematical principles. Second, mathematical concepts can be effectively used during science teaching in order to make scientific concepts more meaningful. Third, both mathematics and science rely on concepts, axioms, functions, theories, and practice; thus, there is a significant degree of structural consistency that allows for integration. Fourth, life situations tend to be characterised by a high degree of flexibility, which means that it is possible to integrate the concepts of science and mathematics in a logical sequence. Finally, there is a strong link between mathematical and scientific reasoning and other types of thinking, particularly creative, critical, and deductive thinking (Ibrahim, 2002; Lee et al., 2011; Merrill & Comerford, 2004; Obaid, 2004).

Research examples of curriculum integration. Dessouky and Yousuf (1999) developed scenarios using a problem-solving methodology in their efforts to integrate science, mathematics, and technology in a public high-school curriculum. Berlin and White (2012) developed scenarios for the integration of science and mathematics, pointing out that technological applications can be combined with these subjects. Qandil (2001) attempted to verify the effectiveness of integrating science, technology, and sociology in order to improve the academic achievement and scientific culture of elementary school students. They taught two units that addressed social problems related to energy transfers. Their results confirmed the effectiveness of this strategy.

Afaneh and Al-Za'anin (2001) critiqued Palestinian curriculum-based mathematics and science courses separately as a basis for proposed scenarios to enrich the integration of mathematics and science. They argued that their approach respected a systemic orientation. Al-Mooji (2000) also verified the effectiveness of an integrated science unit on water in terms of improving the achievement and attitudes of elementary students towards science operations. Berry et al. (2004) found that curriculum integration based on the educational technology of geometric applications was effective in improving student achievement, specifically when integrating mathematics and science instruction. Marrongelle (2004) reported positive results from a program that convinced undergraduate students to adopt mathematics rules in physical applications. Their program also was effective in improving academic achievement. Bell and Garofalo (2005) found that conceptualised integration through the use of computer-based multimedia was effective in improving elementary students' achievement in science and mathematics. Similarly, Saleh and Othman's (2006) integrative problem-solving approach was effective in developing students' achievement.

Rationale for Separation

While there are many arguments for the integration of mathematics and science (Furner & Kumar, 2007), there are also arguments that focus on the differences between the disciplines and on reasons why they should not be integrated. Five types of science and mathematics integration (discipline specific, content, process methodological, and thematic) can be used in interdisciplinary curriculum development (Miller, Davison & Metheny, 1997). Moreover, some studies (such as Berlin & White, 2000) indicate that math and science integration should encourage teacher preparation to implement a new teaching strategy.

Real-life Applications

Underlying the foundation of this study is the idea that efforts to integrate mathematics and science curricula should hinge on relevance to real-life applications (Drake & Burns, 2004). Real-life applications are characterised by a high degree of flexibility and academic mobility that allows for the integration of more than one field of study (Al-Tamimi & Mustafa, 2011; Ammar, 2010). Because most real-world problems are multifaceted, people usually depend on more than one discipline in their daily dealings with these problems, especially when they use their own cognitive abilities in relation to life-application variables (Alhebsieh, 2011; Hamada, 2012).

Al-Rabat (2013) affirmed the effectiveness of life applications in the development of basic science skills in the field of mathematics education, including working effectively in groups, making effective oral and written presentations, and using computers well. Al-Qahtani and Abdul-Hamid (2010) found that life applications of economic concepts were effective in developing problem-solving skills and in reducing mathematics anxiety. Abu Al Hamael (2013) discovered that enrichment activities were effective for the development of personally relevant pedagogy in the field of science education. Moreover, according to Edutopia (2008), 'Integrated study is an extremely effective approach, helping students develop multifaceted expertise and grasp the important role interrelationships can play in the real world' (p. 23). Nevertheless, after conducting a study on integrating science and mathematics, Berlin and Lee (2005) observed that most integration attempts have focused on theoretical rather than on applied aspects.

Prior research confirms the importance of integrating science and mathematics from an instructional perspective. This research shows that curriculum integration has positive effects on the achievement of intended educational objectives. However, the efforts that are currently being made in terms of science and mathematics education in Saudi Arabia are strongly directed towards the separate development of each subject area. Currently, there is no concrete evidence of integration in the instruction of mathematics and science in KSA classrooms. All of the integration that is occurring is at the textbook level rather than at the operational level.

The Educational Context of the Kingdom of Saudi Arabia

Since the beginning of the new millennium, Saudi Arabia's public-school curricula have prioritised the teaching of science and mathematics. Despite the fact that international educational trends emphasise the importance of integrating science and math from an instructional perspective, the efforts that have been made in the KSA are aimed at developing each area separately. Saudi Arabia's current curriculum provides only limited opportunities to recognise the integration between elements of each study subject. This orientation makes it difficult to create a unified vision whereby curriculum planners and educators can break down the boundaries between science and math by proposing proven instructional strategies.

