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REVIEW ARTICLE

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Active Science®: A review of physical activity promotion and science learning

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ABSTRACT

Background: Schools, afterschool programs (ASPs), and outdoor environment have been identified as ideal settings to increase physical activity (PA) levels and improve academic performance of children. The purpose of this review study is to assess the effectiveness of the *Active Science* program in promoting PA and science learning in a variety of settings including in school, afterschool, and the outdoors.
Methods: *Active Science* encompasses PA within exploratory-type educational experiences to create "active education" environments. This approach of using PA as a component of academics is not unique to *Active Science*, and others have successfully demonstrated beneficial effects on activity and academics. This study reviewed the results of the *Active Science* program in three different settings, in school, afterschool, and an outdoor education environment.
Results: Regardless of the setting, the results supported that children had significantly higher PA levels and improved science scores when they participated in *Active Science.*
Conclusion: The *Active Science* approach is one way to get students physically active while promoting science learning during the school day, ASPs, and outdoor education environments.

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Introduction

Children throughout the world are facing an unprecedented obesity epidemic, which is being fueled by pervasive levels of inadequate physical activity (PA) and sedentary lifestyle [1]. Obesity is a condition that is mediated by genetic, behavioral, and environmental factors [2]. It is one of the most significant public health issues facing the international community in this century. Since the 1970s, the percentage of children with obesity in the United States has more than tripled [3]. Today, about one in five school-aged children (ages 6–19) has obesity [4].

The potential health impacts of obesity on the well-being of the youth are devastating. Excess body fat is associated with high blood pressure, type 2 diabetes, high cholesterol, stroke, several cancers, and some forms of arthritis [5,6]. Health risks are not the only concerns; in several large-scale studies, body mass index has been shown to have a significant negative correlation with academic performance in children [7,8]. If a child is overweight or obese, they have an increased risk of developing these various health problems and are more likely to become an overweight or obese adult.

One of the major factors contributing to childhood obesity is a lack of PA. Physical inactivity increases the risk of stroke and other major cardiovascular risk factors such as high blood pressure and diabetes. Research has shown that PA participation during childhood can predict whether children will be active or not during adulthood [9]. Thus, early interventions are crucial to the prevention of physical inactivity and related chronic diseases later in life [10,11]. It is recommended that children and adolescents should participate in daily PA for at least 60 minutes [12]. However, the PA levels of children have been on a steady decline nationwide. Results from the Centers for Disease Control and Prevention Youth Risk Behavior Survey, which

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collects data from students in grades 9–12 in the United States, indicate that 13.8% of students had not participated in PA on any day in the past 7 days and only 49.5% reported that they were physically active 5 or more days in the past 7 days [12]. Only 28.7% actually reported meeting the recommended amount of PA in the past week. In schools, physical education is one method to promote PA, but it often falls short in meeting the daily PA recommendations [12]. Clearly, adolescents are not meeting the recommended amounts of PA.

School-Based Physical Activity

Schools have been identified as an ideal setting to help young people improve and maintain healthy eating and PA behaviors to prevent or reverse obesity [13–15]. After the family, school is one of the most influential institutions in children's social, emotional, and cognitive development. Schools are also a place where students are physically inactive with up to potentially 6 hours a day of sedentary behavior [16]. The World Health Organization and more recently the Institutes of Medicine and The White House Task Force have called upon schools to adopt policies and implement strategies to increase the PA levels of students [13,14,17]. Selected recommendations from these documents include: conducting needs assessment, implementing school-wide policies, supporting quality physical education, engaging all stakeholders within the school environment, and increasing opportunities for PA in the classroom. Schools have one of the most promising opportunities to directly address the global issue of physical inactivity in youth.

Schools are considered one of the main institutions for addressing physical inactivity due to the amount of time spent at school. Recent research also suggests that PA can have positive benefits on academic outcomes. Evidence from multiple studies and research reviews suggests that PA improves many academic outcomes including: overall academic success, cognitive performance, reading and math skills, on-task classroom behavior, positive learning experiences for students, and improved levels of concentration [18–22]. This is important to consider not only when developing evidence-based strategies to reduce obesity, but also relevant when attempting to improve school environments to address undesirable academic achievement scores experienced by a growing number of U.S. public schools.