Recent KSA Mathematics and Science Educational Initiatives

The advantages and disadvantages of an integrated curriculum, especially for female students in the KSA, have not been widely discussed. Loepp (1999) concluded that the prospects for implementing any integrated curriculum on a nationwide basis (in the US) are bleak. But this does not have to be the case for Saudi Arabia. In 2006, the KSA reinforced its commitment to education through High Decree (No. 7544 / MB), (22/10/1427[h]), which directs the Ministry of Education to implement curriculum development projects for math and natural science in collaboration with McGraw-Hill Education, an international educational publisher (Ghazanfar, 2012). Supported

Table 1. Saudi primary school curriculum (Al-Abdul Karim, 2009, p. 21; Ministry of Education, 2009 as cited in Alanazi, 2014)

	Subject Hours per week					
	Grade 1	**Grade 2**	**Grade 3**	**Grade 4**	**Grade 5**	**Grade 6**
Islamic studies	9	9	9	9	9	9
Arabic studies	12	9	9	9	8	8
Social studies	0	0	0	0	2	2
Art education	2	2	2	1	1	1
Science	1	1	2	2	3	3
Mathematics	2	4	4	5	5	5
Physical education	2	2	2	2	2	2

by the KSA government, the Ministry of Education and McGraw-Hill immediately began to modernise the KSA's science and mathematics curricula and methods of instruction (Al-Jazeerah, 2011).

The project was launched in 2007, beginning with the textbooks and other educational materials for Grades 1, 4, 7, and 10. The materials for the remaining grades were gradually developed and implemented over the three subsequent years (Al-Jazeerah, 2011). The foundations for designing and developing the mathematics and natural-science curricula were based on (a) international standards and (b) the most recent research focused on curriculum development, educational environments, and teachers and supervisors. Al-Humaidi (2009) explained that the project had three major dimensions: (a) the construction of advanced science and mathematics curricula in light of international standards, (b) the professional development of senior officials and teachers, and (c) the provision of support for teaching and learning processes while addressing the procedures implemented to ensure the quality of the educational materials.

General Observations on Mathematics and Science Teaching in Saudi Arabia

Table 1 profiles the public-school curriculum in the KSA, organised by separate subjects (Al-Abdul Karim, 2009; Ministry of Education, 2009 as cited in Alanazi, 2014). In particular, it highlights the fact that Islamic studies is allocated the largest number of hours of instruction per week while science and mathematics education receive among the fewest hours per week. Education in Saudi Arabia faces many challenges, including low test marks in mathematics and science. Out of 50 countries participating in the Programme for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMMS), eighth-grade Saudi students were ranked 43rd in mathematics and 39th in science (Barber, Mourshed & Whelan, 2007). Furthermore, Saudi students received low PISA and low TIMSS scores in both 2008 and 2015; in addition to this clear and obvious problem in math and science instruction, this unfortunate trend has not shown any improvement. Thus, the adoption of a novel approach is needed. In this regard, it is important to acknowledge that the heavy emphasis on Islamic studies in the curriculum does not create a barrier to expansion of mathematics and science instruction. After all, as Mansour (2011) explained, 'the Prophet's sayings take a pragmatic and utilitarian view of knowledge, which can be sought outside Islam if necessity demands it' (p. 303). The author agrees with this interpretation of the Hadith suggested by Mansour (2011) and Golshani (2007) and, in particular, with the view that science and mathematics are compatible with traditional Islamic beliefs.

The above-mentioned KSA government initiative to modernize the science and mathematics curricula is unfolding in a compelling educational context. Benefiting from years of experience as a science and mathematics educator in KSA, the author has observed that the textbooks only provide for superficial integration of science and mathematics. Moreover, mathematics and science teachers do not collaborate with each other and, as Al-Abdul Karim (2009) reported, most teachers' scientific and educational competencies are low. Their midterm and final tests tend to target lower-level learning (as per Bloom's taxonomy)—that is, remembering (knowledge) and understanding (comprehension). The tendency is for mathematics and science teachers to focus on memorization and to a lesser extent on comprehension.

This pedagogical approach serves only to inflate students' grades without the kind of learning that enables them to apply their knowledge in real-life situations. The weakness of this preparation means that Saudi students typically experience low achievement in mathematics and in the sciences at the university level. Their lack of readiness necessitates rigorous preparation in a preparatory year, which is a bridge year completed after high school and before university. Compounding the issue is the fact that most students develop an aversion to mathematics and science in high school relative to other subjects (Simmers, 2011). This is partially explained by most parents' prioritization of Arabic and Islamic studies.

Some teachers' comments indicate reference to high school (e.g., 'Mathematics and science teachers to not collaborate with each other'.). However, in many instances, elementary teachers are generalists and the issue is not so much the lack of collaboration among discipline experts but instead the depth of knowledge and confidence of elementary-school teachers in any particular discipline, particularly in science and mathematics. Still, novice teachers would greatly benefit from collaborating with experienced teachers in terms of curriculum development and implementation.

RESEARCH QUESTIONS

This study was inspired by international trends in mathematics and science learning. Berlin and Lee (2005) observed that most attempts at mathematics and science integration have focused on theoretical aspects rather than on applied aspects. Life applications have not been extensively investigated as a common basis for the interdisciplinary teaching of science and mathematics. The focus in the KSA is on integration within each subject (intradisciplinary) rather than between subjects (interdisciplinary). This study proposes and evaluates an instructional strategy in the KSA context to integrate the teaching of science and mathematics based on life applications. The following research questions guided this study: How does an integrated science and mathematics unit based on life applications impact the learning achievements of female elementary-school students in the KSA? What are the strengths and weaknesses of an integrated science and mathematics unit based on life applications with regard to the learning achievements of female elementary-school students in the KSA?"

THEORETICAL FRAMEWORK

The first step in this study was to develop the theoretical framework. It was used to facilitate the development of the instructional unit and strategy to integrate science and mathematics teaching based on life-skills applications. Two lines of scholarly thought informed this framework: the studies that aim to integrate science and mathematics (Al-Mooji, 2000; Berlin & White, 2010; Bosse et al., 2010; Hassanein, 2003; Kurt & Pehlivan, 2013; Lee et al., 2013; Slough & Chamblee, 2007) and the studies that aim to employ life applications as a basis for the design of educational activities (Al-Qahtani & Abdul Hamid, 2010; Al-Rabani, 2011; Al-Shahat et al., 2012; Bouck, 2010; Fuchs et al., 2006; Hamada, 2012; Kliman, Mokros & Parkes, 2001; Mohammed, 2006; Mohammed, 2012). Given the framework developed around the design of the teaching and learning unit that was the focus of this study, some strategies were employed to address the author's inherent bias, such as the expertise of two university professors in math and science pedagogy. The units were also checked by school math and science supervisors on the male and female sides to ensure the rigour of the research before the tests were applied.

Mathematics, Science, and Female Students

Because this study targets the KSA's math and science curricula, we have focused on the advantages and disadvantages of an integrated curriculum for female students. Given the fact that the literature has not elaborated on females in particular and given the fact that, as a female researcher, I only have access to female schools because of the comprehensive policy of gender segregation in Saudi Arabia, I have decided to focus on female students.

Six Curriculum Integration Strategies

A set of six standards was developed to control the process of integrating science and mathematics teaching using life applications (see **Figure 1**).

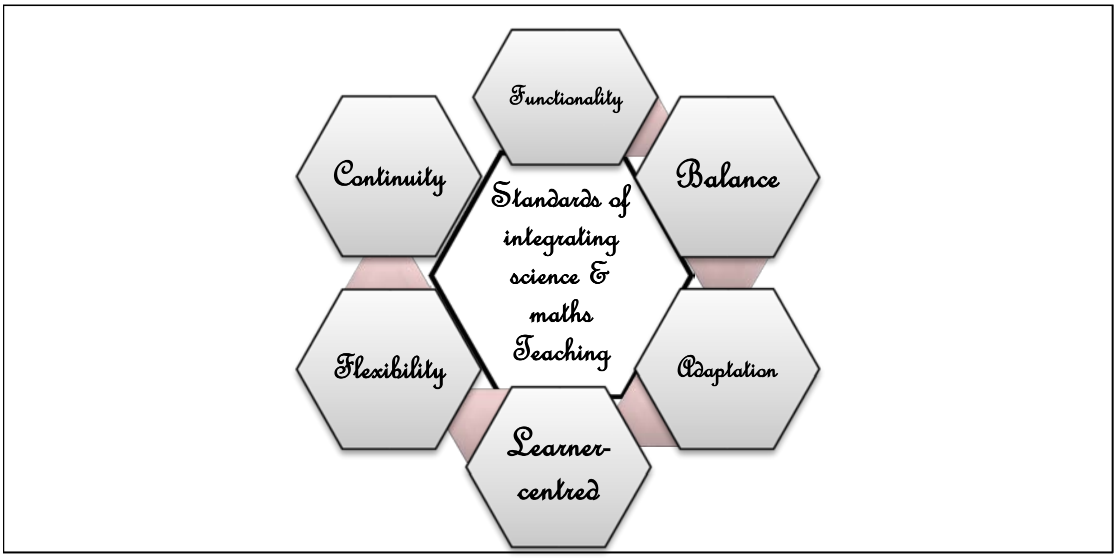

Figure 1. Standards for integrating science and math teaching based on life applications

Standard 1: Balance. The integration process should provide content for mathematics and science in equal measure. The balanced result is a general framework for presenting the integrated material, with other material more simply addressed as it comes up.

Standard 2: Adaptation. The integration of science and mathematics is based on life applications that are consistent with and relevant to students' lives rather than being based only on the interdisciplinary links.

Standard 3: Learner-centred. Integrated teaching of science and mathematics requires that teachers use techniques for coordinating and linking the teaching processes. The resulting classroom experience must move away from teacher-centred approaches towards life-oriented and learner-centred activities anchored in integrated math and science that engage students.