Physical Activity in Afterschool Programs

Around 8.4 million children spend an average of 8 hours per week in afterschool programs (ASPs) [23]. Recently, ASPs have been identified as ideal settings where children (aged 5–14 years) can accumulate a significant portion of their total daily recommended level of MVPA (moderate-to-vigorous physical activity). Recent studies have found that interventions to modify practices at ASPs can increase children's PA [24–30]. Unfortunately, many ASPs have not been able to provide adequate PA opportunities for children. A systematic review of state-level ASPs was conducted to identify existing standards and policies, and the report concluded that policies promoting PA within these organizations were largely absent. Currently, only 14 states and one national organization (i.e., National Afterschool Association) have developed guidelines for the amount of PA for children [3,16].

According to the Robert Wood Johnson Foundation report in 2013, more than 8 million children and teens spend an average of 8 hours per week in ASPs [31]. Recently, ASPs have been identified as possible settings in which physical inactivity and childhood obesity can be combated [30]. According to the recommendations, ASPs should provide children with at least 30 minutes of organized PA for every 3 hours of program time [29]. Unfortunately, ASPs have not been able to provide adequate PA opportunities for children. Therefore, school and afterschool organizations should aim to integrate PA and academic components into their programs to promote movement and learning.

Physical Activity and the Outdoor Environment

The outdoor environment provides a great opportunity for school-aged children to participate in PA. Evidence suggests that children who are physically active outdoors have a lower risk of developing a chronic illness [32]. Moreover, it has been shown that participation by children in activities in nature, such as hiking, camping, and gardening, was associated with an increased likelihood to have positive attitudes toward outdoor activities as adults [33]. Unfortunately, children have been provided fewer opportunities for outdoor play in their home environments, schools, and local communities [33,34]. The evidence shows that children are spending more time participating in indoor activities such as watching TV and less time in the outdoors exploring and engaging in the natural environment [35,36]. As Kellert [37] suggested, our society has become so detached from the natural world that we do not recognize our basic dependence on nature as a condition for growth and development. The literature has shown that the natural environment can have positive effects on children's development and well-being [38].

To our knowledge, there are few programs widely deployed in school, afterschool and outdoor settings that integrate PA and educational experiences. Thus, national recommendations on active education as a means to improve PA and support academic success do not appear to be widely implemented. The *Active Science* program was created to promote PA as well as to support science education among children in school, afterschool, and the outdoor environment. The purpose of this study is to review the results of the *Active Science* initiative in these settings.

Methods

The Active Science approach

The *Active Science* program was founded in 2009 through support from the U.S. Department of Health and Human Services with additional support from various charitable foundations and private sources. *Active Science* is a federally registered trademarked and non-profit service that is available for community organizations and ASP to help support PA and academic achievement in school-aged children. *Active Science* integrates PA and educational experiences. This approach of using PA as a component of academics is not unique to *Active Science*, and others have successfully demonstrated beneficial effects on activity and academics.

The main objective is to improve PA while supporting educational achievement in afterschool and childcare settings and directly during school time. *Active Science* encompasses PA within exploratory-type educational experiences to create "active education" or "ExerLearning" environments. The *Active Science* approach incorporates the use of interactive technologies. Considering children's affinity towards online experiences, digital products, and social media, these technologies add an exciting aspect to this program. In the *Active Science* program setting, children could generate, collect, and analyze their own PA data using digital monitors (i.e., pedometers). These devices allow users to upload personal metrics (i.e., steps, distance, and calories) to an interactive website for evaluating

Figure 1. Active Science flow chart.

and tracking progress (Fig. 1). In essence, children could play, explore, and discover while staying active.