Standard 4: Flexibility. Any life applications that are selected for the integration of science and mathematics teaching should be compatible with *both* disciplines, and should have a high degree of flexibility to conform to students' life experiences.

Standard 5: Continuity. In order to maintain the motivation to learn, students should engage with math-science life applications encountered in class when outside the classroom.

Standard 6: Functionality. Any life applications and activities that are selected should consistently reflect the functional value of *both* science and mathematics. Both subjects should be integral and authentic aspects of students' lives rather than being separate from their lives.

POWER Curriculum Integration Strategy

Using these six standards, the author proposes a strategy for integrating the teaching of science and mathematics based on life applications. This strategy is called POWER, an acronym that captures the following five stages (see Figure 2): planning, organisation, work-life activities, evaluation, and real activities. POWER means having the ability, strength, and capacity to work together to integrate these two disciplines for the students' benefit. POWER refers to the feeling that one has the authority to do something—in this case, to actively create an integrated mathematics and science curriculum based on real-life applications. POWER also means that the teachers have the ability to influence the judgments and opinions of others—in this case, the students, other teachers, parents, administrators, and supervisors. By following the five stages of POWER, educators can make a difference in Saudi Arabia vis-à-vis students' achievement in mathematics and science as it pertains to their daily lives.

1.	**P** *Planning*	. Identify targets in science and mathematics disciplines. . Determine the life activities through which knowledge and skills of science and mathematics can be presented. . Determine the methods and materials needed for carrying out life activities.
2.	**O** *Organization*	. Determine teaching roles to be carried out by teachers independently. . Determine co-teaching points between the science teacher and the math teacher. . Allocate the times of teaching activities inside the classroom. . Organize groups of students who will be taught using the integrated curriculum
3.	**W** *Work life activities*	. Each teacher should extract skills and knowledge related to the science or mathematics lesson. . Each teacher should emphasize the strong relationship between using knowledge and skills in science and mathematics. . The two teachers should collaborate to present activities that stimulate students' thinking. . These activities should be based on life applications from students' environment and their practical experiences.
4.	**E** *Evaluation*	. Each teacher should prepare and present each other's questions and assessment tools in order to ensure that the science *and* mathematics objectives are achieved.
5.	**R** *Real activities*	. To ensure that the students have understood each field and to enhance the integral relationship between the two disciplines, the two teachers should instruct the students to carry out some real-life activities in the fields of science and mathematics.

Figure 2. Proposed five stages, using the six standards, for integrating science and mathematics teaching based on life applications

METHODOLOGY

The research design for this study involved several stages. First, the author formulated the above-mentioned set of standards and the POWER strategy for developing an integrated curriculum based on real-life applications. Using this model, the author developed an integrated math and science unit. This process involved validity checks with professors and then with experienced math and science teachers, as mentioned above. Once finalised, the author chose a school and teachers and students as participants, and then implemented the integrated unit using a two-group pretest-posttest design (comparison and treatment groups) with grade 5 students. Two groups received the integrated curriculum and two groups received traditional curricula (with all courses taught by the same two teachers). This process unfolded between the fall of 2014 and the spring of 2015.

Design of the Integrated Unit

An integrated mathematics and science unit was intended to break down the barriers that seem to exist between the teaching of the sciences and the teaching of mathematics. The author drew on the above-mentioned theoretical standards and POWER framework. This ensured (a) that the six standards for integration were adopted (balance, adaptation, learner-centrism, flexibility, continuity, and functionality) and (b) that the unit was developed using the POWER stages (planning, organisation, work-life activities, evaluation, and real-life activities).

This particular fifth-grade unit was organised to incorporate topics from the mathematics (circumference, area, and size) and science (sound and light) curricula. The major objective was to ensure that students would be able to appreciate the connections between the overlapping science and mathematics concepts while at the same time developing a deeper understanding of each of these disciplines. Attention was directed towards designing a set of activities that could serve as a common foundation for topics drawn from these units. The teachers were expected to deliver mathematics and science as one subject, amalgamated into one class period. A key component of the unit was a rationale for the teachers to share with the students, whereby they introduced the nature of the

Table 2. Overview of final version of the integrated mathematics and science unit

CONTENTS OF THE UNITs	
Lesson	**Pages**
First: Sound and Circumference	4–11
Second: Transmission of Sound and Area	12–20
Third: Light and Prisms	21–29
Fourth: The Reflection and Transmission of Light and the Size of Prisms	30–37

unit and provided justifications for integrating science and math, convincing them of the value of such integration. With a focus on personally relevant pedagogy, the unit contains activities and work sheets designed to enable the learners to record their initial thoughts about the activities, and then to express these thoughts to their teachers.

The penultimate version of the integrated unit was presented to four university faculty members specialising in teaching science and mathematics, as well as to six teachers. Their judgments confirmed the unit's content validity. Moreover, their input helped ensure that the unit reflected an appropriate balance between science and math content, had scientific integrity, and contained life applications and activities that were relevant to the content and target students. The final 40-page integrated unit is summarised in **Table 2** and is available from the author.

Sampling

The study was conducted in Dhahran, a large city located in the Eastern Province of the KSA. Several criteria were used to select the site for this study, including accessibility, university affiliation, and forward-thinking pedagogy. The site was selected because of its proximity to the author, which enabled repeated visits. The school was already associated with a university, thus making it more amenable to participating in a study. Pursuant to this, even though this school is mandated to follow the Saudi science and mathematics Al-Obiakan curriculum (translated from McGraw-Hill), it is one of the few schools that is trying to change its teaching and learning methods by moving beyond didactic learning towards a pedagogy based on critical thinking and problem-solving. The participating school is directed by a scientific committee appointed by the scientific council in the district. The school is known to be the first among all schools in the KSA (since 2008) to obtain the first rank on the national Standardised Aptitude Test and General Aptitude Test.

The school's participating educators comprised one math teacher (Teacher A), one science teacher (Teacher B), and the supervisors for each subject. The supervisors oversee math and science teaching in the school, and were involved in the event of any follow-up on the study's implementation. Teachers A and B collaborated to teach the integrated unit in Classroom A and Classroom B. Teacher A also taught her regular math class (Classroom C) and Teacher B taught her regular science class (Classroom D). The student sample comprised 162 female fifth-grade pupils. Four classes were assigned randomly: two classes for the experimental group, which received the integrated unit (n=76 students, 38 in each class), and two classes for the comparison group, which received the traditional curriculum (n= 86 students, 43 in each class).

Site Preparation

The author met with the four-member research group (teachers and supervisors) at the school six times, averaging 3 to 5 hours for each visit. During the first visit, the researcher collected information on how mathematics and science were taught at the school and more general information on teaching and learning at the school. All of the participants confirmed that they understood the importance of research and its relevance for improving the teaching and learning of science and mathematics. They discussed how the learning of answers is the predominant ethos of contemporary education, rather than the exploring of answers, which an integrated unit would allow. Additionally, ground rules were established during this meeting for the teachers to work together and to work with the researcher over the course of the study.

Table 3. Correlation coefficients for the sciences and mathematics test

Correlation coefficients for the items of the sciences test				Correlation coefficients for the items of the sciences test			
Item No.	**Correlation Coefficient**	**Item No.**	**Correlation Coefficient**	**Item No.**	**Correlation Coefficient**	**Item No.**	**Correlation Coefficient**
1	0.88**	11	0.75**	1	0.83**	11	0.83**
2	0.81**	12	0.74**	2	0.79**	12	0.79**
3	0.75**	13	0.83**	3	0.81**	13	0.81**
4	0.84**	14	0.79**	4	0.84**	14	**0.80
5	0.81**	15	0.81**	5	0.81**	15	0.84**
6	0.72**	16	0.80**	6	0.72**	16	0.81**
7	0.86**	17	0.84**	7	0.86**	17	0.75**
8	0.83**	18	0.81**	8	0.83**	18	0.84**
9	0.74**	19	0.77**	9	0.84**	19	0.81**
10	0.79**	20	0.81**	10	0.79**	20	0.72**

According to the table above, it is clear that all the correlation coefficients are statistically significant at the significance level of (0.05) and ranged for the mathematics test from 0.74 to 0.86, while they ranged for the sciences test from 0.72 to 0.86. These indicators, in addition to the reliability coefficient, give a significance that both tests are reliable and can be practically applied.[1]

During the second meeting, the author explained the experimental research design protocol and shared the rationale for integrating mathematics and science, while drawing on the literature review:

- There is a strong historical relationship between the sciences and mathematics. This can be seen in the fact that the sciences did not achieve rapid progress until they adopted the quantitative approach and began to rely heavily on mathematical equations.
- There is considerable similarity between the structure of the sciences and the structure of mathematics, in terms of the use of axioms, facts, relations, principles, and theories.
- The sciences are a fruitful arena for illustrating the applications of mathematics because mathematics is usually presented in abstract terms by emphasising principles, theorems, and exercises that are not necessarily related to reality in an obvious way.
- Mathematical concepts can be employed in the process of teaching the sciences, thus making mathematical concepts more tangible and meaningful for the learner.
- There exist many life situations and applications in which *both* mathematics and the sciences can make valuable contributions.
- There is convergence in the thinking activities used when teaching mathematics and the sciences, especially in relation to induction, deduction, and inference drawing.

The two teachers received an explanation of the experiment and its objectives, information about cooperating in presenting the activities, a presentation of the unit's academic content, and information about exchanging their respective teaching roles, as shown in **Table 3**.

In the third meeting, the educators and the author discussed in more detail the ways in which the unit would be taught and in which the students would be introduced to this new methodology. Both teachers remained committed but were a little concerned about the students' reactions to mathematics and science being taught during the same class period and about having both teachers together in the same classroom for the first time. In the fourth

[1] Achievement test for the unit of (circumference, area and volume) Annex No. (2), and achievement test for the unit of (sound and light), Annex No. (3).

meeting, the research group sorted out an issue between the two teachers about the difference in teaching time between math and science. Though addressed during an earlier meeting, this issue came up because of the mathematics teacher's concern about losing class time to science.