Results

School-based programs

Active Science was first implemented as a pilot study in an urban middle school. The purpose of this study was to analyze the *Active Science* approach, which incorporated school-based PA into interactive (hands-on and exploratory) science classroom lessons for the 5th and 6th grade Hispanic girls. Specifically, the effects of the *Active Science* approach on PA levels and learning of science inquiry skills and content knowledge were measured. Table 1 showed children's mean heart rates (146 ± 9 bpm); maximal heart rates (196 ± 10.6 bpm); steps (3,050 ± 402.7); calories (99 ± 8.4 kcal); and distance traveled (1.1 ± 0.2 miles) per lesson while performing the *Active Science* curricular activities that met national recommendations for youth PA. Table 2 showed significant improvements in performance on science content and skills tests

Table 1. PA measures of *Active Science* lessons and traditional science lessons.

PA measures	*Active Science*	Traditional science
Steps	3,050 (±402.7)*	77 (±14.3)
Distance	1.1 (±0.2)*	0.08 (±0.003)
Calories	93 (±10.4)*	16 (±0.1)
Average heart rate	146 (±9.0)*	95 (±8.1)
Maximum heart rate	196 (±10.6)*	124 (±3.9)
Time in target heart rate	16.38 (±4.35)*	0.26 (±0.01)

*Indicated measures that were significant at the $p < 0.05$ level (two-tailed).

Table 2. Students' science inquiry skills and content knowledge tests before and after the *Active Science* curriculum.

	Pre-*Active Science* (mean ± SD)	Post-*Active Science* (mean ± SD)	Change (mean ± SD)
Correct answers	16.7 ± 7.4	25.1 ± 5.9*	8.5 ± 4.6
Percent correct	43.9% ± 19.4%	66.3% ± 15.5%*	22.4% ± 0.1%

*Indicated measures that were significant at the $p < 0.05$ level (two-tailed).

were observed (43.9%–66.3%; $p < 0.001$) from pre- to post-curriculum [39].

Afterschool programs

After the in-school study, *Active Science* was implemented in the afterschool setting. The first afterschool study assessed the *Active Science* program's effectiveness among children in one Young Men's Christian Association (YMCA) setting [40]. Specifically, the study examined and compared the effects of the *Active Science* and control groups on PA participation and science performance among boys and girls in an afterschool environment. The results (Table 3) revealed that in 6 weeks, participants in both the *Active Science* and control groups significantly increased their PA participation and science scores.

For the control group, the steps/hour increased from M = 1,977 [standard deviation (SD) = 955] to M = 4,072 (SD = 1,500), Cohen'd = 1.67; the distance/hour increased from M = 0.77 (SD = 0.37) to M = 1.55 (SD = 0.74), Cohen'd = 1.33; and the calories/hour increased from M = 52.40 (SD = 28.66) to M = 105.81 (SD = 61.06), Cohen'd = 1.12. For the *Active Science* group, the steps/hour increased from M = 1,599 (SD = 719) to M = 3,563 (SD = 1,322), Cohen'd = 1.85; the distance (miles)/hour increased from M = 0.67 (SD = 0.38) to M = 1.18 (SD = 0.51), Cohen'd = 1.13; and the calories (kcal)/hour increased from M = 46.75 (SD = 28.66) to M = 94.41 (SD = 61.06), Cohen'd = 1.00.

For the control group, the pre and post science scores increased from M = 46.88 (SD = 17.68) to M = 58.97 (SD = 13.26), Cohen'd = 0.52; For the *Active Science* group, the pre and post science scores increased from M = 44.75 (SD = 13.58) to M = 62.65 (SD = 19.05), Cohen'd = 1.09. In addition, none of the participants in the *Active Science* or control groups achieved the PA recommendation (i.e., 5,100 steps/hour) in the baseline, while 27.3% of participants in the *Active Science* group and 38.5% of the participants in the control group achieved the recommendation.