Pretest and Posttest

The author prepared two tests, one for the mathematics perimeter, area, and volume unit, and one for the science sound and light unit. The mathematics test contained a 12-word vocabulary assessment, and the science test contained a 20-word vocabulary assessment. In the multiple-choice test, the students were offered four options. Although one might think that multiple-choice tests are contrary to the development of critical-thinking skills as prioritised by the author and as targeted through subject integration, the questions were constructed and checked in such a manner as to assure the integration of the critical-thinking component (sample questions such as in Appendix 1). The initial content of the two tests was presented for verification to the same four science and math teachers who vetted the integrated unit, in addition to the same six teachers who vetted the scientific and linguistic suitability of the vocabulary and its relationship with the content. Vocabulary adjustments were made based on their feedback. During the second semester of the 2014-2015 school year, the amended instruments were pilot tested with 25 students in the female section of the private school. Cronbach's alphas revealed internal consistency coefficients of 0.84 for the math test and 0.89 for the science test. These results indicate the reasonable validity and consistency of the pretest and posttest instruments and their applicability to the participating students.

Data Collection

During the fourth meeting with the research group, all 162 students received the pretest (both the treatment and comparison groups), prefaced with an explanation of its purpose to capture their feelings about and understandings of the unit's content. After administering the pretest, the author observed the teachers teaching the integrated and traditional units for two weeks. Each class was observed five times. After each observation, the author shared with the supervisors all of the points observed (recorded in field notes) and all of the materials collected in the sessions. At the end of the unit, the posttest was administered to both the comparison groups and the treatment groups.

Amendments while implementing the experiment. Early into the implementation of the integrated units, the teachers experienced some time-tabling difficulties. The number of weekly science classes (n=3) was lower than the number of math classes (n=5). This issue was resolved with the help of the supervisors and the school administration, who arranged for the math and science periods to be amalgamated and the activity time followed the class time. This created four sessions for content and four sessions for life-based learning (n=8 periods). The comparison group's schedule did not change, with five periods for math and three for science.

At the beginning of the experiment, when implementing the integrated unit, the teachers met before each lesson in order to agree on plans for presentations, on the roles of each teacher, and on how to proceed with presenting the topics. At the beginning of the experiment, students needed a lot of stimulation and encouragement from their teachers to participate in the activities. They also needed continuous monitoring and control during their life-based group activities, perhaps because Saudi female students are not familiar with group activities. The students eventually described it as an interesting educational approach and a useful learning experience.

Data Analysis

The data were analysed using inferential statistics, specifically t-tests, to explore any differences between the comparison and treatment groups (Sprinthall, 2001). A t-test assesses whether the means of two groups are statistically different from one other. This analysis is appropriate whenever one is comparing the pretest and posttest means of two small groups.

Table 4. Results of value T in pre- and post-test of the sound and light unit (science content)

Science pre-test

Group	No.	Mean	S. Deviation	D. F.	t Value	p
Control	41	2.0732	1.36730	75	0.693	0.490
Experimental	36	2.2500	0.73193			

Science post test

Group	No.	Mean	S. Deviation	D. F.	t Value	p
Control	41	11.3902	1.20162	75	7.704	0.000
Experimental	36	14.0833	1.42177			

Table 5. Value T pre- and post-test results for perimeter, area and volume unit (mathematics content)

Mathematics pre-test

Group	No.	Mean	S. Deviation	D. F.	t Value	p
Control	41	2.0488	0.63052	75	1.076	0.285
Experimental	36	2.2778	1.18590			

Mathematics post test

Group	No.	Mean	S. Deviation	D. F.	t Value	p
Control	41	8.9756	1.27452	75	8.569	0.000
Experimental	36	10.02817	1.02817			

RESULTS

This study involved (a) the development of a theoretical framework (standards for integration) and a strategy for developing integrated units, (b) the development and validation of an integrated science and mathematics unit based on life applications, and (c) an experimental research design (experiment/control, pre/post test) to measure the effectiveness of the proposed integrated strategy in terms of improving students' achievement in science and math. In the pretests the groups performed similarly on math and science knowledge. There was a significant difference ($p < 0.01$) between the posttest science scores of the treatment and comparison groups in favour of the former. The t-value was 7.704, df = 75 (see **Table 4**). The effect size was calculated in terms of η2 for t-value (η2 = v 2 / T + 2 + allowance). The value of η2 was (0.44), which is greater than 0.14; this confirms that the experimental group outperformed the control group on the posttest. This is a medium effect size. **Table 4** explains that.

In addition, there was a significant difference ($p < 0.01$) between the posttest math scores of the treatment and comparison groups in favour of the treatment group. The t-value was 8.569 (df = 75). The effect size was 0.49, which is a small effect size. This confirms that the treatment group benefited more than the comparison group. **Table 5** explains that

DISCUSSION

The results of the current study indicate statistically significant differences between the treatment group and the comparison group on the tests for the perimeter, area, and volume (mathematics) unit and for the sound and light (science) unit. In effect, the students taking the integrated units received higher scores than those in the comparison group, who took separate mathematics and science units. Thus, the integrated curriculum based on life applications improved the students' achievement in both subjects. Several factors can explain this success. The integrated teaching strategy linked the female students' life experiences with the academic content of the science and mathematics unit. These linkages served to convince students of the functional value of both science and mathematics.

The life-based learning activities required students to think about what they were learning. The success of this strategy is reflected in the students' improved posttest scores. The proposed strategy also focused on a learner-centred approach, which usually results in better academic attainment, as it provides the learner with more independence. This proved to be the case in this study. Anecdotal evidence revealed that the students were receptive to the experience and to the teaching team of science and mathematics teachers. This is further reflected in the higher scores of the treatment-group students relative to the comparison-group students. The results indicate that the magnitude of the impact of the proposed strategy on academic achievement in mathematics and science was substantial. The effect size for mathematics was (0.49), greater than the impact on science of (0.44).

These results indicate that the impact of the proposed strategy is greater in mathematics than in science. The author believes that such an outcome could reasonably be expected when conducting the experiment based on the fact that the teaching of mathematics in the traditional way is characterised by a higher degree of abstraction than the teaching of science, which is more closely related to concrete examples and real-life applications. Therefore, the teaching of mathematics has the advantage in the current study as the process of integration convinced the students of the functional value of mathematics.

The results of this study are consistent with those of previous studies (Al-Mooji, 2000; Bell & Garofalo, 2005; Berlin & White, 2010; Berry et al., 2004; Hassanein, 2003; Marrongelle, 2004; Qandil, 2001; Saleh & Othman, 2006), which indicated that integrating the teaching of science and mathematics leads to improved academic achievement relative to teaching them separately. The treatment group's mean scores on the posttest were higher than those of the comparison group for both subjects, though this was more the case for science than for mathematics. One of the possible reasons why the science section benefited more than the mathematics section could be due to the confidence level of the teachers. Moreover, the results of the study are consistent with previous studies demonstrating that reliance on life applications in designing integrative teaching activities positively affects student achievement (Al-Qahtani & Abdul Hamid, 2010; Al-Rabani, 2011; Al-Rabat, 2013; Al-Shahat et al., 2012; Bouck, 2010; Fuchs et al., 2006; Hamada, 2012; Kliman et al., 2001; Mohammed, 2006). Berlin and Lee (2005) observed that most integration attempts have focused on theoretical or technological aspects rather than on applied aspects. This study privileged life applications over content, viewing the former as tools for teaching the latter. This study benefitted from the application of a new framework with specific steps for science and mathematics teachers when designing and delivering an integrative curriculum based on life applications. The author believes that these applications represent a broader scope for integration, which at the same time are compatible with modern learner-centred and active-learning educational approaches.

While the treatment group had higher scores on both tests, all students scored higher on their science test than on their math test. Interestingly, the difference was larger between subjects for the treatment group than for the comparison group. The treatment group's mean score was 10 for math and 14 for science (a 4 point difference). The comparison group's mean score was 8.9 for math and 11.3 for science (a 2.4 point difference); these were raw posttest means. It seems that the students who took the integrated unit experienced a wider gap between their test scores on the two topics.

Limitations

This study was limited to one school and one grade level. The Ministry of Education and/or other researchers need to implement this study in a wider range of schools to provide a real opportunity to judge the results of integrating science and mathematics instruction. Detailed studies also need to be conducted on designing teaching units based on the proposed POWER strategy for other subjects like, for example, Arabic language, history, and Islamic studies.

Recommendations

The results of this study have several compelling implications. The designers of science and mathematics curricula should provide clear plans to teachers on how to integrate various academic topics. Teachers and authors of educational programs should be directed to use the proposed POWER strategy for the teaching of science and mathematics. Designers of teacher-training programs should focus on teaching techniques that use integration strategies. Supervisors in various educational fields could work on the expansion of academic cooperation among teachers as a part of performance assessment. Teachers can be encouraged to work in pairs to ensure the success of integration initiatives. University teacher-education programs should instruct pre-service teachers on the skills involved in integrating the teaching of various disciplines, especially as the status quo largely focuses on specialisation. The Ministry of Education could organise competitions for teachers and schools around initiatives to integrate the teaching of various disciplines. The study results support the following recommendations:

- Provide an instructional proposal to be used by teachers of science and mathematics when presenting their daily pre-planned integrative lessons;
- Provide an integrative science and math unit to be used as a model for future attempts to integrate the teaching of science and math, especially at the elementary level;
- Propose life-based situations and activities that can be integrated in a practical way;
- In order to achieve the common goals of the two subjects, support the plans of science and mathematics developers for vertical and horizontal integration;
- Sensitise the designers of professional-development programs to the need to create relevant instructional programs focused on integrating subjects; and
- Provide a professional mechanism that contributes to more effective professional communication between science and mathematics teachers.