The purpose of the second study was to assess the effectiveness of the *Active Science* program delivered in different YMCA site locations across the U.S. The results in Table 4 supported that children had significantly higher PA levels when they participated in *Active Science* compared to their traditional ASP. For PA, the repeated measure analysis revealed that participants had significantly higher steps/30 minutes when they ran the *Active Science* program compared to their participation in the traditional ASP, M = 1,826, SD = 571, M = 685, SD = 161, respectively, $F(1,55) = 280$, $p < 0.001$. Significant differences were found of MVPA%, M = 38.16%, SD = 20.05%, M = 30.03%, SD = 14.83%, respectively, $F(1,55) = 44.8$, $p < 0.001$.

For science learning, the time effect and the interaction effect between time and group were significant, $F(1,36) = 21.88$, $p < 0.001$, $\eta^2 = 0.38$; $F(1,36) = 4.16$, $p < 0.05$, $\eta^2 = 0.10$, respectively. Simple effect test showed that for the *Active Science* group, the pre- and post-improvement was significant, $p < 0.001$. Average science test score for

Table 3. Descriptive results on PA and science achievement.

Group		Steps/hour	Distance/hour	Cal/hour	Science scores
Control	Baseline	1,977 (955)	0.77 (0.37)	52.40 (37.44)	46.88 (17.68)
	Intervention	4,072 (1,500)	1.55 (0.74)	105.81(57.69)	58.97 (13.26)
Active Science	Baseline	1,599 (719)	0.67 (.38)	46.75 (28.66)	44.75 (13.58)
	Intervention	3,563 (1,322)	1.18 (0.51)	94.41 (61.06)	62.65 (19.05)

Table 4. Average steps, MVPA%, and science scores of participants.

Group	Steps/30 minute	MVPA%	Science score
Active Science (n = 72)	1,826 (571)***	38.16 (20.05)***	75.24 (15.61)***
Control (n = 72)	685 (161)	30.03 (14.83)	57.14 (20.56)

***Indicated measures that were significant at the $p < 0.001$ level (two-tailed).

pre- and post-tests were $M = 57.14$, SD = 20.56, and $M = 75.24$, SD = 15.61, respectively. For the control group, the pre- and post-improvement was not significant, $p > 0.05$. Average science test scores for pre- and post-tests were $M = 58.46$, SD = 21.79 and $M = 69.39$, SD = 14.07, respectively.

Outdoor education

With positive results from the in-school and afterschool settings, *Active Science* was implemented in an outdoor education program. The purpose of this study was to assess an outdoor education program aimed at increasing PA and improving science knowledge among elementary school children in an economically disadvantaged urban community. This project demonstrated an innovative approach to integrate PA and science learning in an outdoor environment. Steps/hour and minutes of MVPA/hour increased approximately 3-fold from the baseline to the post-test. The average sedentary minutes/hour decreased. *t*-tests showed steps/hour and MVPA/hour were significantly higher during the outdoor education program compared to in-school, $t(43) = -28.02$, $t(12) = -29.34$, respectively, $Ps < 0.001$. In addition, the sedentary time significantly decreased, $t(12) = 9.80$, $p < 0.001$. The science test score based on 20 items increased approximately 6.5%, $t(43) = -4.18$, $p < 0.01$. The results of this study are currently being published.

Discussion

School-based programs

The data from the in-school study showed that *Active Science* helped students to meet the PA guidelines suggested by major national organizations aiming to improve the health of our nation. The results also showed the amount of PA during Active Science was significantly higher than the activity levels compared to the traditional science classroom. These findings support the inclusion of programs (e.g., *Active Science*), which include a PA component to academic lessons as a way to provide opportunities to infuse meaningful activity during the school day. Classroom teachers have the potential to increase PA levels of children by implementing a PA component into traditional classroom lessons.

When examining the effects of *Active Science* on student's learning of science inquiry skills and content knowledge, there were significant improvements from pre to post science test scores in all the 5th and 6th grade classes. At the conclusion of *Active Science*, the amount of improvement suggested that the students had a strong understanding of science inquiry skills and content knowledge taught during the framework. Regardless of the academic ability of the students, science inquiry skills and content knowledge were improved in the Active *Science* classroom. Overall, the *Active Science* students learned science inquiry skills and content knowledge, which supports the literature that adding PA to the classroom can improve academic achievement [22].