CONCLUSION

Over the last five years, science and mathematics education in the KSA has attracted considerable attention from policymakers and educators. To some extent, this interest emerged in the wake of Saudi students' low PISA and TIMSS scores in 2008 and 2015. The current study is an attempt to employ a new methodology for integrating science and mathematics teaching in elementary classrooms by integrating scientific and mathematics concepts as opposed to teaching the two subjects separately. Treatment-group students' pretest and posttest results showed significant improvements in academic achievement on targeted learning outcomes. This is consistent with Davison et al.'s (1995) finding that '…integration will provide for a more reality-based learning experience' (p. 229). This study affirms that math and science integration yields positive outcomes. Reforming the KSA's math and science curricula in an integrative manner would improve test results, especially when instruction is grounded in real-life applications.

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APPENDICES

Appendix 1

Achievement Test for the Sound and Light Unit for Grade 5 Students

Dear students, **peace** be upon you;

The test at hand is on the sound and light unit. You are required to:

1. Register your information in the required fields on the answer sheet attached to the test;
2. Start to answer after the teacher requests that you do so;
3. Answer all the test questions, of which there are 20 in total;
4. Answer the questions by choosing only one option from the three options provided with each question;
5. Remember that there is only one correct answer to each question;
6. Highlight your answer on the answer sheet by putting a circle around the number for the correct answer (see the example below); and
7. Remember that the maximum time for answering the test questions is 60 minutes.

Best of luck!

Question Number	Options		
	1	(2)	3

Answer Sheet

Main Information		
Name:	School:	Class:
Date:	Period:	Teacher's Name:

Question Number	Options		
1	1	2	3
2	1	2	3
3	1	2	3
4	1	2	3
5	1	2	3
6	1	2	3
7	1	2	3
8	1	2	3
9	1	2	3
10	1	2	3
11	1	2	3
12	1	2	3
13	1	2	3
14	1	2	3
15	1	2	3
16	1	2	3

17	1	2	3
18	1	2	3
19	1	2	3
20	1	2	3

Question No. (1)	The series of compressions and rarefactions transmitted through a certain **type of** matter is ....
1	a medium
2	sound
3	sound waves
Question No. (2)	An area where there are approximately no particles of matter is ...
1	composed of sound waves
2	a vacuum
3	a medium
Question No. (3)	The speed of sound is at its highest possible level in .... matter.
1	Solid
2	liquid
3	gaseous
Question No. (4)	Sound energy is transmitted because of ....
1	repulsion between the particles of the medium
2	conflicts between the particles of the medium
3	**Attraction** between the particles of the medium
Question No. (5)	One of the following statements is correct:
1	Cold air transmits sound more quickly than warm air.
2	There is no difference between cold and warm air in terms of its effect on the speed of sound.
3	Warm air transmits sound more quickly than cold air.
Question No. (6)	An echo involves ....
1	repeatedly hearing a sound because of the reflections of the sound waves
2	the retraction of surface waves away from some surface
3	the absorption of sound energy
Question No. (7)	Frequency is defined as the number of times that a certain body vibrates during ....
1	one minute
2	two seconds
3	a known time
Question No. (8)	One of the following statements is correct:
1	The frequency of a tender voice is high while the frequency of a coarse voice is low.
2	The frequency of a coarse voice is high while the frequency of a tender voice is low.
3	The frequency of a coarse voice is the same as that of a tender voice.
Question No. (9)	We can increase the frequency of sound by moving ....

1	in random directions
2	in a direction that is opposite to the direction of the sound
3	in the same sound direction
Question No. (10)	One of the apparatuses that scientists developed from the idea of the sound echo is
1	the thermometer
2	sonar
3	the anemometer
Question No. (11)	Length of a light wave is the distance between
1	the top and the bottom
2	two successive wave tops
3	five successive wave tops
Question No. (12)	The speed of a wave is calculated by
1	adding the wave length to its frequency
2	multiplying the wave length by its frequency
3	dividing the wave length by its frequency
Question No. (13)	The photon is the smallest part of ……. energy. It exists independently.
1	sound
2	light
3	thermal
Question No. (14)	Which of the following is considered to be a semi-transparent body?
1	plastic
2	wood
3	glass
Question No. (15)	The length of shade depends on ……………….
1	the quantity of rays falling on the body
2	the inclination of the rays falling on the body
3	the type of rays falling on the body
Question No. (16)	We see a body when the light ……….. from it **into** our eyes.
1	is reflected
2	is refracted
3	inclines
Question No. (17)	A reflection appears clearly in the plane mirror because
1	most of the light waves are reflected on its soft surface
2	most of the light waves penetrate to its soft surface
3	most of the light waves are absorbed on its soft surface
Question No. (18)	Refracted light is ………..
1	deviating from its course
2	continuing in the same course
3	going in the opposite direction of its course

Question No. (19)	One of the following colours is not included within the spectral colours:
1	red
2	green
3	brown
Question No. (20)	The colour that has the **longest** wave length is
1	red
2	green
3	indigo

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