Afterschool programs

One of the main goals of the *Active Science* program is to develop a framework for increasing the amount of PA in the afterschool environment. The first afterschool study provided evidence that the *Active Science* curriculum significantly promotes PA among children from a low-income community compared to the traditional ASPs in one afterschool setting. For science knowledge, the reduced sample size made it more difficult to catch the group differences if any existed. Regardless, the *Active Science* group showed the trend of stronger improvement in science knowledge compared to the control group.

With the limitations in the first afterschool study, the second afterschool study examined the *Active Science* program at five different YMCAs across the country. The diverse demographics of the participants further supported the evidence of external validity of the program. Previous research has demonstrated that children who participated in *Active Science* in the afterschool setting improved their PA levels and science performance [21]. However, the previous study failed to demonstrate the differences between the interventional and control groups. This may have been due to the limited number of participants and individual differences between groups. Using a crossover study design, this study addressed the concerns of group differences and ethical issues by having all subjects participate in the intervention (i.e., crossover design). The results supported the hypotheses that *Active Science* improves children's PA levels and science performance in an afterschool setting.

Outdoor education

The results showed that children were significantly more physically active in the outdoor environment compared to the traditional school environment, which was consistent with the previous studies [41]. The evidence from the *Active Science* outdoor education study also supports the effectiveness of science learning through PA in the outdoor environment. Previous studies have shown that PA and science learning can be integrated among children in the afterschool environment. For example, Finn et al. [40] followed a similar integrated approach at a local YMCA where children completed PA in a gymnasium for 30 minutes; then, used the data from their pedometer (e.g., steps, calories, and distances) twice a week as a basis for science inquiry lessons. Results showed that children significantly increased their PA participation compared to their regular ASP, and they also have learned science by collecting and analyzing their own data. However, there is a limited empirical evidence of this application in an outdoor environment. The results of the outdoor education study supported the concept that similar approaches can be applied to the outdoor environment to enhance PA participation as well as improve science learning.

With the rapid development of digital technology, children spend more screen time on their gadgets and have become detached from the natural world [35]. Recognizing the importance of nature to our children's growth and development, we are challenged to create innovative ways to encourage our children back into the natural environment. Previous research has shown that well designed outdoor programs increased children's positive attitudes towards nature, interests in environmental learning, and knowledge [42]. By integrating outdoor PA with science learning, the current study created a unique outdoor experience for children, which may further stimulate their positive attitudes and interests in the environment.

Limitations

Since the *Active Science* program did not prescribe the type of physical activities that were implemented, one limitation of the afterschool study was the lack of control over what activities were chosen and how they were implemented. The children were to engage in moderate-to-vigorous physical activities during the program. Unfortunately, there was no one on site to oversee if the activities met the criteria. However, from a practical perspective, it is an advantage as the staff has the flexibility to implement the PA that fits their curriculum and setting (e.g., space of the gym, weather, etc.). In addition, although this study was a cluster cross-over design, the sample size was too low to calculate the impact of clustering. This should be addressed in future studies.

In the outdoor education study, one of the major limitations of this study is the lack of a control group for the science assessment. It is unclear whether the participants increased their science scores due to the intervention or to a general learning effect from classroom activities. In addition, the science test used in the current study was self-developed. Since it was not a standardized assessment tool, its reliability and validity were unclear. Finally, this study lacked qualitative feedback from the participants to evaluate their experiences in the program.

Conclusion

The purpose of the current paper is to review the effectiveness of the *Active Science* program promoting PA and science learning in a multitude of settings. Many schools have significantly downsized PA programs due to budgetary constraints and increasing pressure to improve standardized test scores. Proponents of school-based PA programs have argued that PA improves academic performance and regular exercise improves students' concentration and cognitive functioning [8]. The *Active Science* data support these findings by suggesting that including PA as a part of academic lessons can facilitate student learning and that the inclusion of PA does not adversely impact academic performance. The *Active Science* approach is one way to get students physically active while promoting science learning in schools, afterschool, and the outdoor environment.

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